$W/L = 1$

$t_{ox} = 34nm$

$\varepsilon_{ox} = 3.9\varepsilon_0$

- $|2\Phi_F| = 0.64v$

$\varepsilon_0 = 8.85pF/m$

V_{gs} (V)	V_{DS} (V)	V_{SB} (V)	I_d (μA)
4	4	0	256
5	5	0	441
4	4	2.6	144
5	5	2.6	289

a) Find V_{to}

$$V_{th} = V_{to} + \gamma\left(\sqrt{|V_{sb} + 2\Phi_F|} - \sqrt{|2\Phi_F|}\right)$$

$$V_{to} = \frac{V_{gs_1} - V_{gs_2}\sqrt{\frac{I_{D_1}}{I_{D_2}}}}{1 - \sqrt{\frac{I_{D_1}}{I_{D_2}}}}$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 1mF$$

$$\gamma = \sqrt{\frac{2qN_A\varepsilon_s}{C_{ox}}}$$

$$I_d = \frac{1}{2}C_{ox}\mu_n\frac{W}{L}\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

for $V_{sb} = 0$, $V_{th} = V_{to}$

$V_{gs_1} = 4v$ $V_{gs_2} = 5v$

$V_{ds_1} = 4v$ $V_{ds_2} = 5v$

$I_{d_1} = 256\mu A$ $I_{d_2} = 441\mu A$

$$\frac{4 - 5\sqrt{\frac{256}{441}}}{1 - \sqrt{\frac{256}{441}}} = \frac{0.19}{0.24} = 0.79v = V_{to} = V_T$$

b) $$\mu_n = \frac{2I_{D_1}}{C_{ox}\frac{W}{L}(V_{gs_1} - V_{th})^2}$$

$$= \frac{512\mu}{(1m)(4-0.79)^2} = \frac{512\mu}{0.01} = 51.2m$$

c) $$(V_{gs_3} - V_{th})^2 = \frac{2I_{d_3}}{C_{ox}\mu_n}$$

$$V_{th} = \sqrt{\frac{2I_{d_3}}{C_{ox}\mu_n}} - V_{gs_3}$$

$$V_{th} = \sqrt{\frac{2I_{d_3}}{C_{ox}\mu_n}} + V_{gs_3} = \sqrt{\frac{288\mu}{512\mu}} + 4 = 6.37v$$

$$V_{TO} = \frac{V_{GS3} - V_{GS4}\sqrt{\frac{I_{d3}}{I_{d4}}}}{1 - \sqrt{\frac{I_{d3}}{I_{d4}}}} = \frac{4 - 5(0.71)}{1 - 0.71} = 1.62\text{v}$$

$$\gamma = \frac{V_{t4} - V_{t0}}{\sqrt{|2\phi_F| + |V_{BS}|} - \sqrt{|2\phi_F|}} = \frac{6.37 - 1.62}{\sqrt{0.64 + 2.6} - \sqrt{0.64}} = \frac{4.75}{1.8 - 0.8} = \underline{4.75}$$