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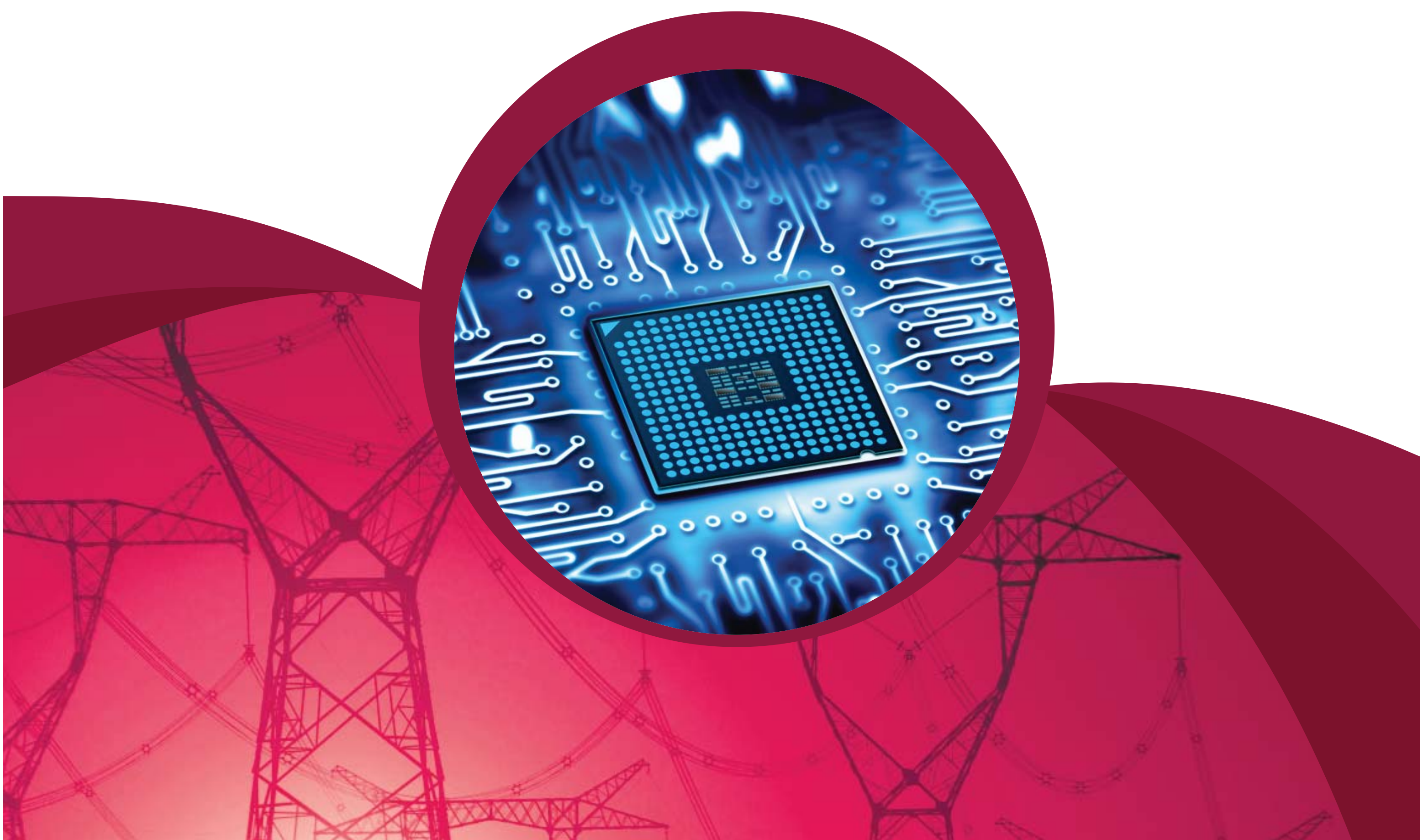
ELECTRICAL ENGINEERING

BASIC ELECTRONICS ENGINEERING

Volume - 1 : Study Material with Classroom Practice Questions



Basic Electronics Engineering

(Solutions for Volume-1 Classroom Practice Questions)

1. Basics of Semiconductor

01. Ans: (a)

Sol: $N_D = 5\times10^{22}\times\frac{1}{10^9}cm^{-3}$

$= 5\times10^{13}\ cm^{-3}$

According to mass action law

$np = n_i^2$

$n_n p_n = n_i^2$

$N_D\, p_n = n_i^2 \qquad (\because n_n \simeq N_D)$

$p_n = \frac{n_i^2}{N_D}$

$p_n = \frac{(1.5\times10^{10})^2}{5\times10^{13}}$

$= 4.5\times10^6\ cm^{-3}$

02. Ans: (b)

Sol: According to law of mass action $n.p = n_i^2$

Where n_i = intrinsic carrier concentration.

N_D = doping concentration for a n- type material.

Majority carrier concentration

$n \cong N_D$

$p = \frac{n_i^2}{N_D}$

$p \alpha \frac{1}{N_D}$

03. Ans: (b)

Sol: V = 5V

L = 100 mm

$\mu_n = 3800\ cm^2/V\text{-}sec$

$\mu_p = 1800\ cm^2/V\text{-}sec$

$V_{dn} = \mu_n E$

$= 3800\times\frac{V}{L}$

$= 3800\times\frac{5}{100\times10^{-1}}$

$= 1900$ cm/sec

04. Ans: (d)

Sol: For the n-type semiconductor with $n = N_D$ and $p = n_i^2/N_D$, the hole concentration will fall below the intrinsic value because some of the holes recombine with electrons.

05. Ans: (c)

Sol: $N_A = \frac{10^{15}}{1.6}$ acceptor/cm^3

$\mu_n = 4000\ cm^2/V\text{-}sec$

$\mu_p = 2000\ cm^2/V\text{-}sec$

$\sigma_p = p\, q\, \mu_p$

$= N_A q \mu_p$ ($\because$ 100% doping efficiency)

$= \frac{10^{15}}{1.6}\times1.6\times10^{-19}\times2000$

$= 0.2$ mho/cm

06. Ans: (d)

Sol: According to mass action law.

$np = n_i^2$

$n_n p_n = n_i^2$

$n_p p_p = n_i^2$

$n_p N_A \simeq n_i^2$

$N_D p_n \simeq n_i^2$

07. Ans: (a)

Sol: $R_H = 3.6\times10^{-4}\ m^3/c$

$\rho = 9\times 10^{-3}\ \Omega\text{–m}$

Let us consider n-type semiconductor

$$R_H = \frac{1}{nq}$$

$$n = \frac{1}{qR_H}$$

$$= \frac{1}{1.6\times10^{-19}\times3.6\times10^{-4}}$$

$$= 1.736\times10^{22}\ m^{-3}$$

08. Ans: (b)

Sol: At equilibrium

No. of e^- density = No. of hole density

$\because$ given e^- density is $n(x_1) = 10\,n(x_2)$

$\Rightarrow n(x_1)$ is majority

$\Rightarrow n(x_2)$ is minority

$\therefore P(x_2) = 10P(x_1)$

09. Ans: (b)

Sol: $\rho_p = 3\times10^3\ \Omega-m$

$\mu_p = 0.12\ m^2/V\text{-sec}$

$V_H = 60mV$

$$\rho_p = \frac{1}{\sigma_p}$$

$$3\times10^3 = \frac{1}{pq\mu_p}$$

$$p = \frac{1}{3\times10^3\times1.6\times10^{-19}\times0.12}$$

$P = 1.736\times10^{16}\ m^{-3}$

$$R_H = \frac{1}{pq}$$

$$= \frac{1}{1.736\times10^{16}\times1.6\times10^{-19}}$$

$$= 360\ m^3/C$$

10. Ans: (b)

Sol: $J_{drift} = n\mu_n qE + p\mu_P qE$

$J_{drift} = [(n.q)\mu_n + (p.q)\mu_p]E$

$J_{drift} = [\rho_n\mu_n + \rho_p\mu_p]$

$J \propto$ ‘ρ’

$\downarrow$

Charge concentration

11. Ans: (c)

Sol: $D_n = 20\ cm^2/s$

$\mu_n = 1600\ cm^2/V\text{–s}$

$$\frac{D}{\mu} = \frac{kT}{q} = V_T$$

$$\Rightarrow V_T = \frac{20}{1600} = 12.5\,mV$$

12. Ans: (d)

Sol: Conductivity of a semiconductor,

$\sigma = (n\mu_n + p\mu_P)q$

Where, $\mu_n \rightarrow$ mobility of electrons

$\mu_p \rightarrow$ mobility of holes

$n \rightarrow$ electron concentration

$p \rightarrow$ hole concentration

$q \rightarrow$ electron charge

13. Ans: (c)

Sol: $N_A = 2.29 \times 10^{16}$

$$E_{Fi} - E_{Fp} = kT \ln\left(\frac{N_A}{n_i}\right)$$

$$= 0.02586 \ln\left(\frac{2.29\times10^{16}}{1.5\times10^{10}}\right)$$

$$= 0.3682 \text{ eV}$$

$$\simeq 0.37 \text{ eV}$$

14. Ans: (b)

Sol: Given,

2 wires $\therefore$ W_1 & W_2

$d_2 = 2d_1$ where d = diameter of wire

$L_2 = 4L_1$ where L = length of wire

Relation between resistances of W_1 & W_2

$$R = \frac{\rho.L}{A} = \frac{\rho L}{\pi r^2} \qquad r = \frac{d}{2}$$

$$R = \frac{\rho.L}{\pi\frac{d^2}{4}} = \frac{4\rho L}{\pi d^2} \qquad R \propto \frac{L}{d^2}$$

$$\frac{R_1}{R_2} = \frac{\frac{L_1}{d_1^2}}{\frac{L_2}{d_2^2}} = \frac{L_1}{d_1^2}\times\frac{d_2^2}{L_2} = \frac{L_1}{d_1^2}\times\frac{(2d_1)^2}{4L_1}$$

$$\Rightarrow \frac{R_1}{R_2} = 1 \qquad \therefore R_1 = R_2$$

15. Ans: (c)

Sol: Hall voltage, V_H is inversely proportional to carrier concentration

$$\Rightarrow \frac{V_{H2}}{V_{H1}} = \frac{P_1}{P_2} = \frac{P_1}{2P_1}$$

$$\therefore V_{H2} = \frac{1}{2}V_{H1}$$

16. Ans: (b)

Sol: $\frac{D}{\mu} = \frac{kT}{q} = V_T$

$$\therefore D = \frac{0.36\times1.38\times10^{-23}\times300}{1.6\times10^{-19}}$$

$$= 9.315\times10^{-3} \text{m}^2/\text{sec}$$

Diffusion length, $L = \sqrt{D\tau}$

$$= \sqrt{9.315\times10^{-3}\times340\times10^{-6}}$$

$$= 1.77\times10^{-3}\text{m}$$

17. Ans: (a)

Sol: In intrinsic semiconductor,

No. of e^- = No. of holes

18. Ans: (a)

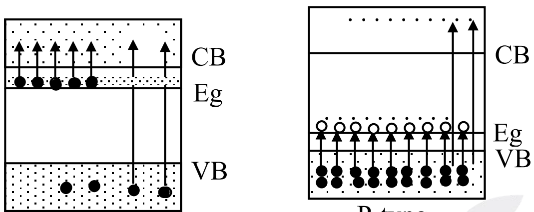
Sol: In P-type, as doping increases hole concentration p increases. According to mass action law $n_p = \frac{n_i^2}{p_p}$ $\Rightarrow$ electron concentration decreases.

19. Ans: (b)

Sol: In intrinsic semiconductor, electron hole pairs are generated due to external energy $\Rightarrow$ true. electron mobility is 2 to 3 times more than hole mobility $\Rightarrow$ true. Both the statements are true but statement II is not a correct explanation of statement I

20. Ans: (a)

Sol: Both statement (I) and (II) are true and statement (II) is the correct explanation of statement (I).

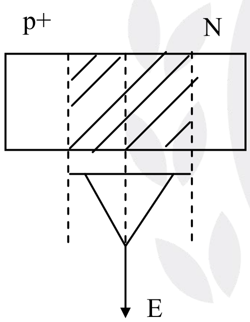


n-type P-type

2. PN Junction Diode

01. Ans: (c)

Sol:



In P^+, '+' indicates heavily region and 'n' indicates lightly doped region.

02. Ans: (a)

Sol: $w = \sqrt{\dfrac{2\varepsilon V_0}{q}\left[\dfrac{1}{N_D} + \dfrac{1}{N_A}\right]}$

$$\frac{w_2}{w_1} = \sqrt{\frac{V_0 - V_{R2}}{V_0 - V_{R1}}}$$

$$\frac{w_2}{2\mu m} = \sqrt{\frac{0.8-(-7.2)}{0.8-(-1.2)}}$$

$w_2 = 4\ \mu m.$

03. Ans: (a)

Sol: $I = \left[\dfrac{AeD_P p_{n0}}{L_P} + \dfrac{AeD_n n_{P0}}{L_n}\right]$

$$\Rightarrow I = \frac{AeD_p p_{no}}{L_P}$$

$$\frac{I}{A} = \frac{eD_P p_{no}}{L_P}$$

$$= \frac{1.602\times10^{-19}\times12\times10^{12}}{1\times10^{-3}}$$

$$= 1.92\ \text{mA/cm}^2$$

04. Ans: (c)

Sol: $1\text{ mA} = I_{GO}(e^{V_G/\eta V_T} - 1) = I_{SO}(e^{V_S/\eta V_T} - 1)$

$$\frac{I_{GO}}{I_{SO}} = \frac{e^{0.718/(2\times0.026)}}{e^{0.1435/(1\times0.026)}} \cong 4000 = 4\times10^3$$

05. Ans: (c)

Sol: In a PN Junction diode the dynamic conductance $g_m = \dfrac{\Delta I}{\Delta V}$, $g_m = \dfrac{I_C}{V_T}$

i.e. $g_m \propto I_C$

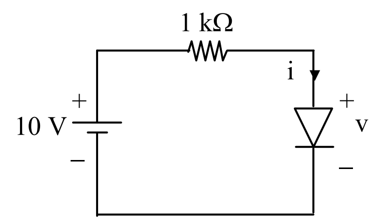
06. Ans: (d)

Sol: i – v characteristic of the diode

$i = \dfrac{v-0.7}{500}$ A, $v \geq 0.7$ V ….. (1)

From the given circuit, Loop equation :

$v = 10 - 1000\,i,\ v \geq 0.7$ V ….. (2)



Eliminating 'v' from (1) and (2) :

$$i = \frac{10 - 1000\,i - 0.7}{500} = \frac{9.3}{500} - 2i$$

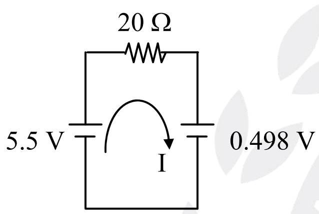
$$3i = \frac{9.3}{500}, \quad i = \frac{3.1}{500}\,A = 6.2\ mA$$

07. Ans: (b)

Sol: Given,

$V_\gamma = 0.498$ V

$V_T = 2$ mV



$$\therefore\ I = \frac{5.5 - 0.498}{20}$$

$$= 0.2501 \Rightarrow 250\ mA$$

08. Ans: (a)

Sol: Given $I_2^1 = I_1 \times 32$

Given $T_1 = 40°C$ T_2 =?

$$I_2^1 = I_1\left(2^{\frac{T_2 - T_1}{10}}\right)$$

$$I_1 \times 32 = I_1\left(2^{\frac{T_2 - T_1}{10}}\right)$$

$$2^5 = 2^{\frac{T_2 - T_1}{10}}$$

$$\Rightarrow \frac{T_2 - T_1}{10} = 5$$

$T_2 - T_1 = 50$ $\qquad$ $T_2 = 50 + T_1$

$T_2 = 90°C$

09. Ans: (b)

Sol: For either Si (or) Ge

$$\frac{dV}{dT} \cong -2.5\ mV/^0C$$

To maintain constant current

$$\frac{(V_2 - 700mV)}{(40 - 20)}\ \frac{V}{°C} = -2.5 \times 10^{-3}\ \frac{V}{°C}$$

$\rightarrow V_2 = 650$ mV $\cong 660$ mV

10. Ans: (b)

Sol: $C = \frac{\varepsilon_0 \varepsilon_r A}{d} \Rightarrow \frac{C}{A} = \frac{\varepsilon_0 \varepsilon_r}{d}$

$$= \frac{11.7 \times 8.85 \times 10^{-12}}{10 \times 10^{-6}}$$

$= 10\ \mu F$

11. Ans: (d)

Sol: The cut-in voltage for Germanium diode is 0.3volt whereas the cut-in voltage for silicon diode is 0.7. So, cut-in voltage for silicon diode is greater than that for Germanium. Therefore, statement-I is false.

The reverse saturation current of Germanium diode is in the order of 'μA' whereas that for silicon diode is 'nA'. So, Germanium diode has a higher reverse saturation current than silicon diode. Therefore, statement-II is true.

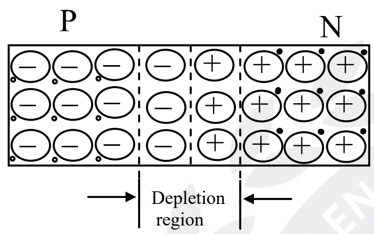
12. Ans: (b)

Sol: In all practical cases, the reverse saturation current (I_0) increased by 7% per ^oC rise in temperature. I_0 approximately doubles for every 10^oC temperature rise for both Si and Ge materials. So, Statement-I is true.

In practical cases, $\frac{dV_0}{dT} = -2.5\,mV/^oC$ i.e., at room temperature, the p-n junction voltage decreases by about 2.5 mV per ^{o}C with rise in temperature. So, statement-II is true but not the correct explanation of statement-I.

13. Ans: (c)

Sol:



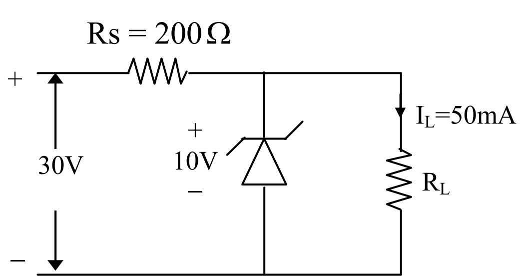
The depletion region of an unbiased pn-junction contains negative ions in the p-side and positive ions in the n-side. So, an unbiased pn-junction develops a built-in potential at the junction with the n-side positive and the p-side negative. Therefore, statement-I is true.

The pn diode is a passive device. The pn-junction cannot behaves as a battery. Therefore statement-II is false.

3. Zener Diode

01. Ans: (d)

Sol:



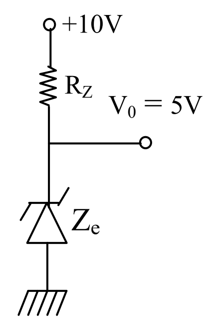
$V_s = 30 - 10 = 20V$

$$\text{Power dissipation} = \frac{V_s^2}{R_s}$$

$$= \frac{20^2}{200} = 2\text{ W}$$

02. Ans: (c)

Sol: Power rating of Zener diode = 5 mW



$I_Z V_Z = 5 \times 10^{-3}$

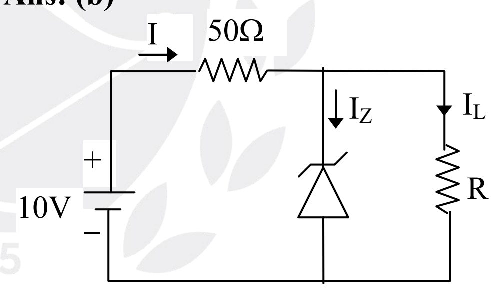
$$I_Z = \frac{5 \times 10^{-3}}{5} = 1\,mA$$

∴ Current flows through the circuit is = 1 mA

$$R_Z = \frac{10-5}{1m} = 5K\Omega$$

03. Ans: (b)

Sol:



Given that, $V_z = 6V$

$I_{zmin} = 5mA$

$R_{min} \Rightarrow I_L max$

$$I = \frac{10-6}{50} = \frac{4}{50} = 80\,mA$$

$I = I_{zmin} + I_{Lmax}$

$I_{Lmax} = 75$ mA

$$R_{L\,min} = \frac{V_z}{I_{L\,max}}$$

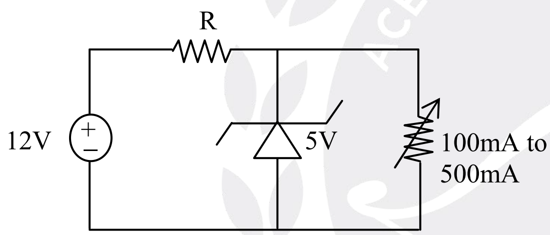
$$= \frac{6}{75\times10^{-3}} = 80\,\Omega$$

04. Ans: (b)

Sol: In –ve cycle of i/p diode forward biased, so replace by short circuit, so o/p = i/p with –12V in o/p only option 'b' exists, so using method of elimination answer is b.

05. Ans: (d)

Sol: Given circuit,



Given, source voltage

$V_s = 12V$

$I_{Lmin} = 100$ mA

$I_{Lmax} = 500$ mA

$V_z = 5V$

$I_{z\,min} = 0A$

$$\therefore R = \frac{V_s - V_z}{I_{z\,min} + I_{L\,max}}$$

$$R = \frac{12-5}{500mA}$$

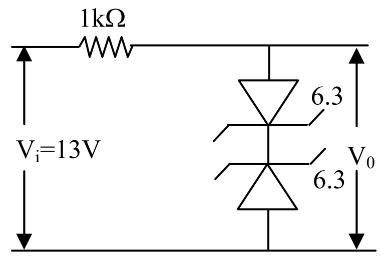
$$R = \frac{7\times10^3}{500}$$

$$R = \frac{70}{5}\Omega$$

$$R = 14\,\Omega$$

06. Ans: (c)

Sol: Given circuit,



$V_0 = 0.6 + 6.3 = 6.9$ V

07. Ans: (a)

Sol: The ideal characteristic of a stabilizer is constant output voltage with low internal resistance

08. Ans: (a)

Sol:
- In PN junction diode break down depends on doping. As doping increases breakdown voltage decreases.
- In Zener diode breakdown is less than 6 V
- It has Negative Temperature coefficient (operate in R. B)
- Avalanche diode breakdown greater than 6 V.

09. Ans: (b)

Sol: Both statement (I) and (II) are true but statement (II) is not a correct explanation of statement (I) because DC voltage stabilizer circuit can be implemented by using other components like Op-Amp also. There is no need that only Zener diode to be used.

4. Special purpose diodes

01. Ans: (a)

Sol: Tunnel diode

It is highly doped S.C ($1 : 10^3$)

It is an abrupt junction (step) with both sides heavily doped made up of Ge (or) GaAs

It carries both majority and minority currents.

It can be used as oscillator

Operate in Negative Resistance region

Operate as fast switching device

02. Ans: (c)

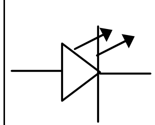
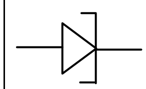
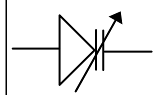
Sol: The values of voltage (V_D) across a tunnel-diode corresponding to peak and valley currents are V_P and V_V respectively. The range of tunnel-diode voltage V_D for which the slope of its I-V_D characteristics is negative would be $V_P \leq V_D < V_V$

03. Ans: (c)

Sol: Schottky diode is made of metal and semiconductor to decrease the switching times, hence it can be used for high frequency applications.

04. Ans: (a)

Sol:

Symbol	**Circuit name**	**Applications**
	LED	Direct Band gap
	Tunnel diode	Fast Switching circuits
	Varactor diode	Electronic Tuning

05. Ans: (a)

Sol: The tunnel diode has a region in its voltage current characteristics where the current decreases with increased forward voltage known as its negative resistance region. This characteristic makes the tunnel diode useful in oscillators and as a microwave amplifier.

5. Bipolar junction Transistor

01. Ans: (b)

Sol: $\alpha = \beta/(1+\beta) = 0.9803$

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

$\rightarrow \beta^* = 0.9803/0.995$

$= 0.9852$

02. Ans: (d)

Sol: $I_C = 4mA$

$r_0 > 20k\Omega$

$$r_0 = \frac{V_A}{I_C}$$

$$\frac{V_A}{I_C} > 20k\Omega$$

$V_A > 20k\Omega \times I_C$

$V_A > 20 \times 10^3 \times 4 \times 10^{-3}$

$V_A > 80$

03. Ans: (d)

Sol: $V_A = 100$ V

$I_C = 1$ mA

$V_{CE} = 10$ V

$$I_{CQ}\left(1+\frac{V_{CE}}{V_A}\right) = I_C$$

If $V_A \to \infty \Rightarrow I_C = I_{CQ}$

$$\Rightarrow I_C = I_{CQ} = \frac{1}{1+\frac{10}{100}}$$

$= 0.909$ mA

04. Ans: (b)

Sol: The phenomenon is known as "Early Effect" in a bipolar transistor refers to a reduction of the effective base-width caused by the reverse biasing of the base-collector junction.

05. Ans: (a)

Sol: Given $\alpha = 0.995$, $I_E = 10$mA,

$I_{co} = 0.5$mA

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

$$I_{CEO} = \left(1+\frac{\alpha}{1-\alpha}\right)I_{CBO}$$

$I_{CEO} = (1+199) \times 0.5 \times 10^{-6}$

$I_{CEO} = 100\mu$A

06. Ans: (b)

Sol: I_{CBO} is greater than I_{CO}. Reverse leakage current double for every Ten degrees rise in temperature.

07. Ans: (b)

Sol: Given base width $W_B = 50\times10^{-6}$ cm

Base doping $N_B = 2\times10^{16}$ cm^{-3}

$\varepsilon_r\varepsilon_0=\varepsilon$ and $\varepsilon = 10^{-12}$ F/cm

$$V_{punch} = \frac{qN_BW_B^2}{2\varepsilon}$$

$$= \frac{1.6\times10^{-19}\times2\times10^{16}\times\left(50\times10^{-6}\right)^2}{2\times10^{-12}}$$

$$V_{punch} = \frac{1.6\times2\times2500}{2}\times10^{-3} = 4\text{V}$$

08. Ans: (a)

Sol: $\alpha = 0.98$

$I_B = 40\ \mu$A

$I_{CBO} = 1\ \mu$A

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = 49$$

For a CE active BJT

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

$= 49 \times 40 \times 10^{-6} + 50 \times 10^{-6}$

$= 2.01$ mA

09. Ans: (b)

Sol: $I_{CBO} = 0.4\ \mu$A

$I_{CEO} = 60\ \mu$A

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

$$1+\beta = \frac{I_{CEO}}{I_{CBO}}$$

$$= \frac{60}{0.4} = 150$$

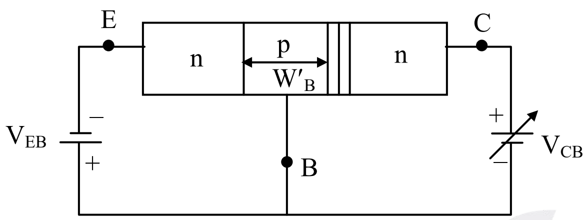
$\beta = 150 - 1$

$= 149$

$$\alpha = \frac{\beta}{1+\beta} = \frac{149}{150} = 0.993$$

10. Ans: (c)

Sol: Variation of base width due to reverse biased voltage across collector - base junction is known as "Early Effect".



As V_{CB} increases, effective base width (W'_B) decreases

11. Ans: (a)

Sol: Both statement (I) and (II) are true and statement (II) is the correct explanation of statement (I)

At very high temperature, extrinsic semiconductors will behave as intrinsic i.e., charge carriers will remains constant.

12. Ans: (b)

Sol:

Junction		Region of operation
E - B	C - B	
F. B	F.B	Saturation Region
F.B	R.B	Active Region
R.B	F.B	Inverse active Region
R.B	R.B	Cut-off Region

13. Ans: (c)

Sol: High power transistors are made of Si to withstand high temperature: Silicon is an indirect band gap material.

6. Junction Field Effect Transistor

01. Ans: (d)

Sol: $V_G \rightarrow 4.2$ V to 4.4 V

$I_D \rightarrow 2.2$ mA to 2.6 mA

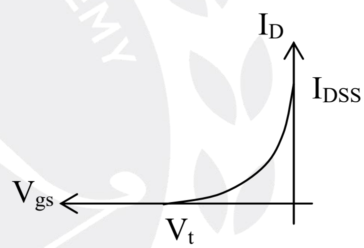
$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$= \frac{(2.6-2.2)\times 10^{-3}}{4.4-4.2}$$

$$= 2\ m℧$$

02. Ans: (c)

Sol:



$V_{gs} = V_t$ $\quad$ $I_D = 0$

$V_{gs} = 0$ $\quad$ $I_D = I_{DSS}$

03. Ans: (b)

Sol: $I_{Dmax} = I_{Dss} = 10$ mA

$V_P = -4V$

$V_{GS} = -1$ V

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$$

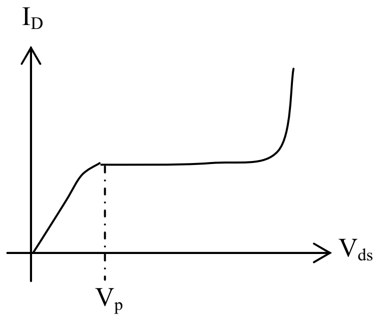
$$= 10\times 10^{-3}\left(1-\frac{-1}{-4}\right)^2$$

$$= 10\times 10^{-3}\times\left(\frac{3}{4}\right)^2$$

$$= 5.625 \text{ mA}$$

04. Ans: (d)

Sol:



Drain current remains constant at pinch off region even if the drain voltage increases.

05. Ans: (c)

Sol: JFET acts as a voltage controlled current source

06. Ans: (a)

Sol: Mobility of electron is higher than mobility of hole

<u>Si</u>

Electron mobility : $1350\ cm^2/v-s$

Hole mobility : $450\ cm^2/v-s$

<u>Ge</u>

Electron mobility : $3600\ cm^2/v-s$

Hole mobility : $1800\ cm^2/v-s$

: Low leakage current means high input impedance

: Reverse bias increases, channel width reduces (wedge shaped)

07. Ans: (c)

Sol: $V_P = -8$ V

$I_{DSS} = 12$ mA

From the given circuit,

$V_G = -5$ V

$V_S = 0$ V

$V_{GS} = -5$ V

V_{DS} at which pinch –off region means

$(V_{DS})_{min} = V_{GS} - V_P$

$= -5 - (-8)$

$= -5 + 8$

$= 3$ V

08. Ans: (d)

Sol: P. Voltage controlled device –FET (3)

Q. Current controlled device –BJT (1)

R. Conductivity modulation device-- IMPATT diode (4)

S. Negative conductance device -UJT (2)

09. Ans: (d)

Sol: $I_{DSS} = 12$ mA

$V_P = -6$ V

$V_{GS} = 0$ V

$V_{DS} = 7$ V

At $V_{GS} = 0V$, $I_D = I_{DSS}$

$$= 12mA \quad \left(\because I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2\right)$$

10. Ans: (d)

Sol:

Device :	**Application**
A. Diode	Rectifier (3)
B. Transistor	Amplifier (1)
C. Tunnel diode	Oscillator (2)
D. Zener diode	Reference Voltage (4)

11. Ans: (a)

Sol: $g_{m0} = \left|\frac{2I_{DSS}}{V_p}\right|$

$$= \frac{2\times 25\times 10^{-3}}{10} = 5$$

12. Ans: (b)

Sol: BJT is current controlled current source

($R_i = 0$; $R_o = \infty$)

Gain × B.W is high

FET is voltage controlled current source

($R_i = \infty$; $R_o = 0$)

Gain × B.W is low

UJT is a negative resistance device and can be used as an oscillator

UJT can be used as switch but can't be amplification

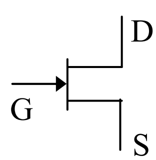
13. Ans: (a)

Sol: In FET majority carriers only exist.

In BJT majority & minority carriers exist.

14. Ans: (a)

Sol:



N – channel FET

Input resistance of FET is of the order of tens (or) hundreds of mega ohms (MΩs)

: V_{gs} is reverse bias.

: In reverse bias very small leakage current I_{CO} flows through the gate.

15. Ans: (c)

Sol: FET's has high input impedance when compared to BJT. Because of this FET's are more suitable at the input stage of milli voltmeter and CRO's than BJT's. Generally FET has input impedance in the range of several MΩ

Statement (II) is false. So, option 'c' is correct

16. Ans: (d)

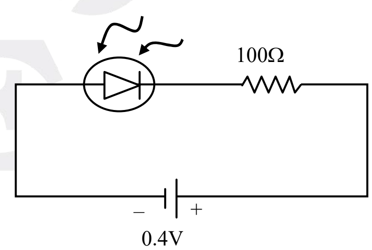
Sol: Statement (I) is false, because FET is a voltage control current source.

Statement (II) is true. Why because operation of FET does not depends on minority carrier i.e. FET operation depends on either electrons or holes as a majority carriers.

7. Optoelectronic Devices

01. Ans: (a)

Sol:



By KVL,

$0.4 - 100\times 1.8\times 10^{-3} - V_P = 0$

$V_P = 0.4 - 100\times 1.8\times 10^{-3}$

$= 0.22$ V

$V_P = r_p I$

$$r_p = \frac{V_P}{I}$$

$$= \frac{0.22}{1.8\times10^{-3}}$$

$$= 122.22\ \Omega$$

02. Ans: (b)

Sol: If illumination doubled then current passing through the photo diode is doubled

$I_D = 2\times1.8 = 3.6$mA

Voltage across photo diode is

$= 0.4 - 3.6\times10^{-3}\times100$

$= 0.4 - 0.36$

$V_p = r_pI_p$

$$r_p = \frac{V_p}{I_p}$$

$$= \frac{0.04}{3.6}\times10^3$$

$= 0.01111\times10^3$

$= 11.11\Omega$

03. Ans: (b)

Sol: Avalanche photo diodes are preferred over PIN diodes in optical communication because Avalanche photo diodes are (APDs), extracted from avalanche gain and excess noise measurement and higher sensitivity. PIN diodes generate more noise.

04. Ans: (c)

Sol: Photo diode always operates in reverse bias. When no light falls on photo diode, Small amount of reverse saturation current flows through the device called "dark current".

05. Ans: (a)

Sol: Give,

$E_g = 1.12$ eV,; $\lambda_1 = 1.1\ \mu$m

$\lambda_2 = 0.87\ \mu$m; E_{g2} =?

$$E_g = \frac{12400\,A^0}{\lambda} \Rightarrow E_g\alpha\frac{1}{\lambda}$$

$$\frac{E_{g_1}}{E_{g_2}} = \frac{\lambda_2}{\lambda_1}$$

$$\Rightarrow E_{g_2} = E_{g_1}\times\frac{\lambda_1}{\lambda_2} = 1.12\times\frac{1.1}{0.87}$$

$= 1.416$ eV

06. Ans: (a)

Sol: Sensitivity of photo diode depends on light intensity and depletion region width.

07. Ans: (d)

Sol: $I_D = \frac{24-1.8}{820}$

$= 0.02707$ A

$= 27.07$ mA

08. Ans: (c)

Sol: Photo diode operate in R.B: Photo diode works on the principle of photo electric effect.

09. Ans: (b)

Sol: Voltage across PN junction diode resulting in current which in turn produce photons and light output. This inversion mechanism also called injection electro luminescence observed in LED's.

10. Ans: (b)

Sol: $\lambda = 890\ A^o$

$$\lambda = \frac{1.24\times10^{-6}}{E_G}\ m$$

$$= \frac{1.24\times10^{-6}}{890\times10^{-10}} = 13.93\ eV$$

11. Ans: (d)

Sol: Solar cell converts optical (sunlight) energy into electrical energy.

12. Ans: (b)

Sol: R = 0.45 A/W

$P_0 = 50\ \mu W$

$$R = \frac{I_P}{P_0}$$

$I_P = R\,P_0$

$= 0.45 \times 50$

$= 22.5\ \mu A$

Load current $= I_P + I_0$

$= 22.5\ \mu A + 1\mu A$

$= 23.5\ \mu A$

13. Ans: (d)

Sol: LED: F.B

Photo diode: R.B

Zener diode: R.B

Ordinary diode: F.B

Tunnel diode: F.B

Variable capacitance diode: R.B

Avalanche diode: R.B

14. Ans: (c)

Sol: Tunnel diode is always operated in forward bias and light operated devices are operated in reverse bias. (Avalanche photo diode).

15. Ans: (b)

Sol: LED's and LASER's are used in forward bias.

Photo diodes are used in reverse bias.

16. Ans: (b)

Sol: Both statement (I) and (II) are true but statement (II) is not a correct explanation of statement (I).

17. Ans: (a)

Sol: Both statement (I) and (II) are true and statement (II) is the correct explanation of statement (I).

8. MOSFET

01. Ans: (c)

Sol: $V_T = 1$

$V_{DS} = 5 - 1 = 4$ V

$V_{GS} = 3 - 1 = 2$ V

$V_{GS} - V_T = 2 - 1 = 1$ V

$V_{DS} > V_{GS} - V_T$

$4 > 1 \rightarrow$ Saturation

02. Ans: (d)

Sol: In active region (or) saturation region, channel is pinched off. Number of carriers present in the channel decreases from source end to drain end due to potential increases from source to drain.

03. Ans: (d)

Sol: $\frac{I_{D_2}}{I_{D_1}} = \frac{K_n[V_{GS2} - V_T]^2}{K_n[V_{GS1} - V_T]^2}$

$\frac{I_{D_2}}{1\,mA} = \frac{[1400-400]^2}{[900-400]^2}$

$I_{D_2} = 4\,mA$

04. Ans: (d)

Sol: $A = 1$ sq $\mu m = 10^{-12}$ m^2

$d = 1\ \mu m = 1 \times 10^{-6}$ m

$N_D = 10^{19}/cm^3$

$n_i = 10^{10}$

No. of holes = concentration × volume

Volume = A × d = 10^{-18} m

$p = \frac{n_i^2}{n} = \frac{10^{20}}{10^{19}}$

$= 10\ holes/cm^3 = 10 \times 10^6\ holes/m^3$

∴ No. of holes = $10 \times 10^6 \times 10^{-18}$

$= 10^{-11}$ holes

≈ 0

05. Ans: (b)

Sol:
- Since it has n-type source & drain, it is n-channel MOSFET.
- Drain current flows only when $V_{GS} > 2V$, it implies it has threshold voltage (V_{th}) of +2V

  ⇒ It is enhancement type MOSFET.
- $V_{Th} = +2V$
- $g_m = \mu_n C_{ox} \frac{W}{L}[V_{GS} - V_{Th}]$,

  transconductance depends upon electron mobility.

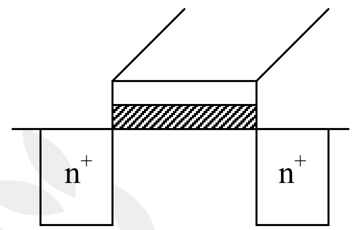
06. Ans: (b)

Sol: $C_{sbo} = \frac{\varepsilon_{si} A}{d}$

d = 10 nm

$\varepsilon_{si} = \varepsilon_{rsi}\, \varepsilon_0$

$= 11.7 \times 8.9 \times 10^{-12}$ F/m



$A = (0.2\mu \times 1\mu) + (0.2\mu \times 1\mu) + (0.2\mu \times 1\mu)$

$= 3(0.2\mu \times 1\mu) = 0.6 \times 10^{-12}$ m^2

$C_{sbo} = \frac{11.7 \times 8.9 \times 10^{-12} \times 0.6 \times 10^{-12}}{10 \times 10^{-9}}$

$C_{sbo} = 6.24 \times 10^{-15}$

≈ 7 fF

In practical IC, this cap will provided to front and back sides also then area may be

$A = (0.6 \times 10^{-12}) + (0.2\mu \times 1\mu) + (0.2\mu \times 1\mu)$

$A = 0.68 \times 10^{-12}$ m^2

$C_{sbo} = \frac{11.7 \times 8.9 \times 10^{-12} \times 0.68 \times 10^{-12}}{10 \times 10^{-9}} = 7fF$

07. Ans: (a)

Sol: $L_{ov} = \delta = 20$ m

d = 10 nm, w = 1 μm

$\varepsilon_{rsi} = 11.7$, $\varepsilon_{rox} = 3.9$

$\varepsilon_0 = 8.9 \times 10^{-12}$ F/m

$C_{ov} = C_{ox}\, w\, L_{ov} = \frac{\varepsilon_{ox}}{t_{ox}} w\, L_{ov}$

$$= \frac{\varepsilon_{rox}\,\varepsilon_0}{t_{ox}} w\,L_{ov}$$

$$= \frac{3.9\times 8.9\times 10^{-12}\times 1\times 10^{-6}\times 20\times 10^{-9}}{1\times 10^{-9}}$$

$$= 0.69\times 10^{-15} = 0.69\text{ fF} \approx 0.7\text{ fF}$$

08. Ans: (a)

Sol: $A = 1\times 10^{-4}\ \text{cm}^2$

$\varepsilon_{si} = 1\times 10^{-12}$ F/cm

$\varepsilon_{ox} = 3.5\times 10^{-13}$ F/cm

$C_0 = 7$ pF

$$C_0 = C_{ox}A = \frac{\varepsilon_{ox}A}{t_{ox}}$$

$$t_{ox} = \frac{\varepsilon_{ox}}{C_0}A = \frac{3.5\times 10^{-13}\times 1\times 10^{-4}}{7\times 10^{-12}}$$

$$= 5\times 10^{-6}\text{ cm} = 50\text{ nm}$$

09. Ans: (b)

Sol: $$\frac{C_0 C_d}{C_0 + C_d} = 1\text{pF}$$

$$\frac{7C_d}{C_d+7} = 1 \Rightarrow C_d = \frac{7}{6}\text{pF}$$

$$C_d = C_{dep}A = \frac{\varepsilon_{si}}{d}A$$

$$d = \frac{\varepsilon_{si}}{C_d}A$$

$$= \frac{1\times 10^{-12}}{\frac{7}{6}\times 10^{-12}}(1\times 10^{-4})\text{cm} = 0.857\,\mu\text{m}$$

10. Ans: (b)

Sol: $V_{Th} = 0.5$V

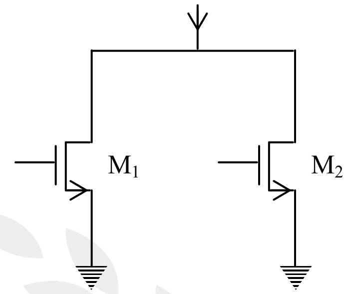
$V_G = 3$V

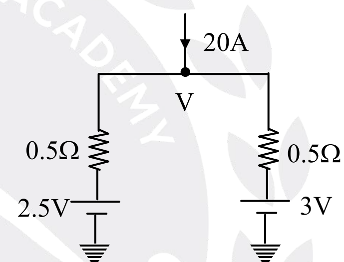
Pinch-off occurs when

$V_D = V_G - V_{Th} = 3 - 0.5 = 2.5$V

11. Ans: (a)

Sol:





$$20 = \frac{V-2.5}{0.5} + \frac{V-3}{0.5}$$

V = 7.75 Volts

$$I_{D_1} = \frac{7.75-2.5}{0.5} = 10.5\text{A}$$

$$I_{D_2} = \frac{7.75-3}{0.5} = 9.5\,\text{A}$$

12. Ans: (b)

Sol: The input impedance of insulated gate MOSFET is very high because of SiO_2 layer and revere bias at gate to source junction (i.e.at input junction)

Statement (II) also true but not the correct explanation of statement (I)

13. Ans: (d)

Sol: Statement (I) is false, for same drain current rating n-channel MOSFET occupies less area than p-channel MOSFET why because electron mobility is higher than hole mobility

14. Ans: (a)

Sol: An Enhancement type MOSFET can be operate only in Enhancement mode. For n-channel EMOSFET, if V_{GS} (positive) > V_{th}, than only channel will formed between source and drain. So, for n-type EMOSFET only positive voltage can be applied to the gate with respec to the substrate. Therefore, statement-I is true.

Only with a positive voltage to the gate an "Inversion layer" is formed and conduction can take place. So statement-II is true and correct explanation of statement-I.

15. Ans: (b)

Sol: The drain current (I_D) of a MOSFET is controlled by the gate voltage. Therefore statement-I is true.

The input impedance for a MOSFET is very and the current through the gate terminal (I_G) is zero. Therefore, MOSFET is an insulated gate FET. So statement-II is true but not the correct explanation for statement-I.

9. Biasing

01. Ans: (c)

Sol: $R_D = \dfrac{V_{DD} - V_D}{I_D}$

$$= \frac{20V - 12V}{2.5mA} = 3.2\,k\Omega$$

In self bias

$V_{GS} = -I_D R_S$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

$$V_{GS} = V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right)$$

$V_{GS} = -1.06$ V

$$R_S = \frac{V_{GS}}{-I_D} = \frac{-1}{-2.5} = 400\,\Omega$$

02. Ans: (b)

Sol: $V_G = V_{GS} + I_D R_S$

$$I_D = \frac{16-8}{1.8K} = 4.4\,mA$$

$$V_G = \frac{16\times 47}{138} = 5.45\,V$$

$$R_S = \frac{V_G - V_{GS}}{I_D}$$

$$= \frac{5.4-(-2V)}{4.4m} = 1.68k\Omega$$

03. Ans: (c)

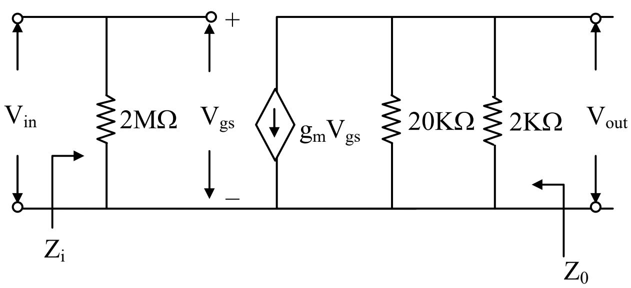
Sol: $V_{DS} = V_{DD} - I_D(R_D + R_S)$

$= 30\text{ V} - 4\text{ mA}(3.3K + 1.5K)$

$V_{DS} = 10.8$ V

04. Ans: (b)

Sol: AC analysis,



$Z_i = 2M\Omega$, $\quad Z_0 = 20\Omega \,||\, 2\Omega$

$$\Rightarrow Z_0 = \frac{20}{11}\Omega$$

05. Ans: (a)

Sol: $I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_p}\right]^2$

$$= 10\times10^{-3}\left[1 - \frac{-2}{-8}\right]^2 = 5.625\text{mA}$$

KVL at output loop,

$$-20 + \left(2\times10^3 I_D\right) + V_{DS} = 0$$

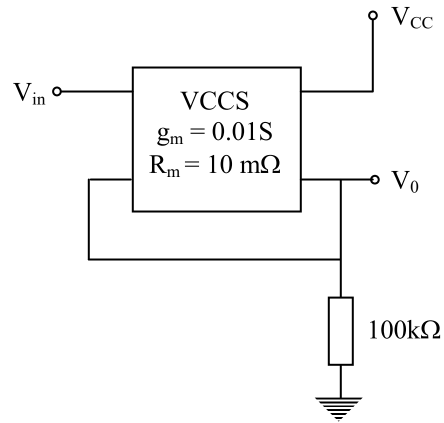
$$V_{DS} = 20 - \left(2\times10^3 \times 5.625\times10^{-3}\right)$$

$= 8.75V$

06. Ans: (b) (By Printing Mistake in Volume-I Answer (c) is wrong, Correct answer is (b))

Sol: By observing,

The circuit is common drain i.e., source follower circuit.



$$R_0 = r_d \,||\, R_s \,||\, \frac{1}{g_m}$$

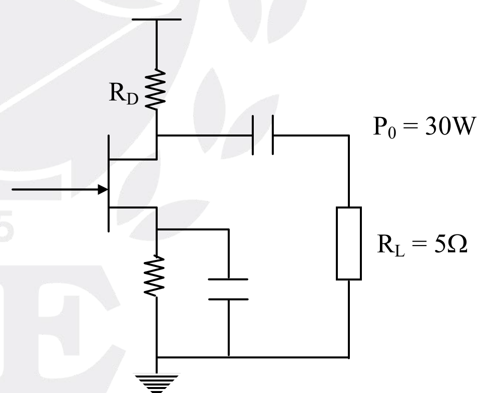
$= 10\ M\Omega \,||\, 100\ k\Omega \,||\, 100\ \Omega$

$= 100\ \Omega$

FREQUENCY ANALYSIS

01. Ans: (d)

Sol:



$$P_0 = \frac{V_0^2}{R_L}$$

$30 \times 5 = V_0^2$

$V_0 = 12.25$ V

$$A_V = \frac{V_0}{V_i}$$

$A_{v\,(dB)} = 20\log_{10} A_v$

$$20 = 20\log_{10} A_v$$

$$A_v = 10^1 = 10$$

$$\frac{V_0}{V_i} = 10$$

$$V_i = \frac{V_0}{10} = \frac{12.25}{10}\,V = 1.225\,V$$

02. Ans: (b)

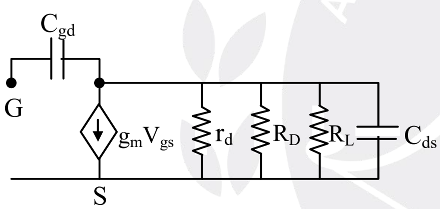
Sol: $A_{v(dB)} = 20\log_{10} A_v$

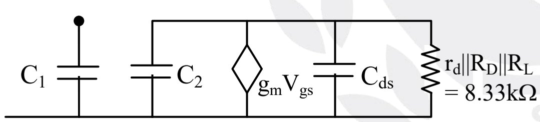
$$50 = 20\log_{10} A_v$$

$$A_v = 10^{(5/2)} = 316.228$$

03. Ans: 6.123×10^6 Hz

Sol: Small signal equivalent

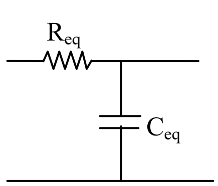




$$C_2 = C_{gd}\left(1 - \frac{1}{A_v}\right),$$

A_v = mid-band,

gain = $g_m(r_d||R_D||R_L) = -16.66$



$$C_2 = 2pF\left(1 - \frac{1}{-16.66}\right) = 2.12\text{ pF}$$

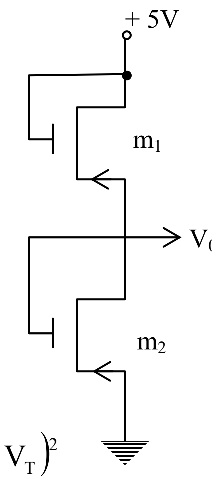
$$f_H = \frac{1}{2\pi C_{eq} R_{eq}}$$

$C_{eq} = 1 + 2.12 = 3.12$ pF, $R_{eq} = 8.33k\Omega$

$\Rightarrow f_H = 6.123 \times 10^6$ Hz

MOSFET BIASING

01. Ans: (b)



Sol: $V_T = 0.8$

$K_n = 30 \times 10^{-6}$

$$\left(\frac{W_1}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = 40$$

$$V_{D_1} = +5$$

$$I_{D_1} = I_{D_2}$$

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS_1} - V_T)^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS_2} - V_T)^2$$

$$V_{GS_1} = V_{D_1} - V_0 = +5 - V_0$$

$$V_{GS_2} = V_{G_1} - V_S = V_0 - 0 = V_0$$

$$\left(\frac{W}{L}\right)_1 (5 - (V_0) - 0.8)^2 = \left(\frac{W}{L}\right)_2 (V_0 - 0.8)^2$$

$$V_0 = 2.5V$$

02. Ans: (a)

Sol: $\left(\frac{W}{L}\right)_1 (V_{GS_1} - V_T)^2 = \left(\frac{W}{L}\right)_2 (V_{GS_2} - V_T)^2$

$$40\,(4.2 - V_0)^2 = 15(V_0 - 0.8)^2$$

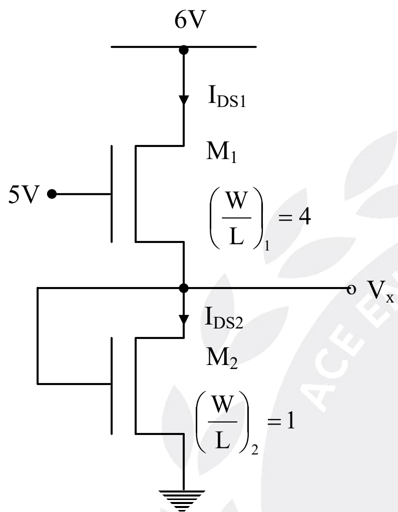
$$V_0 = 2.91\text{ V}$$

03. Ans: (c)

Sol: From figure $I_{DS1} = I_{DS2}$.

$$\frac{1}{2}\mu_n C_{0x}\left(\frac{W}{L}\right)_1 \left(V_{GS_1} - V_t\right)^2$$

$$= \frac{1}{2}\mu_n C_{0x}\left(\frac{W}{L}\right)_2 \left(V_{GS_2} - V_t\right)^2$$



$$\therefore\ 4(5 - V_x - V_t)^2 = 1(V_x - V_t)^2$$

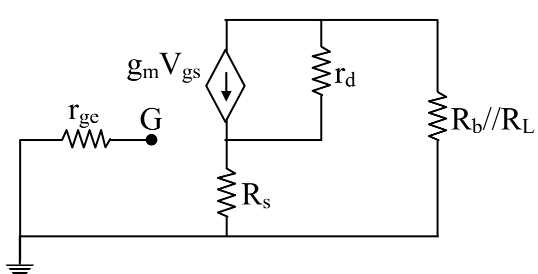
$$(\because V_{GS1} = V_G - V_x = 5 - V_x)$$

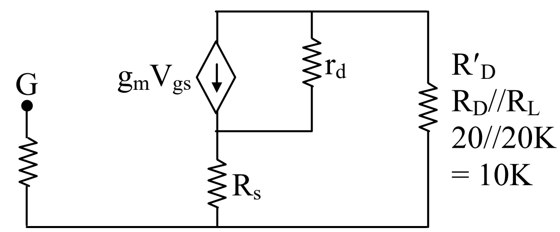
$$\Rightarrow 2(5 - V_x - V_t) = (V_x - V_t)$$

$$\therefore\ V_x = 3V$$

04. Ans: $\approx$**-7** (By Printing Mistake in Volume-I Answer (7) is wrong, Correct answer is (–7))

Sol:





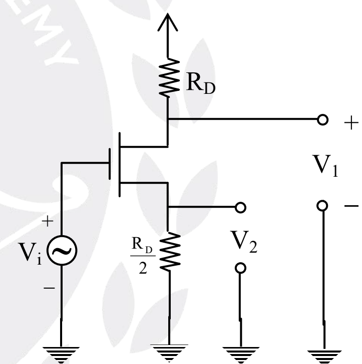
$$A_V = \frac{-g_m r_d R'_D}{R'_D + R_s + r_d + g_m r_D . R_s}$$

$$= \frac{5 \times 10K \times 10K}{10K + 1K + 10K + 5mA/V.10K.1K}$$

$$= -7.042$$

05. Ans: (d)

Sol:



$$\frac{V_2}{V_i} = \frac{g_m R_s}{1 + g_m R_s} \qquad \text{………..… (1)}$$

$$\frac{V_1}{V_i} = \frac{-g_m R_D}{1 + g_m R_s} \qquad \text{……….. (2)}$$

$(1) \div (2) \Rightarrow$

$$\frac{V_2}{V_1} = \frac{R_s}{-R_D}$$

$$\frac{V_2}{V_1} = \frac{-1}{2}$$

$$V_1 = -2V_2$$

06. Ans: (c)

Sol: $I_{DSS} = 6$ mA

$V_P = -3$ V

$V_{GSQ} = 1$V

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$= 6\times10^{-3}\left(1 - \frac{1}{-3}\right)^2$$

= 10.667 mA

From the given circuit

$V_S = I_D \times 0.75$ kΩ

$= 10.667\times10^{-3}\times0.75\times10^{3}$

= 8 V

$V_{GSQs} = 1$ V

$V_G - V_S = 1$ V

$V_G = V_S + 1$

= 9 V

$$9 = \frac{18R_2}{R_2 + 110M\Omega}$$

$\Rightarrow$ $R_2 = 110$ MΩ