Solution 4.1

a) $(V_{\text{GS}} = 0.2\text{V}) < (V_{\text{T}} = 0.4\text{V}) \Rightarrow$ Cutoff

b) $(V_{\text{GS}} = 0.1\text{V}) < (V_{\text{T}} = 0.4\text{V}) \Rightarrow$ Cutoff

c) $(V_{\text{GS}} = 1.2\text{V}) > (V_{\text{DS}} = 0.2\text{V}) \Rightarrow$ Linear

d) $(V_{\text{GS}} - V_{\text{T}} < 0.4\text{V}) < (V_{\text{DS}} = 1.0\text{V}) \Rightarrow$ Saturation
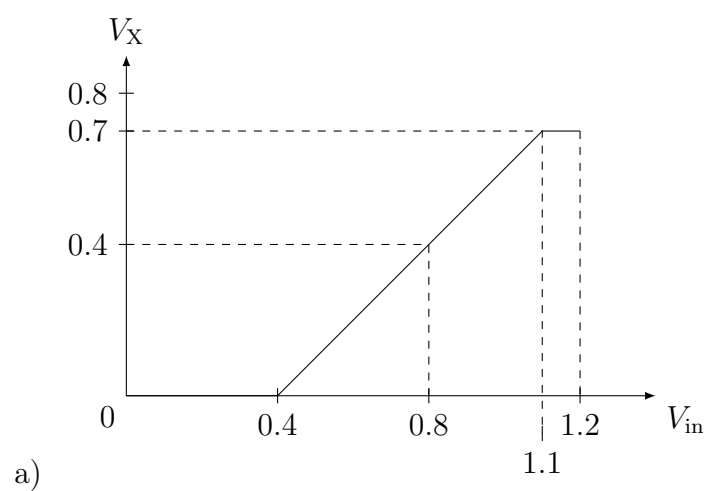
Solution 4.2

Figure 4.2: Operation of the NMOS Transistor as Voltage Follower
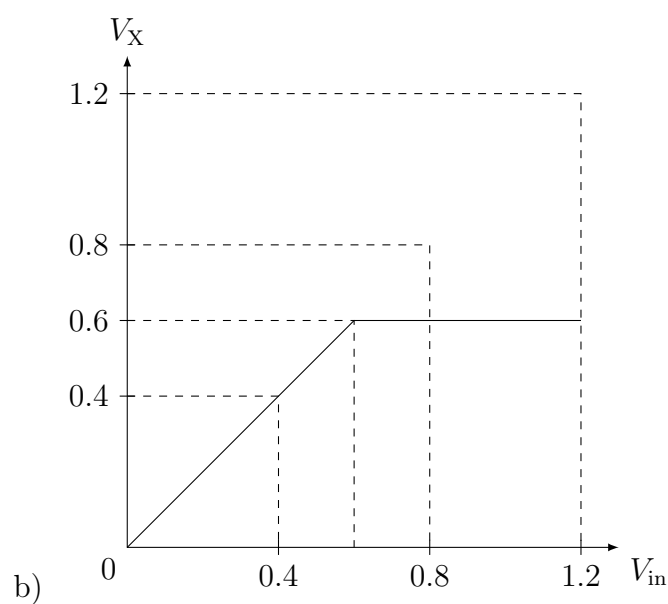
Figure 4.3: Operation of the NMOS Transistor as Current Follower

Solution 4.3

$$C_\mathrm{g} = L\epsilon_\mathrm{ox}/t_\mathrm{ox} = (4 \cdot 8.85 \cdot 10^{-14}\mathrm{AsV}^{-1}\mathrm{cm}^{-1} \cdot 0.1\mu\mathrm{m})/(22\mathrm{\AA}) \cong 1.6\mathrm{fF}\mu\mathrm{m}^{-1}$$

$$C_\mathrm{G} = C_\mathrm{g}W = 1.6\mathrm{fF}/\mu\mathrm{m} \cdot 0.4\mu\mathrm{m} = 0.64\mathrm{fF}$$

Cutoff ($V_\mathrm{GS} = 0$)	:	$C_\mathrm{GB} = 1/2 \cdot C_\mathrm{G}$
Linear	:	$C_\mathrm{GS} = C_\mathrm{GD} = 1/2 \cdot C_\mathrm{G}$
Saturation	:	$C_\mathrm{GS} = 2/3 \cdot C_\mathrm{G}$

Cutoff ($V_\mathrm{GS} = 0$	:	$C_\mathrm{GS} = 0\mathrm{fF}, C_\mathrm{GD} = 0\mathrm{fF}, C_\mathrm{GB} \cong 0.64\mathrm{fF}/2 = 0.32\mathrm{fF}$
Linear	:	$C_\mathrm{GS} = 0.32\mathrm{fF}, C_\mathrm{GD} = 0.32\mathrm{fF}, C_\mathrm{GB} = 0\mathrm{fF}$
Saturation	:	$C_\mathrm{GS} = 2/3 \cdot 0.64\mathrm{fF} = 0.43\mathrm{fF}, C_\mathrm{GD} = 0\mathrm{fF}, C_\mathrm{GB} = 0\mathrm{fF}$

Solution 4.4

a)

$$\Phi_\mathrm{B} = \frac{\mathrm{kT}}{\mathrm{q}} \ln \frac{N_\mathrm{A}N_\mathrm{D}}{n_\mathrm{i}^2} = 0.026\mathrm{V} \cdot \ln \left(\frac{3 \cdot 10^{17}\mathrm{cm}^{-3} \cdot 10^{20}\mathrm{cm}^{-3}}{(1.45 \cdot 10^{10}\mathrm{cm}^{-3})^2} \right) = 1\mathrm{V}$$

$$C_\mathrm{jb} = \sqrt{\frac{\epsilon_\mathrm{si}\mathrm{q}}{2\Phi_\mathrm{B}} \frac{N_\mathrm{A}N_\mathrm{D}}{N_\mathrm{A} + N_\mathrm{D}}} \approx \sqrt{\frac{\epsilon_\mathrm{si}\mathrm{q}N_\mathrm{A}}{2\Phi_\mathrm{B}}}$$

$$= \sqrt{\frac{(11.7)(8.85 \cdot 10^{-14}\mathrm{AsV}^{-1}\mathrm{cm}^{-1})(1.6 \cdot 10^{-19}\mathrm{As})(3 \cdot 10^{17}\mathrm{cm}^{-3})}{2 \cdot (1\mathrm{V})}} \approx 1.6\frac{\mathrm{fF}}{\mu\mathrm{m}^2}$$

b)

$$C_\mathrm{J}(0\mathrm{V}) = C_\mathrm{jb}(Y + x_\mathrm{j})W = 1.6\frac{\mathrm{fF}}{\mu\mathrm{m}^2} \cdot (0.3\mu\mathrm{m} + 0.05\mu\mathrm{m}) \cdot 0.4\mu\mathrm{m} \approx 0.22\mathrm{fF}$$

$$C_\mathrm{J}(-1.2\mathrm{V}) = \frac{C_\mathrm{jb}(Y + x_\mathrm{j})W}{(1 - V_\mathrm{J}/\Phi_\mathrm{B})^\mathrm{m}} = \frac{0.22\mathrm{fF}}{(1 - (-1.2)/1.0)^{1/2}} = 0.16\mathrm{fF}$$

c)

$$K_\mathrm{eq} = \frac{C_\mathrm{eq}}{C_\mathrm{jb}} = \frac{-2\Phi_\mathrm{B}^{1/2}}{V_2 - V_1} \left[(\Phi_\mathrm{B} - V_2)^{1/2} - (\Phi_\mathrm{B} - V_1)^{1/2} \right]$$

$$= \frac{-2 \cdot (1\mathrm{V})^{1/2}}{0\mathrm{V} - (-1.2\mathrm{V})} \left[(1\mathrm{V} - 0\mathrm{V})^{1/2} - (1\mathrm{V} - (-1.2\mathrm{V}))^{1/2} \right] = 0.8$$

$$C_{\mathrm{J}} = K_{\mathrm{eq}} C_{\mathrm{jb}} (Y + x_{\mathrm{j}}) W$$

$$= 0.8 \cdot 1.6 \frac{\mathrm{fF}}{\mu\mathrm{m}^2} \cdot (0.3\mu\mathrm{m} + 0.05\mu\mathrm{m}) \cdot 0.4\mu\mathrm{m} \approx 0.18\mathrm{fF}$$

Solution 4.5

$$C_{\mathrm{f}} = \frac{2\epsilon_{\mathrm{ox}}}{\pi} \ln\left(1 + \frac{T_{\mathrm{poly}}}{t_{\mathrm{ox}}}\right)$$

$$= \frac{2 \cdot (4) \cdot (8.85 \cdot 10^{-14}\mathrm{AsV}^{-1}\mathrm{cm}^{-1})}{3.14} \ln(1 + 100) \approx 0.1 \frac{\mathrm{fF}}{\mu\mathrm{m}}$$

$$C_{\mathrm{ov}} = C_{\mathrm{ox}} \cdot L_{\mathrm{D}} = 1.6 \cdot 10^{-6} \frac{\mathrm{F}}{\mathrm{cm}^2} \cdot 10 \cdot 10^{-9}\mathrm{m} = 0.16 \frac{\mathrm{fF}}{\mu\mathrm{m}}$$

$$C_{\mathrm{ol}} = C_{\mathrm{ov}} + C_{\mathrm{f}} = 0.16 \frac{\mathrm{fF}}{\mu\mathrm{m}} + 0.1 \frac{\mathrm{fF}}{\mu\mathrm{m}} = 0.26 \frac{\mathrm{fF}}{\mu\mathrm{m}}$$