Problem 1. Find \( i_D (\mu_p C_{ox}(W/L) = 1.5 \text{ mA/V}^2, \lambda = 0, \text{ and } V_{tp} = -1 \text{ V}) \).

Since \( i_G = 0 \), the 100 k and 200 k resistors form a voltage divider and \( V_G = 9 \times (10^5)/(10^5 + 2 \times 10^5) = 3 \text{ V} \).

\[
\text{SG-KVL: } 9 = 10^3 i_D + v_{SG} + V_G = 10^3 i_D + V_{OV} + |V_{tp}| + V_G \\
\rightarrow 9 - 1 - 3 = 5 = V_{OV} + 10^3 i_D \\
\text{SD-KVL: } 9 = 10^3 i_D + v_{SD} + 10^3 i_D = v_{SD} + 2 \times 10^3 i_D
\]

PMOS cannot be in cut-off because if \( i_D = 0 \), SG-KVL gives \( V_{OV} = 5 > 0 \). Assume PMOS in saturation:

\[
i_D = 0.5 \mu_p C_{ox}(W/L) V_{OV}^2 \\
\text{SG-KVL: } 5 = V_{OV} + 10^3 \times 0.5 \times 1.5 \times 10^{-3} V_{OV}^2 \\
0.75 V_{OV}^2 + V_{OV} - 5 = 0 \quad \rightarrow \quad V_{OV} = -3.33 \text{ V} \quad \text{and} \quad V_{OV} = 2 \text{ V}
\]

Negative root is unphysical (we need \( V_{OV} > 0 \)). Thus, \( V_{OV} = 2 \text{ V} \) and

\[
\text{SG-KVL: } 5 = V_{OV} + 10^3 i_D \quad \rightarrow \quad i_D = 3 \text{ mA} \\
\text{SD-KVL: } 9 = v_{SD} + 2 \times 10^3 i_D \quad \rightarrow \quad v_{SD} = 3 \text{ V}
\]

Since \( v_{SD} = 3 > V_{OV} = 2 \text{ V} \), our assumption of PMOS in saturation is justified.

Problem 2. Find \( v_o \) in terms of \( v_i \) in the circuit below with a Si diode.

1) Diode is ON (\( v_D = 0.7 \text{ V}, i_D \geq 0 \)):

\[
v_o = v_D = 0.7 \text{ V}
\]

\[
\Omega-\text{Law: } i_1 = \frac{0.7}{R} \quad \& \quad i = \frac{v_i - 0.7}{R}
\]

\[
\text{KCL: } i_D = i - i_1 = \frac{v_i - 1.4}{R} \geq 0 \quad \rightarrow \quad v_i \geq 1.4 \text{ V}
\]

Thus, when \( v_i \geq 1.4 \text{ V} \), diode is ON and \( v_o = 0.7 \text{ V} \).
2) Diode is OFF \((i_D = 0, v_D < 0.7 \text{ V})\): By voltage divider:

\[
\frac{R}{R + R} \times v_i = 0.5v_i
\]

\[
v_D = v_o = 0.5v_i < 0.7 \quad \rightarrow \quad v_i < 1.4 \text{ V}
\]

Thus, when \(v_i < 1.4 \text{ V}\), diode is OFF and \(v_o = 0.5v_i\).

**Problem 3.** Find \(v_o\) (Si BJTs with \(\beta_1 = 100\) and \(\beta_2 = 50\)).

![Diode Circuit Diagram](image)

BE-KVL: \(2 = 200 \times 10^3 i_B1 + v_{BE1} + v_{BE2}\)

CE1-KVL: \(9 = v_{CE1} + v_{BE2}\)

CE2-KVL: \(9 = 470i_{C2} + v_{CE2}\)

Because \(i_{E1} = i_{B2}\), this is a Darlington pair and Q1 and Q2 are either both ON or both OFF. (if \(i_{B1} > 0\), we will have \(i_{B2} = i_{E1} > 0\))

Assume Both are ON: \(v_{BE1} = v_{BE2} = 0.7 \text{ V}, i_{B1} > 0\) (No need to check \(i_{B2}\)):

BE-KVL: \(2 = 200 \times 10^3 i_{B1} + 0.7 + 0.7 \quad \rightarrow \quad i_{B1} = 3 \mu\text{A}\)

Since \(i_{B1} > 0\), our assumption of both BJTs ON are justified. Furthermore:

CE1-KVL: \(9 = v_{CE1} + v_{BE2} = v_{CE1} + 0.7 \quad \rightarrow \quad v_{CE1} = 8.3 \text{ V}\)

Since \(v_{CE1} > 0.7 \text{ V}\), Q1 is in active and \(i_{E1} \approx i_{C1} = \beta_1 i_{B1} = 300 \mu\text{A}\) and \(i_{B2} = i_{E1} = 300 \mu\text{A}\).

Assume Q2 in active. Then, \(i_{C2} = \beta_2 i_{B2} = 15 \text{ mA}\) and

CE2-KVL: \(9 = 470i_{C2} + v_{CE2} \quad \rightarrow \quad v_{CE2} = 9 - 7.05 = 1.95 \text{ V}\)

Since \(v_{CE2} > 0.7 \text{ V}\), assumption of Q2 in active is justified.

Finally \(v_o = v_{CE2} = 1.95 \text{ V}\).