Lecture 24.12.25

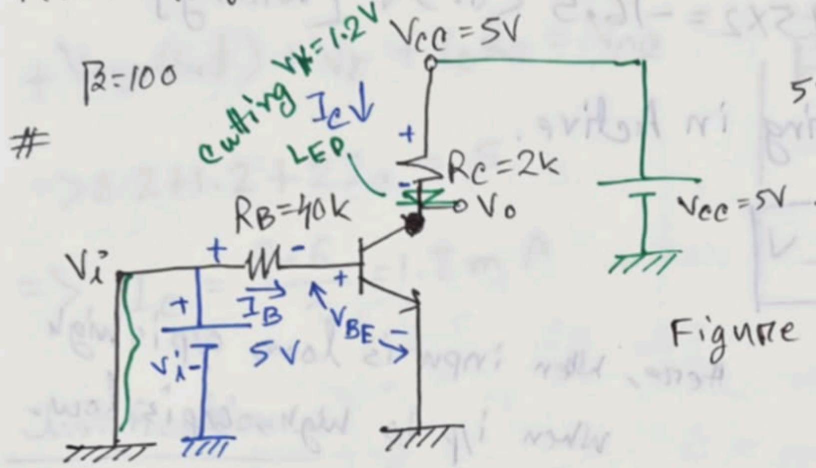
BJT/MOSFET Switching:

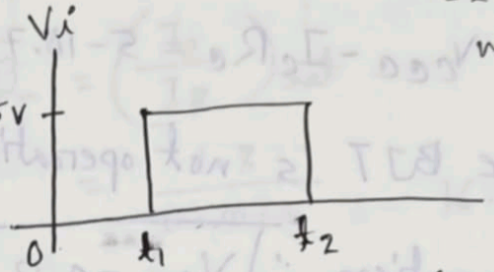
For switching - 2 area of operation is required.

BJT : ON(Sat) $\longleftrightarrow$ OFF (cut-off) $\boxed{\text{BJT}}$

MOSFET : ON(Triode) $\longleftrightarrow$ OFF (cut-off)

#





=2 input
when - $V_i=0$
and $V_i=5$

Figure out what the output.

for $0<t<t_1$, $V_i=\boxed{0V}$ => Now Analyze the BJT.

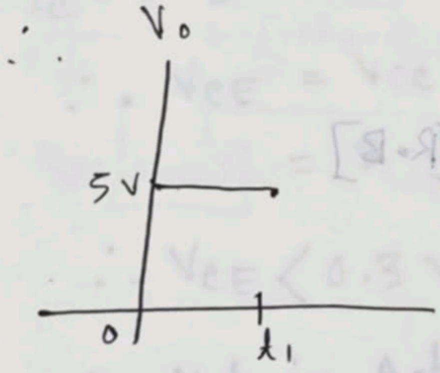
Check EBJ: $V_p - V_n = 0 < 0.7\,V$ [R.B]

BJT is operating in cut-off. $\therefore I_B = I_C = I_E = 0$.

For V_o (check VCE): $\therefore V_o = V_{CE} = V_{CC} - \cancel{I_C R_C}^{\,0}$

$\therefore V_o = V_{CE} = V_{CC} = 5V$

$\therefore$



For $t_1 < t < t_2$, $\boxed{V_i = 5V}$

Check EBJ : $V_p - V_n = 5-0 = 5 > 0.7\,V$ [F.B]

Either operating In Active or Saturation.

Assume Active: (α, β) allowed. Verification: $V_{CE} > 0.3V$; $V_{CB} > -0.4V$

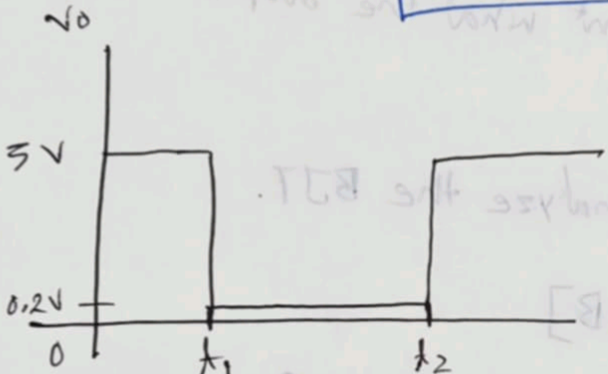
$$I_B = \frac{V_i - V_{BE}}{R_B} = \frac{5-0.7}{40} = \frac{4.3}{40} = 0.1075\ mA$$

$$\therefore I_C = \beta I_B = 100 \times 0.1075 = 10.75\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 5 - 10.75\times 2 = -16.5 < 0.3V \text{ [Wrong]}$$

∴ The BJT is not operating in Active.

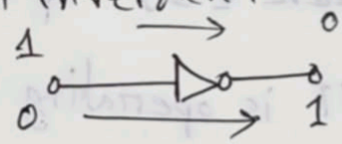
∴ saturation. ∴ $\boxed{V_{CE} = 0.2V}$



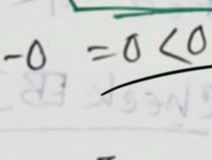
Here, when input is low, o/p is high. When i/p is high, o/p is low.

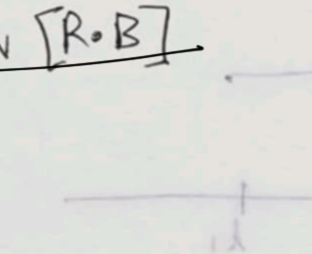
∴ The BJT inverts the signal.

∴ Acts like an inverter. or NOR Gate



Lets Assume the LED attached has a Cutting Voltage, $V_\gamma = 1.2V$





For BJT, For $0 < t < t_1$ $\boxed{V_i = 0V}$

Check EBJ $= 0 - 0 = 0 < 0.7V$ [R.B]

cut-off, $I_B = I_C = I_E = 0$

The LED is off.

For $t_1 < t < t_2$, $V_i = 5\,V$

check EBJ; $V_p - V_n = 5-0 > 0.7\,V$ [F.B] [Not in cut-off]

Assume Saturation:

$$I_B = \frac{V_i - V_{BE}}{R_B} = \frac{5-0.7}{40} = \frac{4.3}{40} = 0.1075\,mA$$

LED

$$+V_{CE(sat)} + V_\gamma + I_C R_C = V_{CC}$$

$$\Rightarrow 0.2 + 1.2 + 2I_C = 5$$

$$\Rightarrow I_C = \frac{3.6}{2} = 1.8\,mA$$

$$\beta_f = \left(\frac{I_C}{I_B}\right)_{sat} = \frac{1.8}{0.1075}$$

$\cancel{16.74 < \beta}$

Justification:

Assume Active: α/β allowed

$\therefore I_B = 0.1075\,mA$

$\therefore I_C = \beta I_B = 10.75\,mA$

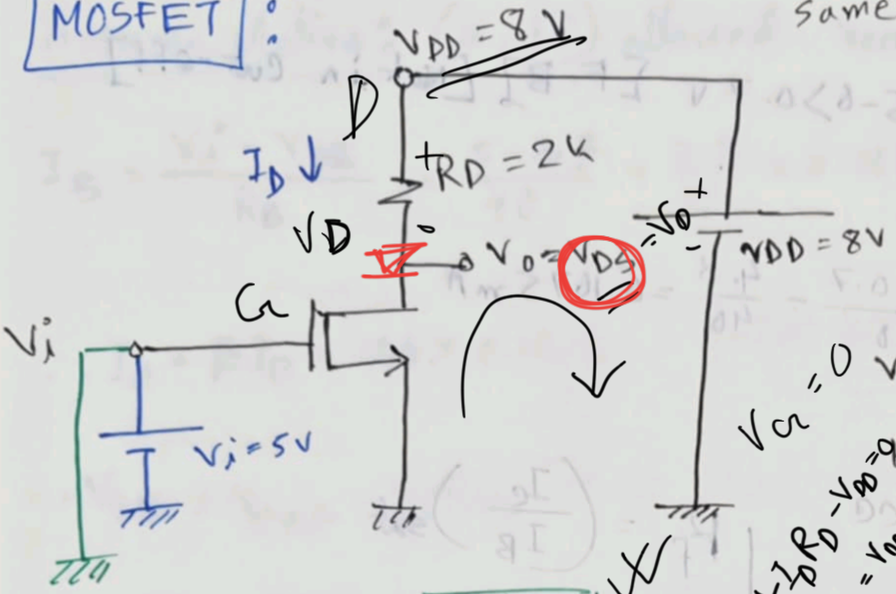
$\therefore V_{CE} = V_{CC} - I_C R_C - V_\gamma = -17.7\,V < 0.3\,V$

$= 5 - 10.75 \times 2 - 1.2$

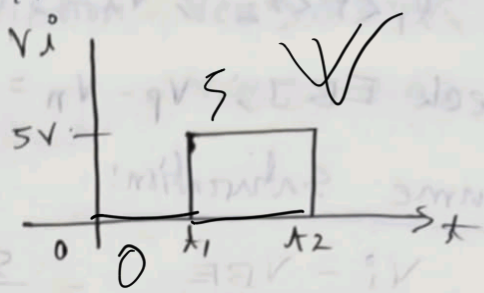
$\therefore V_{CE} < 0.3\,V$ [Assumption wrong]

$\therefore$ Not in Active.

MOSFET :



same i/P



$V_G = 0$ $V_{TN} = 1\,V$

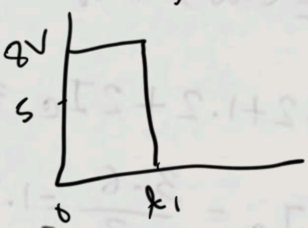
$K = 2\ mA/V^2$

$V_0 + I_D R_D - V_{DD} = 0$

$\Rightarrow V_0 = V_{DD} - I_D R_D$

$\Rightarrow V_0 = V_{DD}$

$I_D = 0$



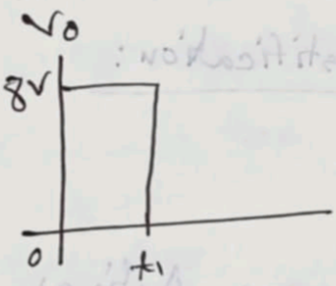
For $0 < t < t_1$, $\boxed{V_i = 0V}$

check the ch. is induced or not.

$V_{GS} = V_G - V_S = 0 - 0 < V_{TN}$ [No. ch. Ind]

Cut off region, $I_D = 0$

$V_0 = V_{DS} = V_{DD} - \cancel{I_D R_D}^{\,0} = V_{DD} = 8\,V$



For, $t_1 < t < t_2$, $\boxed{V_i = 5\,V}$ $V_G = 5V$, $V_S = 0$

check the ch. is induced or not. I_D

$V_{GS} = \underline{V_G - V_S} = 5 - 0 > V_{TN}$ [ch is induced]

[Not cut-off]

For switching, consider MOSFET ~~saturation~~ $\boxed{\text{Triode}}$ in Triode by default.

$$I_D = K_n[2(V_{GS}-V_{TN})V_{DS} - V_{DS}^2]$$

$$= 2[2(5-1)(V_D - \cancel{V_S}) - (V_D - \cancel{V_S})^2]$$

$$I_D = 16V_D - 2V_D^2 = \frac{V_{DD}-V_{DS}}{R_D}$$

$V_{DS} + I_D R_D - V_{DD} = 0$

$\Rightarrow V_{DD} - V_{DS} = I_D R_D$

$\Rightarrow I_D = \frac{V_{DD}-V_{DS}}{R_D}$

$$= \frac{8 - V_D}{2}$$

$$\Rightarrow \frac{8-V_D}{2} = 16V_D - 2V_D^2$$

$$= 8 - V_D = 32V_D + V_D - 4V_D^2$$

$$\Rightarrow 4V_D^2 - 33V_D + 8 = 0$$

$$\therefore V_{D_1} = 8\,V$$

$$V_{D_2} = \frac{1}{4}\,V$$

To justify,

$V_{GD} \geq V_{TN}$

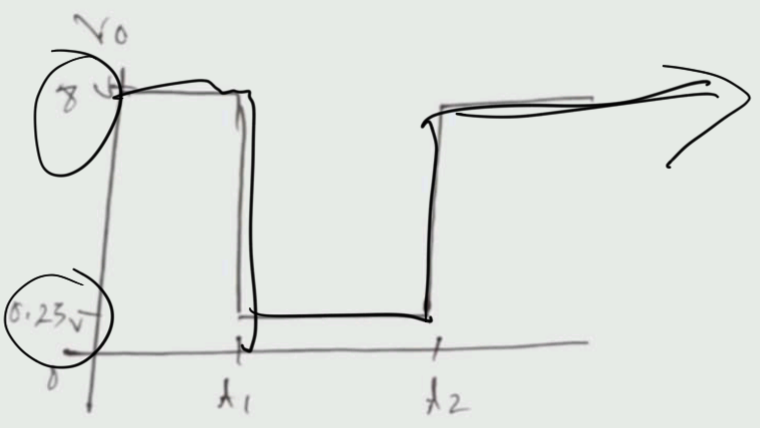
$V_{GD} = V_G - V_D = 5 - 8 = -3\,V$ X

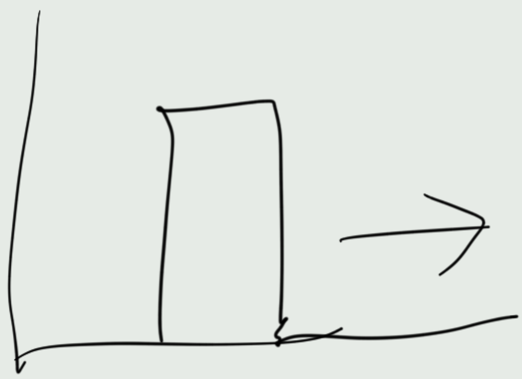
$V_G - V_D = 5 - 0.25 = 4.75$

Triode

$V_D : 8\,V$ X, $0.25\,V$

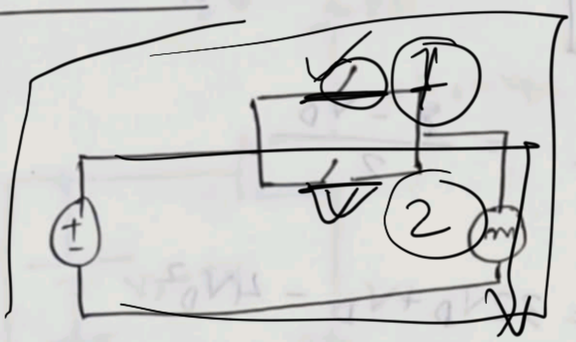
$\therefore V_D = 0.25\,V$ $V_O = 0.23\,V$

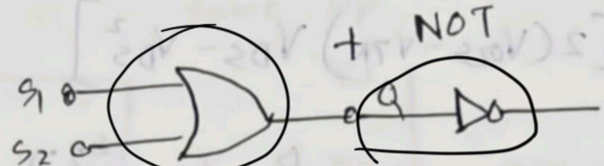




Logic Gates

OR Gate:



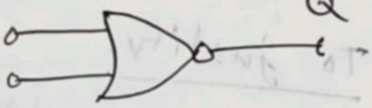


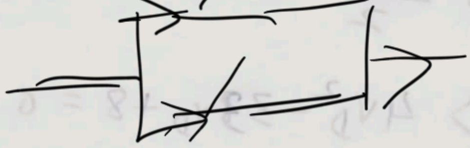
+ NOT = NOR Gate

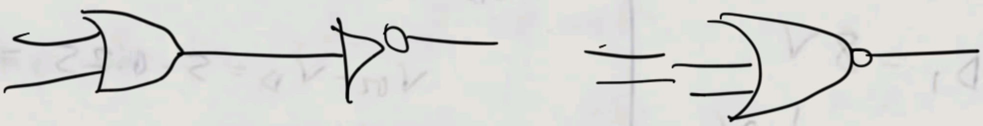
S_1	S_2	Q	$\bar{Q}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

$\bar{Q}$

∴ NOR Gate:







TYU 3.12 The circuit shown in Figure 3.45 is biased at $V_{DD} = 10$ V, and the transistor parameters are $V_{TN} = 0.7$ V and $K_n = 4$ mA/V^2. Design the value of R_D such that the output voltage will be $v_O = 0.20$ V when $v_I = 10$ V. (Ans. 0.666 kΩ)

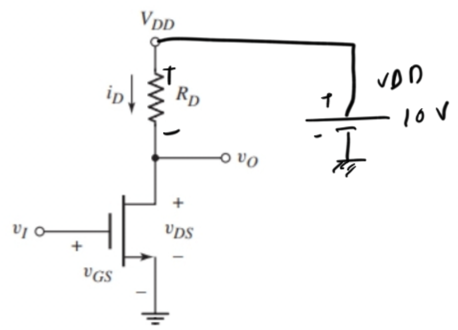


Figure 3.45 NMOS inverter circuit

$V_{DS} + I_D R_D - V_{DD} = 0$

Nmos,

$V_{TN} = 0.7V$

$K_n = 4\ mA/V^2$

For $V_i = 10V$, Check V_{GS},

$V_G = 10V$, $V_S = 0V$

$\therefore V_{GS} = 10 - 0 = 10V > V_{TN}$ [ch induced]

Triode [Assuming]

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

$$= K_n\left[2(V_G - \cancel{V_S}^{0} - 0.7)\,V_D - \cancel{V_S}^{0} - V_D^2\right]$$

$$= 4\left[2(10-0.7)V_D - V_D^2\right] = \left[74.4V_D - 4V_D^2\right.$$

$$I_D = \frac{V_{DD} - V_{DS}}{R_D}$$

$$\Rightarrow 74.4(0.2) - 4(0.2)^2 = \frac{V_{DD} - \cancel{V_{DS}}^{0.2}}{R_D}$$

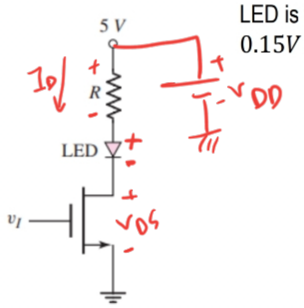
$[V_D = V_{DS} = 0.2]$

$$\Rightarrow 14.88 - 0.16 = \frac{10 - 0.2}{R_D}$$

$$\Rightarrow 14.72 = \frac{9.8}{R_D}$$

$\therefore R_D = 0.666\,k\Omega$

1. The transistor in the circuit shown in Figure has parameters $K_n = 4\ ^{mA}/_{V^2}$ and $V_{TN} = 0.6V$, and is used to switch the LED on and off. The LED cutin voltage is $V_\gamma = 1.2V$. The LED is turned on by applying an input voltage of $V_I = 5V$. $R = 1.2k$. Determine I_D and V_{DS}.
2. The transistor in the circuit shown in Figure has parameters $K_n = 3\ ^{mA}/_{V^2}$ and $V_{TN} = 0.6V$, and is used to switch the LED on and off. The LED cut-in voltage is $V_\gamma = 1.6V$. The LED is turned on by applying an input voltage of $V_I = 5V$. Design R such that $V_{DS} = 0.15V$ for $V_I = 5V$. Determine I_D.



$V_{DS} + 1.2 + I_D R_D - V_{DD} = 0$

$\Rightarrow \frac{V_{DD} - V_{DS} - 1.2}{R_D} = I_D$

Given, $K_n = 4$, $V_{TN} = 0.6V$, $V_\gamma = 1.2V$ [$V_G = 5V$, $V_S = 0$]

$V_i = 5V$, $R = 1.2K$ $\quad I_D = ?$, $V_{DS} = ?$

First, check $V_{GS} = V_G - V_S = 5 > V_{TN}$ [ch induced]

Assume Triode,

$$I_D = K_n[2(V_{GS} - V_{TN})V_{DS} - V_{DS}^2]$$

$$= 4[2(5 - 0.6)V_D - V_D^2] = \frac{V_{DD} - V_{DS} - 1.2}{R_D}$$

$$\Rightarrow 35.2V_D - 4V_D^2 = \frac{5 - 1.2 - V_D}{1.2} \Rightarrow 42.24V_D + V_D - 4.8V_D^2 - 3.8 = 0$$

$$\Rightarrow 4.8V_D^2 - 43.24V_D + 3.8 = 0$$

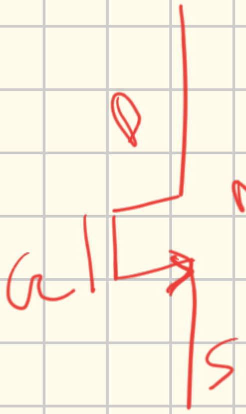
$$V_D = 8.919,\ 0.088$$

Check V_{GD}:

$V_G - V_{D_1} \Rightarrow 5 - 8.919 < V_{TN}$ ✗

$V_G - V_{D_2} \Rightarrow 5 - 0.088 > V_{TN}$ ✓ $\quad \therefore V_D = 0.088$

$$\therefore I_D = \frac{V_{DD} - V_D}{1.2} = \frac{5 - 1.2 - 0.088}{1.2} = 3.093\ mA$$



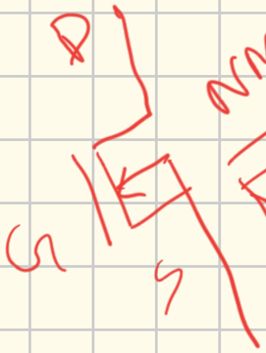
NMOS

PMOS

PMOS

$\boxed{V_{GS} < V_{TP}}$

$\boxed{V_{GD} \le V_{TP}}$



NMOS

$\boxed{V_{GS} > V_{TN}}$

$\boxed{V_{GD} \ge V_{TN}}$

Saturation:

$$I_D = K_n(V_{GS}-V_{TP})^2$$

Saturation:

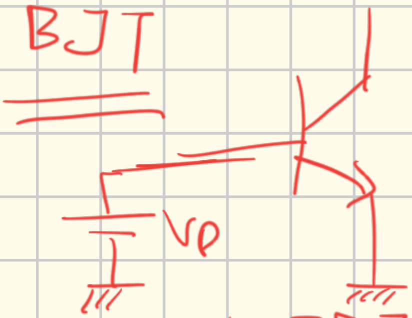
$$I_D = K_n(V_{GS}-V_{TN})^2$$

Triode:

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

BJT

NPN



Check EBJ $= V_P - V_N > 0.7$

[F.B] → Active or Saturation

[R.B] → Cutoff

Active, $V_{BE} = 0.7\,V$

$V_{CE} > 0.3\,V$

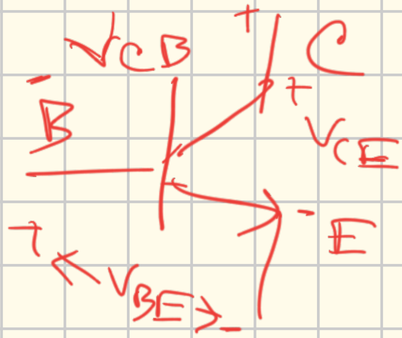
$V_{BC} > -0.4\,V$

Saturation,

$V_{CE} = 0.2\,V$

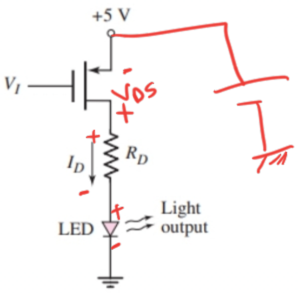
$V_{BE} = 0.7\,V$

$V_{CB} = -0.5$



Activee

1. The transistor in the circuit shown in Figure has parameters $K_P = 3\ ^{mA}/_{V^2}$ and $V_{TP} = -0.6V$, and is used to switch the LED on and off. The LED cutin voltage is $V_\gamma = 1.2V$. The LED is turned on by applying an input voltage of $V_I = 0V$. Design R_D such that $V_{DS} = -0.12V$ for $V_I = 0V$. Determine I_D.



Given, $K_P = 3$

$V_{TP} = -0.6V$

$V_\gamma = 1.2V$

$V_i = 0V$

$V_o = V_{DS} = -0.12V$

$V_S = 5V$

Check V_{GS}, $V_G - V_S = 0-5 = -5 < V_{TP}$ [ch induced]

Assume Triode,

$$I_D = K_n[2(V_{GS}-V_{TP})V_{DS} - V_{DS}^2]$$

$$= 3[2(-5+0.6)(-0.12) - (0.12)^2] = 3.1248\,mA$$

$$\therefore +1.2 + I_D R_D - V_{DS} - V_{SS} = 0$$

$$\Rightarrow R_D = \frac{V_{DS}+V_{SS}-1.2}{I_D} = \frac{-0.12+5-1.2}{3.1248} = 1.178\,k\Omega$$

$\therefore R_D = 1.178\,k\Omega$ (Ans.)