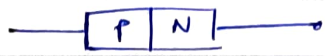
Electronics

Diode (P-N Junc Diode)

- No Bias ($V_D = 0V$)

- Forward Bias ($V_D > 0V$)
- Reverse Bias ($V_D < 0$)



$$I_{D\,Tot} = I_{majority} + I_{minority}$$
$$= \underset{(mA)}{I_D} + I_s (\mu A)$$

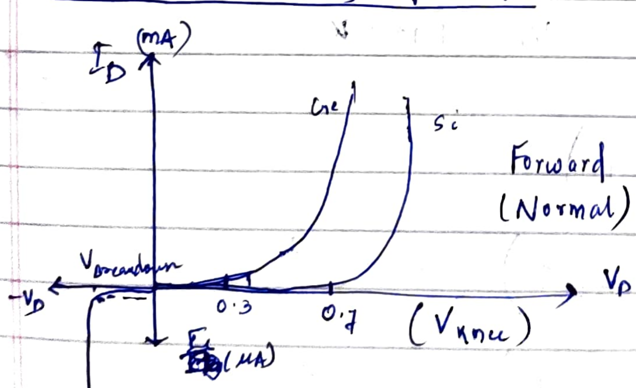
$$I_D = I_s \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

$\eta = 1$ for Ge
$\eta = 2$, for Si

I_s = Reverse saturation current
V_D = Diode Voltage
$V_T = \frac{KT}{q}$ (Thermal potential)

$K = 1.38 \times 10^{-23}$ J/K Boltzmann const.
T = absolute temp = $273° + (°C)$
$q = 1.6 \times 10^{-19}$ C.

V-I characteristics of diode



$$I_D = I_s \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

$V_D = 0$, $I_D = 0$
$V_D > 0V$, $I_D = \uparrow$
$V_D < 0$, $I_D \approx I_s$

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Q. Determine the Germaninum p-n junction diode, current for the forward biased voltage of 0.22 V and room temperature 25 °C with ~~the temperature~~ reverse saturation current is 1mA.

$$I_D = I_s \left(e^{\frac{V_D}{n V_T}} - 1 \right)$$

$$= 1 \times 10^{-3} \left(e^{\frac{0.22}{1 \times 0.0257}} - 1 \right)$$

$$= 10^{-3} \left(e^{8.56} - 1 \right)$$

273
25
298

$$V_T = \frac{KT}{q}$$

$$= \frac{1.38 \times 10^{-23} \times 298}{1.6 \times 10^{-19}}$$

$$= \frac{1.38 \times 298}{1.6} \times 10^{-4}$$

$= 257.025 \times 10^{-4}$

0.0257

Q. The current voltage of a p-n junction diode is given by Schokeby's eq. The diode current is 0.5 mA at V = 340 mV and 15 mA at V = 440 mA

The value of n where $\frac{KT}{q} = 25\,mV$

$I_D = 0.5\,mA$

$V_D = 340\,mV$

$I_D = 15\,mA$

$V_D = 440\,mV$.

68
340
25

88
440
25

$$I_D = I_s \left(e^{\frac{V_D}{n V_T}} - 1 \right)$$

$$\Rightarrow 0.5 = I_s \left(e^{\frac{340}{n \times 25}} - 1 \right) \quad \text{--- (1)}$$

$$\Rightarrow 0.5 = I_s \left(e^{\frac{68}{5n}} - 1 \right) \quad \text{--- (1)}$$

$$\Rightarrow 15 = I_s \left(e^{\frac{440}{25 n}} - 1 \right) \quad \text{--- (2)}$$

$$\Rightarrow 15 = I_s \left(e^{\frac{88}{5n}} - 1 \right)$$

$$\frac{0.5}{15} = \frac{e^{\frac{68}{5n}} - 1}{e^{\frac{88}{5n}} - 1}$$

$$\Rightarrow 0.5\left(e^{\frac{88}{5n}} - 1\right) = 15\left(e^{\frac{68}{5n}} - 1\right)$$

$$\Rightarrow \sout{0.5\, e^{\frac{88}{5n}} - 15\, e^{\frac{68}{5n}} = -15 + 0.5}$$

$$\Rightarrow 0.5\, e^{\frac{88}{5n}} = 15\, e^{\frac{68}{5n}}$$

$$\Rightarrow \frac{e^{\frac{88}{5n}}}{e^{\frac{68}{5n}}} = \frac{15}{0.5}$$

$$\Rightarrow e^{\frac{88}{5n} - \frac{68}{5n}} = \frac{15}{5} \times 10$$

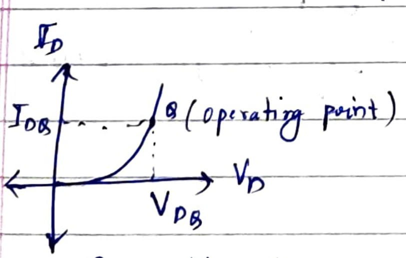
$$\Rightarrow \frac{20}{5n} = \log 30 \Rightarrow \frac{20}{\log_e 30} = 5n$$

$$\Rightarrow n = \frac{20}{5 \log_e 30}$$

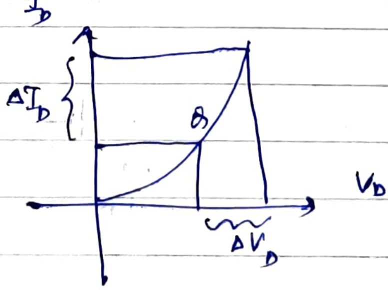
$$n = \frac{20}{5 \times 3.4} = \frac{20}{17} = 1.176$$

Resistance of Diode

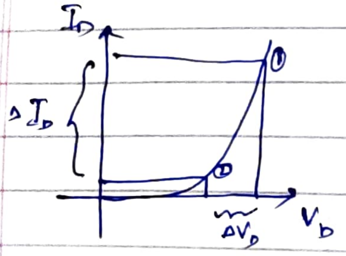
- Static Resistance R_D
- Dynamic Resistance → AC resistance (r_{ac}), → Avg. resistance (r_{avg})



$$R_D = \frac{V_{DQ}}{I_{DQ}}\Bigg|_{\text{at fixed P.t.}}$$



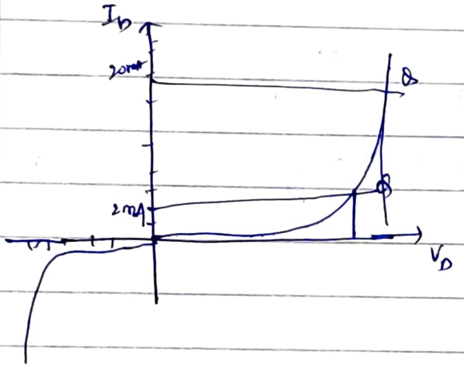
$$r_{ac} = \frac{\Delta V_D}{\Delta I_D} = \frac{26\,mV}{I_D}\Bigg|_{\text{at fixed P.t.}}$$



$$r_{avg} = \frac{\Delta V_D}{\Delta I_D} \Bigg|_{Pt-Pt}$$

Q. Determine the DC resistance levels at (i) $I_D = 2mA$,
(ii) $I_D = 20 mA$,
(iii) $V_D = -10 V$.

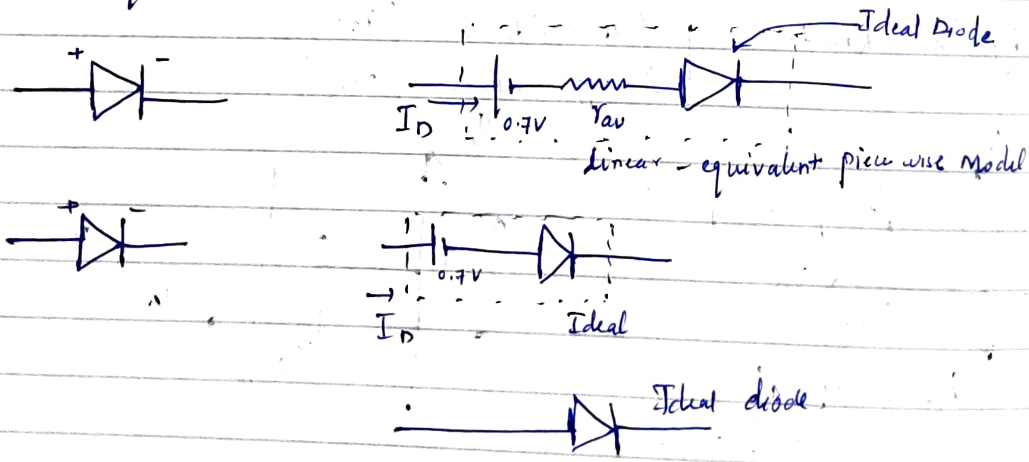
Q. For the characteristic curve :-
(a) Determine the AC resistance at $I_D = 2mA$
(b) Determine the AC resistance at $I_D = 25 mA$



$$R_D (at\ I_D = 2mA) = \frac{V_{DQ}}{2mA}$$

$$R_D (at\ I_D = 20 mA) = \frac{V_{DQ}}{20 mA}$$

Diode equivalent circuit



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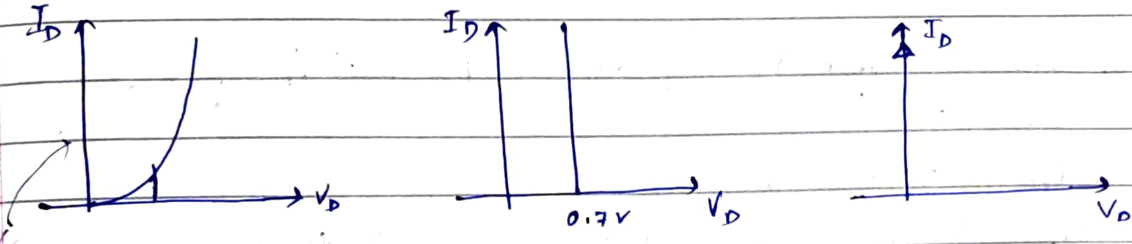
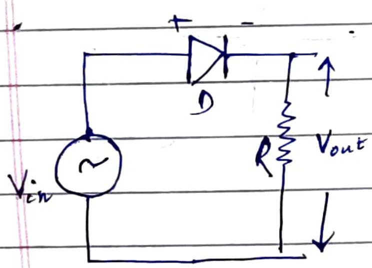
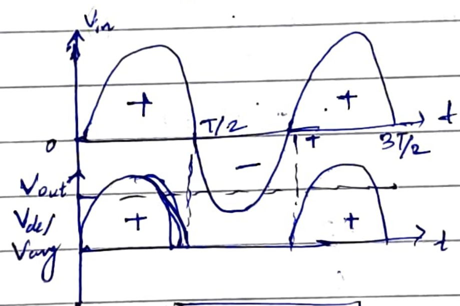


LEPWM   Ideal   Ideal diode

Rectifiers (A.C to D.C)

Half wave Rectifier
Full wave Rectifier → Center-tap
                    → Bridge





Peak Inverse Voltage ← $P_{IV} = V_m$

$$V_{av}/V_{dc} = \frac{1}{T}\int_0^{T/2} V_m \sin\omega t \, dt = 0.318\,V_m = \frac{V_m}{\pi}$$

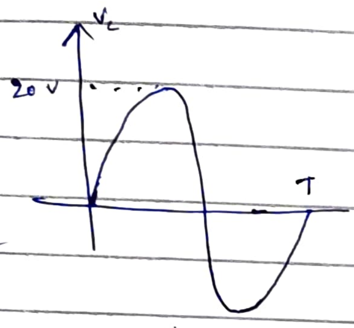
$$V_{rms} = \frac{1}{T}\int_0^{T/2} (V_m \sin\omega t)^2 \, dt = \frac{V_m}{2}$$

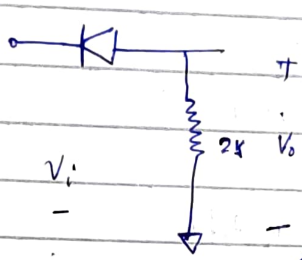
If V_T, then $V_{dc} = 0.318\,(V_m - V_T)$

Q. Sketch the output V_o and determine DC level of output for the network :

(i) Repeat if ideal diode is silicon diode

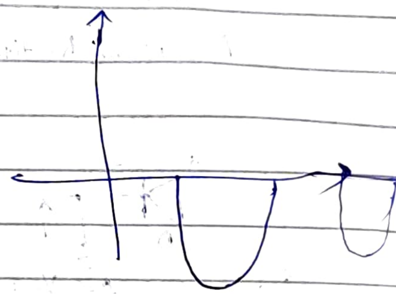
(ii) Repeat if V_m is 200V and compare the result to ans 1.





~~$V_{DC} = 0.318 \times 20$~~ $\quad V_T = 0.7$

$$V_{dc} = 0.318\,(20 - 0.7)$$
$$= 0.318 \times 19.3$$
$$= -6.1374$$



$$V_{dc} = 0.318 \times 200$$
$$= 63.6$$

Efficiency of HWR

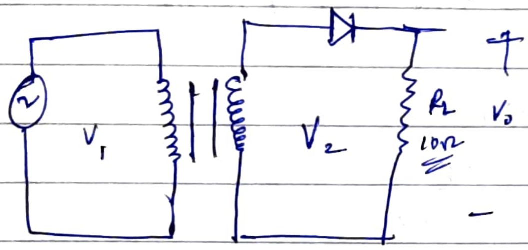
$$\eta = \frac{\text{d.c O/P power}}{\text{A.C I/P power}} = \frac{P_{dc}}{P_{ac}} = \frac{V_{dc} \cdot I_{dc}}{V_{ac} \cdot I_{ac}}$$

$$V_{dc} = \frac{V_m}{\pi} \qquad I_{dc} = \left(\frac{V_m}{\pi}\right) / R_L \qquad I_f(r_f) : I_{dc} = \frac{V_m}{\pi} / (R_L + r_f)$$

$$P_{dc} = I_{dc} \times V_{dc} = \frac{V_m}{\pi} \cdot \frac{I_m}{\pi} = \left(\frac{I_m}{\pi}\right)^2 R_L$$

$$P_{ac} = I_{rms}^2$$

Q. A AC supply of 230 V is applied to a half wave rectifier through a transformer ratio 10:1, Find the output DC power and peak inverse voltage of HWR.



$V_{rms} = 230V$

$V_m = V_{rms} \times \sqrt{2}$

$= 230 \times \sqrt{2} = 325 V$

$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{10}{1}$

$\frac{325}{V_2} = \frac{10}{1}$

$\boxed{V_2 = 32.5}$

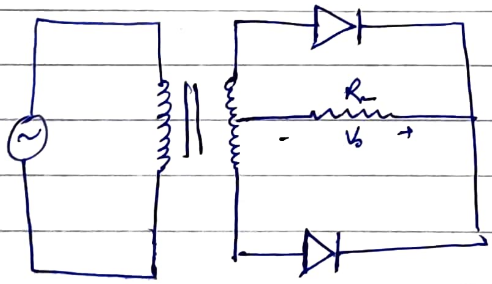
$\boxed{P_{IV} = 32.5}$

$V_{dc} = \frac{V_m}{\pi} = \frac{32.5}{\pi}$

$P_{dc} = \frac{(V_{dc})^2}{R_L} = \left(\frac{32.5}{\pi}\right)^2 \cdot \frac{1}{10}$

Full wave Rectifier

Center-tap Rectifier



$P_{IV} = 2V_m$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

$V_{dc} = \frac{1}{T}\int_0^T V_m \sin\omega t \, dt$

$V_{rms} = \frac{1}{T}\int_0^T (V_m \sin\omega t)^2 \, dt$

If V_T then $V_{dc} = \frac{2(V_m - V_T)}{\pi}$

Q. A FWR uses 2 diode, the internal resistance of each diode is 20 Ω. The transformer RMS secondary voltage from centre tap to each end of secondary is 50V and load resistance is 980 Ω. Find the mean load current and the rms value of current

$$V_m = V_{rms} \times \sqrt{2} = 50\sqrt{2}$$

$$I_m = \frac{V_m}{r_f + R_L} = \frac{50\sqrt{2}}{20+980} = \frac{50\sqrt{2}}{1000}$$

$$I_{dc} = \frac{2I_m}{\pi} = 45 \text{ mA}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 50 \text{ mA}.$$

Efficiency calculation (η)

$$I_{dc} = \frac{2I_m}{\pi}$$

$$P_{dc} = I_{dc}^2 \times R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

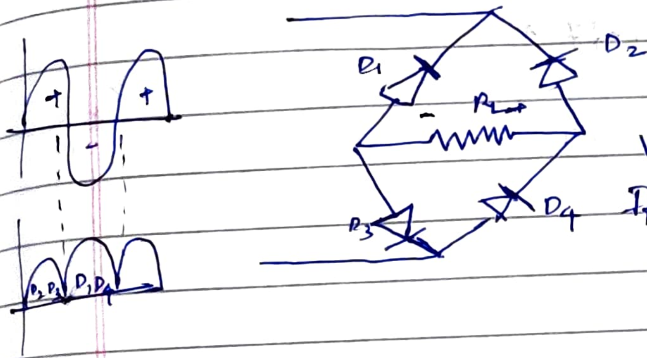
$$I_{rms} = I_m/\sqrt{2}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(2I_m/\pi)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)}$$

$$= \frac{0.812 R_L}{r_f + R_L} = 0.812 = 81.2\%$$

$$F.W.R(\eta) = 2 \times H.W.R(\eta)$$

Full Wave Bridge Rectifier :-



$P_{IV} = V_m$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

$V_{dc} = 2\,[0.318\,V_m] = 0.636\,V_m$

If V_T, then $V_{dc} = 0.636\,(V_m - 2V_T)$

Ripple factor :-

$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$

$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$

Ripple factor $= \frac{I_{ac}}{I_{dc}}$

$= \frac{1}{I_{dc}} \sqrt{(I_{rms})^2 - (I_{dc})^2}$

H.W.R → Ripple factor $= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2} = 1.21$

F.W.R $= \sqrt{}$

Q. For a full wave bridge rectifier with 120V rms, sinosoidal input has a load resistor of $1k\Omega$

(a) If silicon diodes are employed what is the Vdc available at load.

(b) Determine the required Piv rating of each diode.

(c) Find the max^m current through each diode during conduction.

(d) What is the required power rating of each diode.

$V_T = 0.7$ $\quad V_{rms} = 120V$ $\quad \frac{0.7}{2}$

$V_{dc} = 0.636\,(120\sqrt{2} - 1.4)$ ~~= 0.6~~

$= 0.636\,(169.7 - 1.4) =$ ~~[illegible]~~ 106.59

$P_{IV} = V_m = 169.7.$

$I_{dc} = \frac{V_{dc}}{R}$

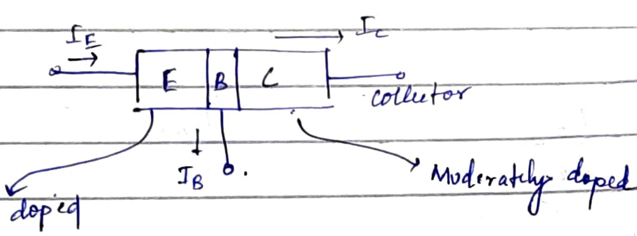
$I_m = \frac{V_m}{R_L} = \frac{169.7}{1000} = 0.1697\ A.$

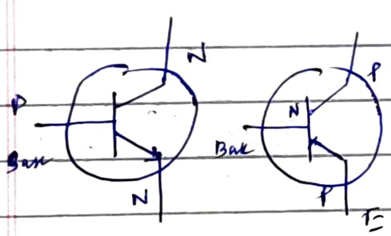
Rating $= \frac{V_{dc}}{I_{dc}} = 106.59$

BJT (Bipolar Juction Transistor)

N-P-N

P-N-P

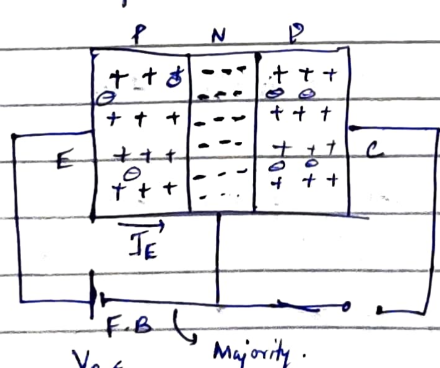




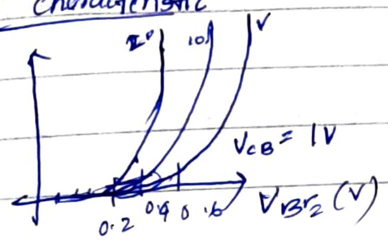
- common - base configuration
- Common - emittor configuration
- Common - collutor configuration
- Active region
- Saturation region
- cutoff region

$\alpha \rightarrow$ amplification factor in C.B

$\beta \rightarrow$ amplification functor in



I/P characteristic

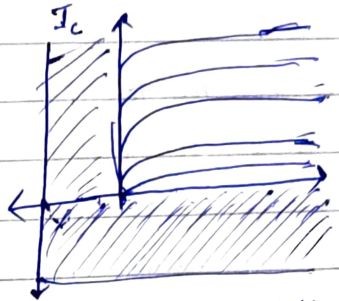


$\alpha_{dc} = I_C / I_E$

$I_C = \alpha I_E + I_{CB}$

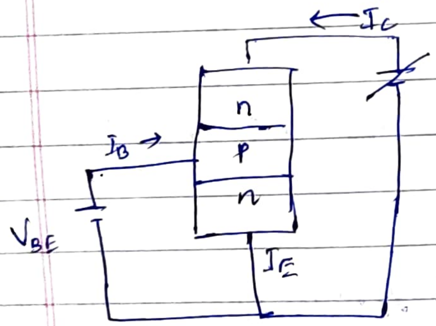
$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}$

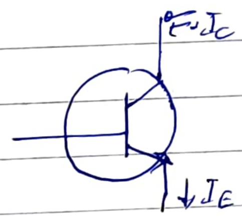
O/P characteristics

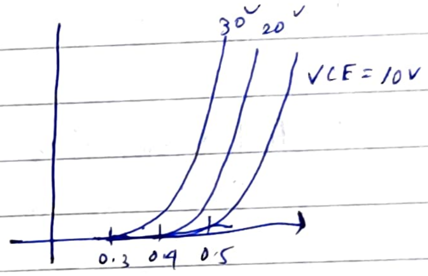


$r_o = \frac{\Delta V_{CB}}{\Delta I_C}$

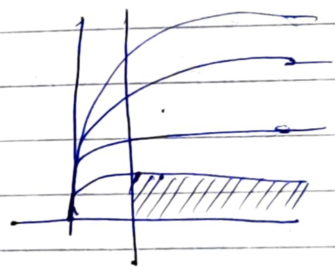
Common - Emitter Configuration:







$I_E = I_B + I_C$



$\beta|_{dc} = \frac{I_C}{I_B}$ $\qquad I_C = \beta I_B$

$\beta|_{ac} = \frac{\Delta I_C}{\Delta I_B}$

$I_C = \alpha I_E + I_{CBO}$ $\qquad \alpha = 0.99$

$= \alpha (I_C + I_B) + I_{CBO}$

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

$$\boxed{I_C = 250\, I_{CBO}}$$

$\alpha = \frac{\beta}{1+\beta}$ $\qquad \beta = \frac{\alpha}{1-\alpha}$

1. The saturation current density of pn junctionion is $150\ mA/m^2$ at 300 K

Find the voltage that has to apply across a junction to cause a forward current density of $10^5\ A/m^2$ to flow.

2. Find the static and dynamic resistance of p-n junction Germanium diode if the temp. is 27°C and I_s is 1 micro A for the applied bias of 0.2V.

3. Find the value of β if $\alpha = 0.9$, $\alpha = 0.98$, $\alpha = 0.99$

4. Calculate I in a transistor for which $\beta = 50$ and $I_B = 20\ mA$.

5. Find α rating of a transistor and determine the value of I_c using both α and β
$I_B = 240\ mA$, $\beta = 49$

6. Collector leakage current of a transistor is 300 mA in c arrangement. If the transistor is connected in CB ~~transisto~~ arrangement. What will be the
Given

7. In CB connection emitter current is 1 milli A ~~is~~ if emitter circuit is open
Collector

273
27
0

2. R_D

$I_s = 10$

$I_D = I_s \left(e^{\frac{V_D}{n V_T}} - 1\right)$

$= 10^{-6}\left(e^{\frac{0.2}{1 \times 0.0258}} - 1\right)$

$= 10^{-6}\left(e^{7.75} - 1\right)$

$= 10^{-6}(2321.5 - 1)$

$= 2320.5 \times 10^{-6}$

$= 2.32 \times 10^{-3}$ A

$V_T = \frac{KT}{q}$

$= \frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}}$

$= \frac{1.38 \times 300}{1.6} \times 10^{-4}$

$= \frac{414}{1.6} \times 10^{-4}$

$= 258.75$

$= 0.0258$

$R_D = \frac{V_D}{I_D} = \frac{0.2}{2.32 \times 10^{-3}} = 0.0862 \times 10^{3}$

$= 86.2\ \Omega$.

$R_{ac} = \frac{26 mV}{I_D} = \frac{26 \times 10^{-3}}{2.32 \times 10^{-3}} = 1.07$ mA.

3. $\alpha = 0.9$

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9} = \frac{0.9}{0.1} = 9$

$\alpha = 0.98$

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = 49$

$\alpha = 0.99$

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = \frac{0.99}{0.01} = 99$

4. $I_E = 1.02$ mA.

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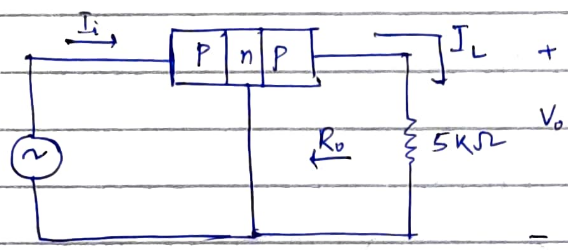
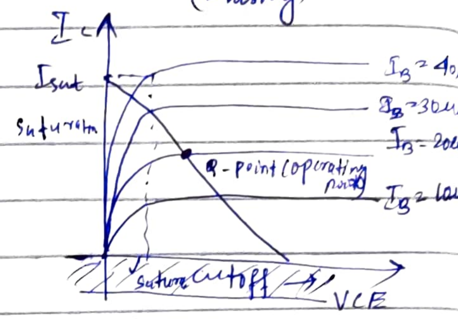
Transistor As an amplifier

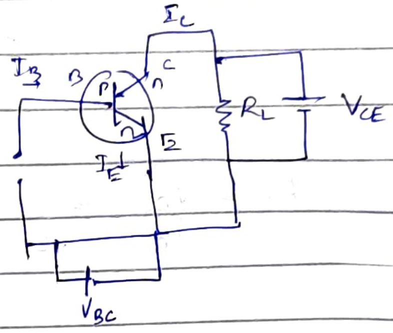
(Biasing)



$A_v = \frac{V_o}{V_i}$



$I_i = \frac{V_i}{R_i} = \frac{200\,mV}{20\Omega} = 10\,mA.$

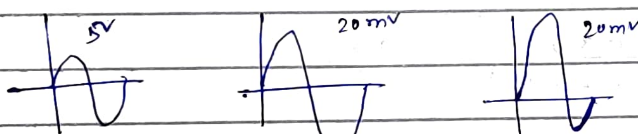


$I_L = I_i = 10\,mA$

$I_L = I_C = 10\,mA$

$V_o = I_L . R = (10\,mA)(5\,K\Omega)$

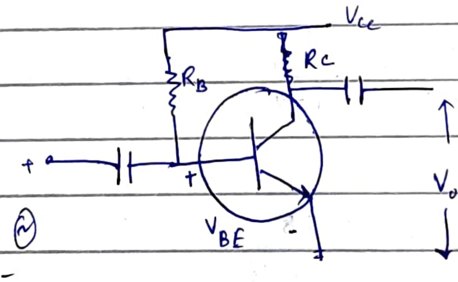
$= 50\,V$



faithful Amplifier

unfaithful.

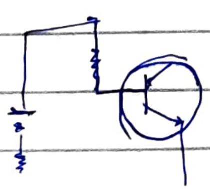
1. Fixed bias configuration
2. Emitter bias configuration
3. Voltage divider bias
4. Voltage - Feedback bias.



D.C Analysis of Transistor

Remove all A.C and Capacitor open.

I/P Loop



$V_{CE} = 0, \; I_{c\,sat} = \frac{V_{cc}}{R_c}$

$I_c = 0, \; V_{CE\,sat} = V_{cc}$

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For the fixed bias configuration determine I_{CQ}, I_{BQ}, V_{CE}, V_C, V_B, V_E.

$R_B = 470K$, $R_C = 2.7K$, $V_{CC} = 16V$.

$$16.00 - 0.7 = 15.3$$

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$16 - I_B \cdot (470K) - 0.7 = 0$$

$$16 - 0.7 = I_B \times 470 \times 10^3$$

$$I_{BQ} = \frac{15.3}{470} \times 10^{-3} = 0.03255 \times 10^{-3}$$

$$= 32.55 \times 10^{-6} A$$

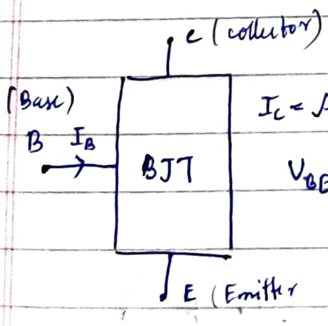
$$= 32.55 \mu A.$$

$$I_{CQ} = \beta \cdot I_{BQ} = 100 \times 32.55 \mu A = 3.25 mA.$$

FET (Field effective Transistor)

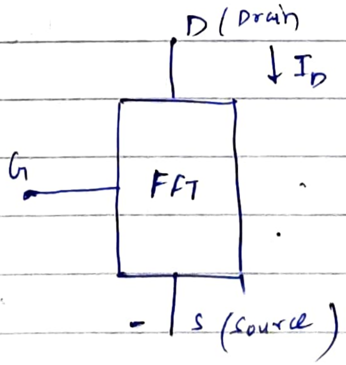
JFET → FET
→ MOSFET → Depletion type MOSFET → D-MOS
→ Enhancement type MOSFET → E-MOS

- BJT vs FET
- Construction operation
- MOSFET (N types & p-type)
- D-MOS (N types & p-type)
- E-MOS (N types & p-type)



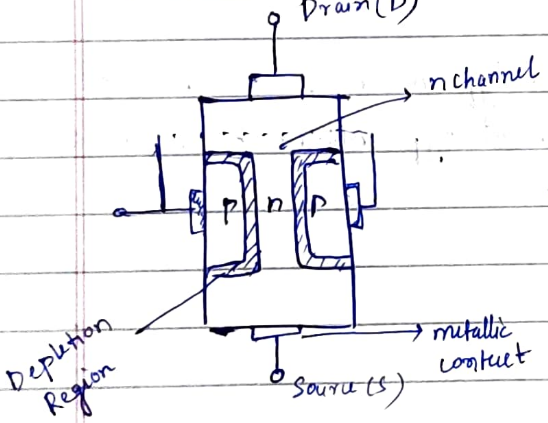
$I_C = \beta I_B$

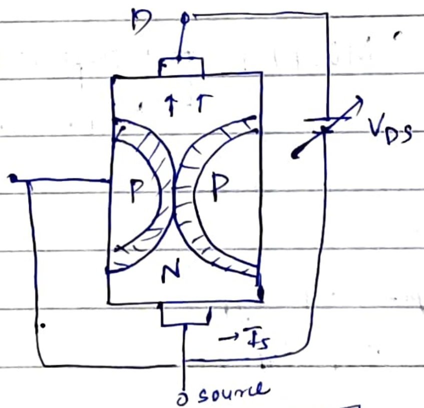
$V_{BE} = 0.7$



BJT	FET
(i) It is a Bipolar device that is current conduction due to two types of carriers $e^{\ominus}$ & holes	(i) It is a unipolar device i.e. due to current conduction due to one type of carrier.
(ii) Input of BJT is forward bias having low input Impedance.	(ii) Input of FET is reverse biase hence.
(iii) BJT is a current control device ~~and FET is a voltage control device~~	(iii) FET is a voltage control device.
(iv) In BJT two junctions	(iv) In FET no junctions
(v) Noise level is more in BJT	(v) Noise level is low in BJT.

<u>Construction:</u>

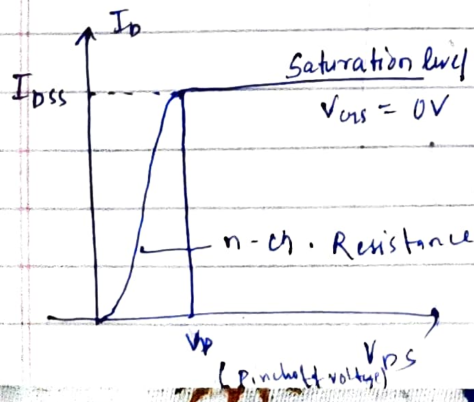


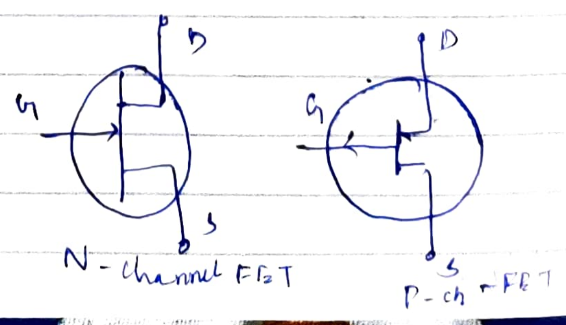


I_{DSS}
↳ shorted gate Drain current.

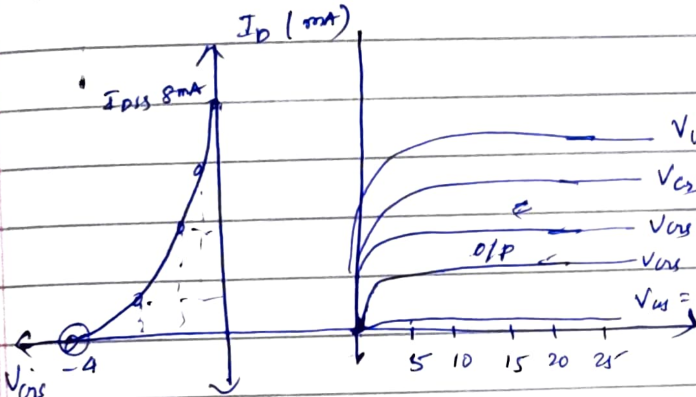
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

Schokely's eq^n.





Transfer characteristics



V_{GS}	V_P
0	I_{DSS}
$0.3 V_p$	$I_{DSS}/2$
$0.5 V_p$	$I_{DSS}/4$
V_p	0 mA

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

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

$V_{GS} = V_P$, $I_D = 0mA$

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

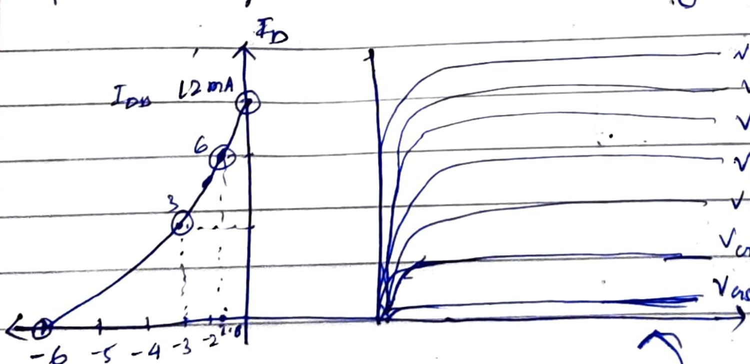
$$\left(1 - \frac{V_{GS}}{V_P}\right)^2 = \frac{I_D}{I_{DSS}}$$

$$1 - \frac{V_{GS}}{V_P} = \sqrt{\frac{I_D}{I_{DSS}}}$$

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

Q. Draw the transfer characteristics.
$I_{DSS} = 8 mA$, $V_p = -4V$.

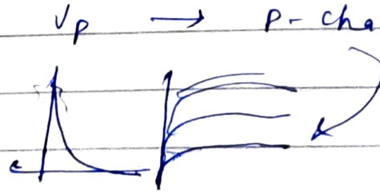
Q. Sketch the transfer characteristics defined by $I_{DSS} = 12 mA$ and $V_P = -6V$



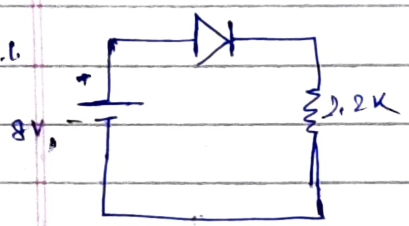
V_{GS}	V_P
0	12
-1.8	12/2 6
3.0	12/4 3
-6	0

positive V_p → N-ch

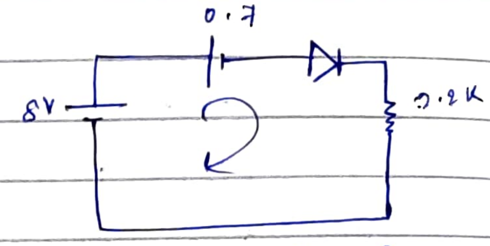
$-V_e$ V_p → P-channel



Q.1



$V_D = ?$
$V_R = ?$
$I_D = ?$



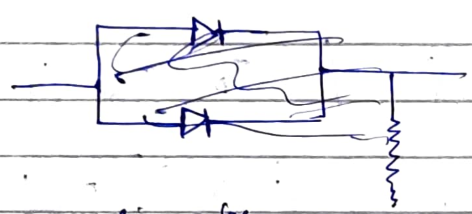
$8 - 0.7 - 2.2\, I_D = 0$

$7.3 = 2.2\, I_D$

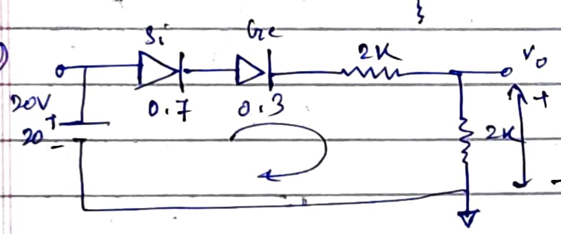
$\Rightarrow I_D = \frac{7.3}{2.2} = 3.31\ mA$

$V_D = 8 - 0.7$
$= 7.3$

(2)



(2)

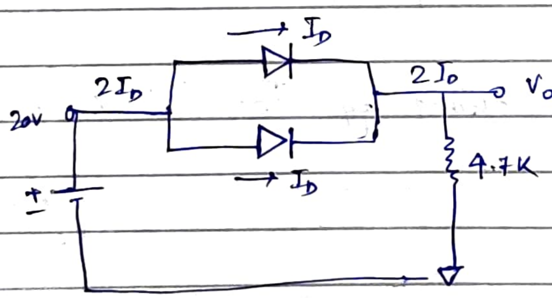


$V_o = ?$
$I = ?$

$20 - 0.7 - 0.3 - 4I = 0$

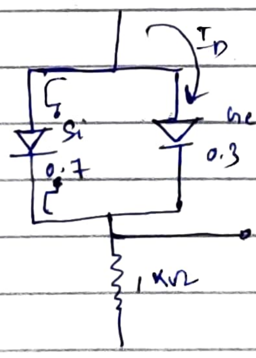
$\Rightarrow I = \left(\frac{19}{4}\right) mA.$

(3)



$20 - 0.7 - 2 \times 4.7K \times I_D = 0$

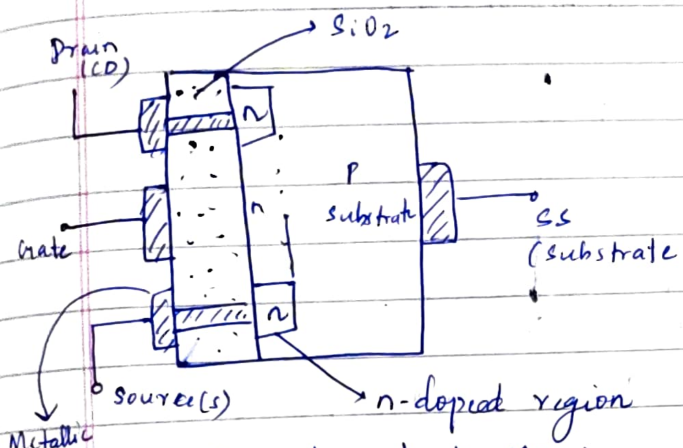
(4)

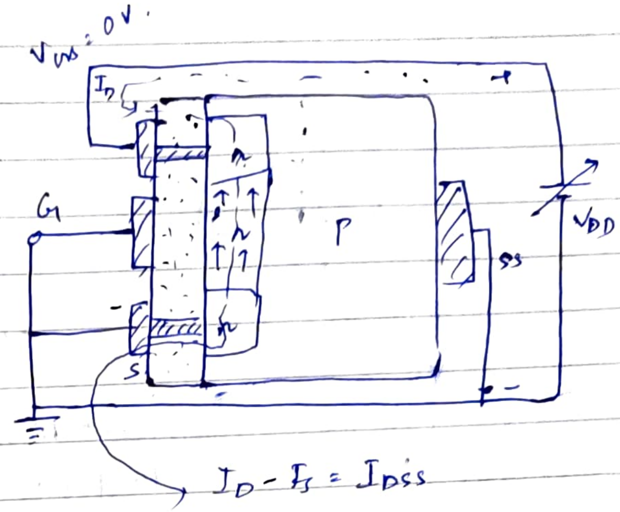


V_0

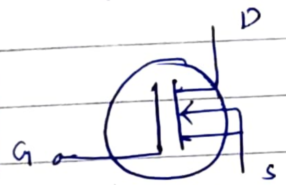
$-10 - 0.3$

Depletion type of MOSFET: (D-MOS)

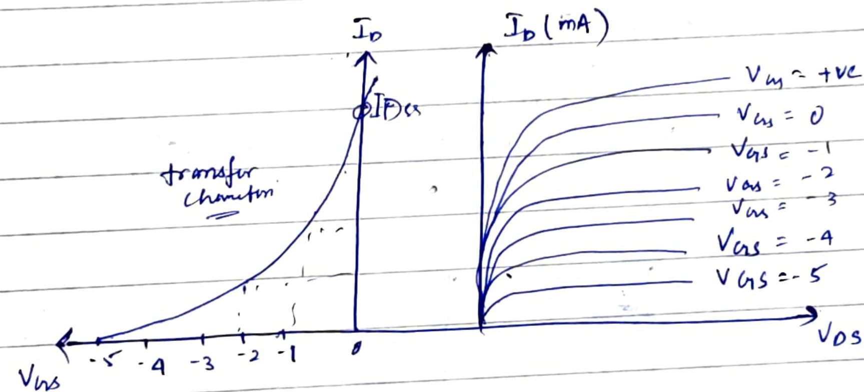




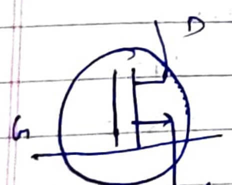
(N-channel D-MOS)



(n-ch)

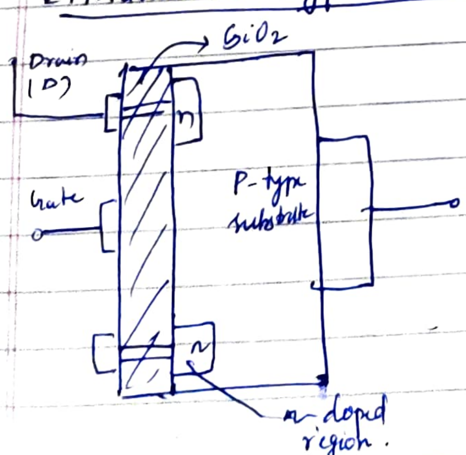


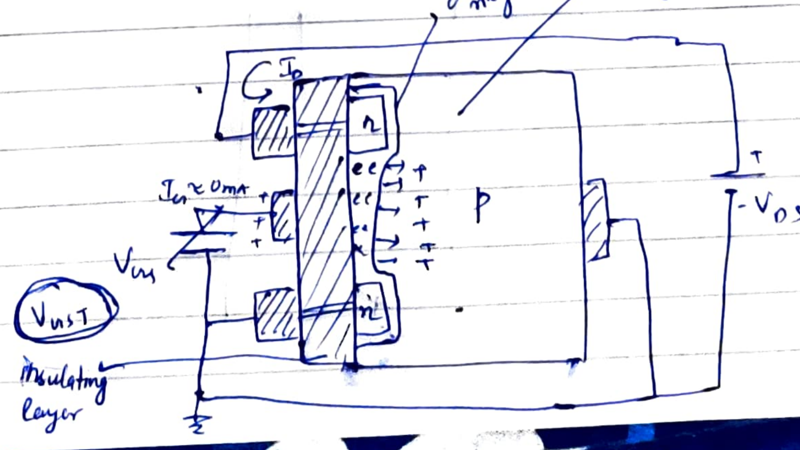
$V_p \rightarrow$ pinchoff



(P-ch)

Enhancement type MOSFET :→ N-channel & P-channel





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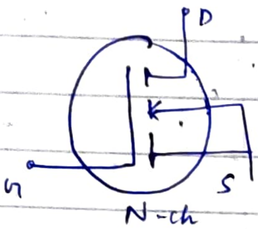
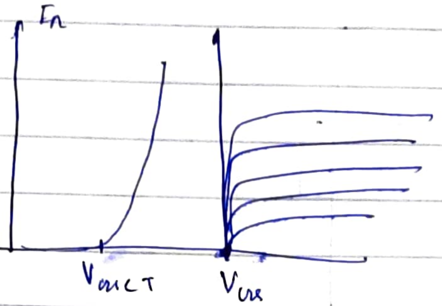
$$I_D = K(V_{GS} - V_T)^2$$

$$K = \frac{I_{D(on)}}{(V_{GS(on)} - V_T)^2}$$



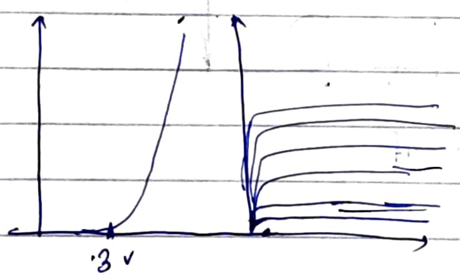


- Q: For the enanchement MOSFET $I_{D(on)} = 3\,mA$, $V_{GS(ON)} = 10\,V$ and $V_{GST} = 3\,V$. Find out the resulting value of K and transfer characterist.

$$K = \frac{I_{D(on)}}{(V_{GS(ON)} - V_T)^2}$$

$$\frac{3 \times 10^{-3}}{7}$$

$$K = \frac{3\,mA}{(10-3)^2} = 0.061 \times 10^{-3}\ A/V^2$$



$V_{GS} = 11V$

$$\therefore I_D = 0.061 \times 10^{-3}(11-3)$$
$$= 0.061 \times 10^{-3}(8)$$
$$= 0.488 \times 10^{-3}$$

$$I_D = 0.061 \times 10^{-3}(12-3)$$
$$= 0.549 \times 10^{-3}$$

$$I_D = 0.061 \times 10^{-3}(15-3)$$
$$= 0.732 \times 10^{-3}.$$