1) 9.87

\[ I = \frac{1}{2} \mu_n C_{ox} \left( \frac{W}{L} \right) V_{OV}^2 \]

\[
0.1 = \frac{1}{2} \times 0.2 \times 50 \times V_{OV}^2
\]

\[ \Rightarrow V_{OV} = 0.14 \text{ V} \]

\[ g_{m1,2} = \frac{2 \times (I/2)}{V_{OV}} = \frac{2 \times 0.1}{0.14} = 1.4 \text{ mA/V} \]

\[ r_{o2} = \frac{r_{o4}}{I/2} = \frac{5 \times 0.5}{0.1} = 25 \text{ k}\Omega \]

2) 9.88

\[ A_d = g_{m1,2} (r_{o2} || r_{o4}) \]

\[ g_{m1,2} = \sqrt{2k'_n \left( \frac{W}{L} \right)} I_d \]

\[ = \sqrt{4I} = 2\sqrt{I} \]

\[ r_{o2} = r_{o4} = \frac{|V_A|}{I/2} = \frac{2|V_A|}{I} = 2 \times 5 = 10 \frac{\text{V}}{\text{I}} \]

\[ A_d = 2\sqrt{I} \times \frac{1}{2} \times \frac{10}{I} = \frac{10}{\sqrt{I}} \]

\[ 20 = \frac{10}{\sqrt{I}} \]

\[ \Rightarrow I = 0.25 \text{ mA} \]

3) 9.92

\[ G_m = g_{m1,2} = \frac{2(I/2)}{V_{OV1,2}} = \frac{0.2}{0.2} = 1 \text{ mA/V} \]

\[ r_{o2} = \frac{V_{An}}{I/2} = \frac{20}{0.1} = 200 \text{ k}\Omega \]

\[ r_{o4} = \frac{|V_{Ap}|}{I/2} = \frac{12}{0.1} = 120 \text{ k}\Omega \]

\[ R_o = r_{o2} || r_{o4} = 200 \parallel 120 = 75 \text{ k}\Omega \]

\[ A_d = G_m R_o = 1 \times 75 = 75 \text{ V/V} \]

The gain is reduced by a factor of 2 with \( R_L = R_o = 75 \text{ k}\Omega \).
4) **14.31** (a) To obtain \( V_M = V_{DD}/2 \), the inverter must be matched. The noise margins can now be found as

\[
\frac{W_p}{W_n} = \frac{\mu_n}{\mu_p} = 2.1
\]

\[ NMH = V_{OH} - V_{IH} \]

\[ \Rightarrow W_p = 2.5W_n = 1 - 0.5375 = 0.4625 \text{ V} \]

Silicon area = \( \sqrt{NM_L = V_{IL} - V_{OL}} \)

\[ = 1.5 \times 65 \times 6! = 0.4625 - 0 = 0.4625 \text{ V} \]

\[ = 1.5 \times 65 \times 6! = 22,181 \text{ nm}^2 \]

The noise margins are equal at approximately 0.46 V; a result of the matched design of the inverter.

(b) \( V_{OH} = V_{DD} \)

\( V_{OL} = 0 \text{ V} \)

(c) Since the inverter is matched, the output resistances in the two states will be equal. Thus,

\[
r_{DSP} = r_{DSN} = 1 / \left[ (\frac{\mu_n C_{ox}}{L}) (V_{DD} - V_I) \right]
\]

\[ = \frac{1}{0.47 \times 1.5(1 - 0.35)} = 2.18 \text{ k}\Omega \]

To obtain \( V_{IH} \), we use Eq. (14.36):

\[
V_{IH} = \frac{1}{8} (5V_{DD} - 2V_I)
\]

\[ = \frac{1}{8} (5 \times 1 - 2 \times 0.35) \]

\[ = 0.5375 \text{ V} \]

To obtain \( V_{IL} \), we use Eq. (14.36):

\[
V_{IL} = \frac{1}{8} (3V_{DD} + 2V_I)
\]

\[ = \frac{1}{8} (3 \times 1 + 2 \times 0.35) \]

\[ = 0.4625 \text{ V} \]
5) 14.36

The current reaches its peak at $v_t = V_M = \frac{V_{DD}}{2}$. At this point, both $Q_N$ and $Q_P$ are operating in the saturation region and conducting a current

$$I_{DP} = I_{DN} = \frac{1}{2} k_n \left( \frac{W}{L} \right) \left( \frac{V_{DD}}{2} - V_t \right)^2$$

$$= \frac{1}{2} \times 500 \times 1.5 \left( \frac{1.3}{2} - 0.4 \right)^2$$

$$= 23.4 \ \mu A$$