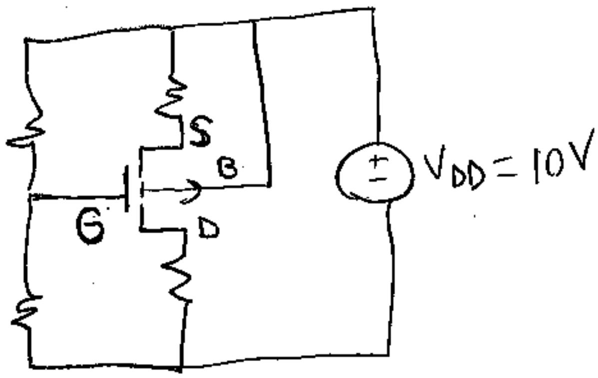
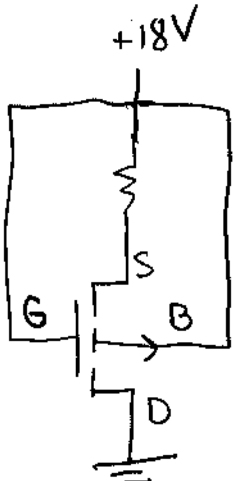
4.55

Arrow out means PMOS, so $V_{DS} < 0$

a)

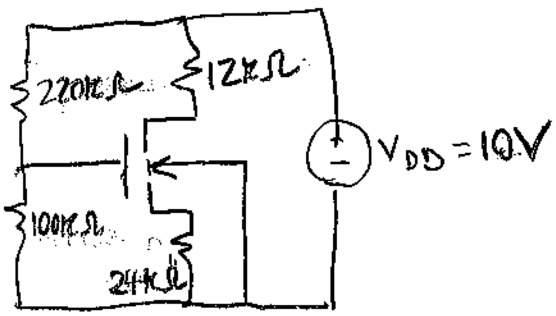


b)



4.93 part (a) only

NMOS



$V_T = 1V$

$\gamma = 0 \Rightarrow$ No Body effect.

$K' = 100\mu A/V^2$

$\frac{W}{L} = \frac{6}{1}$

$$V_g = 10V \cdot \left(\frac{100k\Omega}{220k + 100k\Omega}\right) = 3.125V$$

- Assume Saturation region as initial guess.

$$I_D = \tfrac{1}{2}K' \tfrac{W}{L} (V_{gs} - V_T)^2 = 100\mu A/V (6)(V_{gs} - V_T)^2$$

$$0 = 10V - I_D(24k\Omega) - V_{DS} - I_D(24k\Omega)$$

$$V_S = I_D(24k\Omega)$$

$$V_{gs} = 3.125V - I_D(24k\Omega)$$

$$I_D = (\tfrac{1}{2})100\mu A/V^2(6)(3.125V - I_D(24k\Omega) - 1V)^2$$

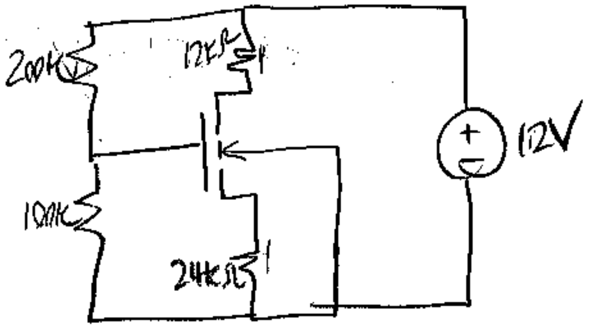
Solve for I_D, $I_D = 68.6\mu A$ or $114\mu A$ → This current would give a $V_{gs} < V_T$, so it is not a physical answer

$$\boxed{\begin{aligned} V_{gs} &= 3.125V - (68.6\mu A)(24k\Omega) = 1.48V \\ V_{DS} &= 10V - (68.6\mu A)(36k\Omega) = 7.53V \\ I_D &= 68.6\mu A \end{aligned}}$$

$V_{DS} > V_{gs} - V_T$, so saturation assumption verified.

4.99

Hand calculation for $V_{DD} = 12V$, $\frac{W}{L} = 6$,



$K' = 100\mu A/V^2$

$\gamma = 0$

$V_g = 12V\left(\frac{100k\Omega}{220k + 100k\Omega}\right) = 3.75V$

Assume Saturation

$V_{gs} = 3.75V - I_D(12k\Omega)$

$V_{DS} = 12V - I_D(36k\Omega)$

$I_D = (\tfrac{1}{2})100\mu A/V^2(6)(3.75V - I_D(24k\Omega) - 1)^2$

solve, $I_D = 91.6\mu A$ or $\cancel{143\mu A}$ → Not physical $V_{gs} < V_T$

$$\boxed{\begin{aligned} V_{gs} &= 3.75V - (91.6\mu A)(24k\Omega) = 1.55V \\ V_{DS} &= 12V - (91.6\mu A)(36k\Omega) = 8.70V \\ I_D &= 91.6\mu A \end{aligned}}$$

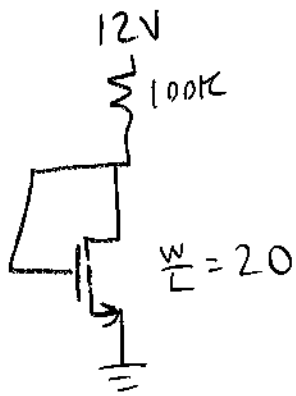
$V_{DS} > V_{GS} - V_T$, so saturation verified.

From Spice:

$I_D = 91.6\mu A$, $V_{ds} = 8.7V$, $V_{gs} = 1.55V$

4.111 NMOS

a)



$V_{GS} = 12V - I_D(100k\Omega)$

$V_{DS} = V_{GS} = 12V - I_D(100k\Omega$

$V_{DS} = V_{GS} > V_{GS} - V_T$, therefore Saturation

$K' = 100\mu A/V^2$, $V_T = 0.75V$

$I_D = K' \frac{W}{L}(V_{GS} - V_T)^2$

$I_D = (\tfrac{1}{2})(100\mu A/V^2)(20)(12V - I_D(100k\Omega) - 0.75V)^2$

solve for I_D

$$\boxed{\begin{array}{l} I_D = 109\mu A \quad \text{or} \quad \cancel{116\mu A} \\ V_{DS} = V_{GS} = 12V - (109\mu A)(100k\Omega) = 1.08V \end{array}}$$

b) calculation same, except $R = 330k\Omega$.

$I_D = (\tfrac{1}{2})100\mu A/V^2(20)(12V - I_D(330k\Omega) - 0.75V)^2$

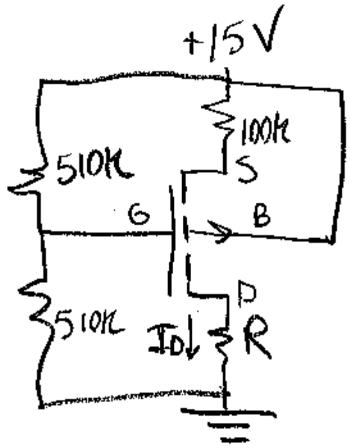
$$\boxed{\begin{array}{l} I_D = 33.5\mu A \quad \text{or} \quad \cancel{34.7\mu A} \\ V_{DS} = V_{GS} = 12V - (33.7\mu A)(330k\Omega) = 0.933V \end{array}}$$

Because $I_g = 0A$, the $10M\Omega$ resistor doesn't matter.

4.138

PMOS

a)



$\gamma = 0$, ⇒ No Body effect

$\frac{W}{L} = 20$

$K' = 40\mu A/V^2$

$V_{T0} = -0.75V$

$R = 50k\Omega$

Assume saturation

$V_g = 7.5V = 15V \frac{510k\Omega}{510k + 510k\Omega}$

$V_{DS} = -15V + I_D(100k + 50k)$

$V_{gs} = 7.5V - (15V - I_D(100k))$

$I_D = (\frac{1}{2})(40\mu A/V^2)(20)(7.5V - (15V - I_D(100k)) - (-0.75V))^2$

Solve for I_D, $I_D = 63.5\mu A$ or ~~71.7~~μA

$$\boxed{\begin{array}{l} V_{DS} = -5.47V \\ V_{gs} = -1.15V \\ I_D = 63.5\mu A \end{array}}$$

$-V_{DS} > -(V_{gs} - V_T)$ so saturation is verified.

b) Solve for R w/ $V_{DS} = V_{gs} - V_T \doteq -0.398V$ for maximum allowed R.

$V_{DS} = -15 + (100k\Omega + R)I_D$

$-0.398 = -15 + (100k\Omega + R)(63.5\mu A)$

Note that in saturation, I_D is constant for $\lambda = 0$, so I_D is same as part (a)

$\boxed{R = 130k\Omega \text{ or less}}$

4.139

Hand calc:

$$\boxed{\begin{aligned} V_{DS} &= -5.47V \\ V_{gs} &= -1.15V \\ I_D &= 63.5\mu A \end{aligned}}$$

Spice:

$$\boxed{\begin{aligned} I_D &= 63.5\mu A \\ V_{DS} &= -1.15V \\ V_{gs} &= -5.47V \end{aligned}}$$

5:9

Starting from eq. 5.13 in book...

$$I = I_E$$

$$V = V_{BE}$$

$$V_{BE} = 0V$$

$$I_E = I_S\left[\exp\left(\frac{V_{BE}}{V_T}\right) - \cancelto{1}{\exp\left(\frac{V_{BC}}{V_T}\right)}\right] + \frac{I_S}{\beta_F}\left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right]$$

$$I_E = I_S\left(\frac{\beta_F + 1}{\beta_F}\right)\left[\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right]$$

The transistor behaves like a diode with

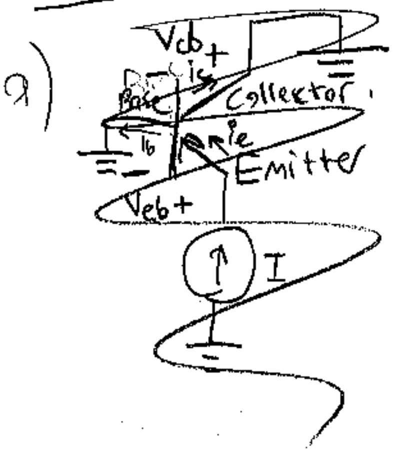
$$I_{S\,Diode} = I_S\left(\frac{\beta_F + 1}{\beta_F}\right)$$

$$= 4 \times 10^{-15} A \left(\frac{101}{100}\right)$$

$$\boxed{I_{S\,Diode} = 4.04 \times 10^{-15} A}$$

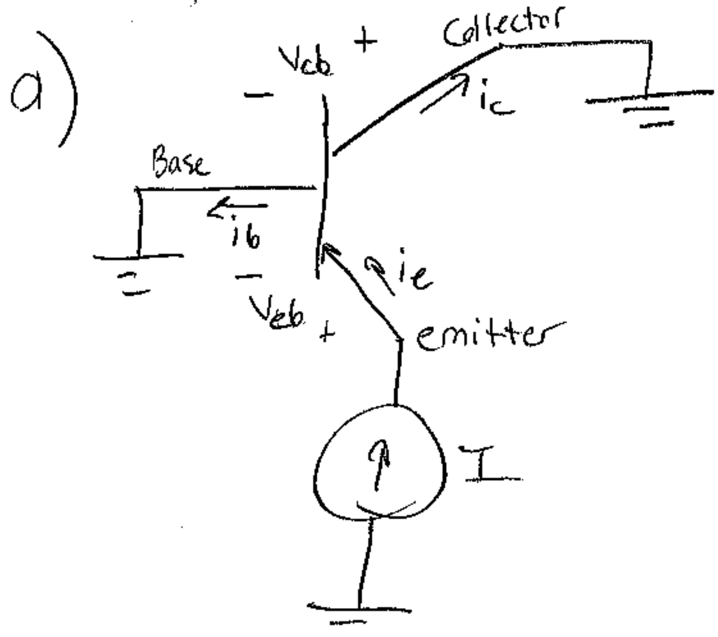
5.18

a)



b) PNP BJT.

a)



d) $I = \boxed{300\mu A = I_e}$

$I_e = (\beta+1) I_b \Rightarrow I_b = \frac{1}{\beta+1}(I_e) = \frac{1}{101} 300\mu A = \boxed{2.97\mu A}$ I_b

$I_c = \frac{\beta}{\beta+1} I_e = \beta I_b = \boxed{297\mu A}$ I_c

$I_E = I_s\left(\exp\left(\frac{V_{EB}}{V_T}\right) - \cancel{\exp\left(\frac{V_{CB}}{V_T}\right)}\right) + \frac{I_s}{\beta_F}\left(\exp\left(\frac{V_{EB}}{V_T}\right) - 1\right)$

because $V_{CB} = 0V$

$I_E = I_s\left(\frac{\beta_F+1}{\beta_F}\right)\left(\exp\left(\frac{V_{eb}}{V_T}\right) - 1\right)$

$300\mu A = (5\times10^{-16} A)\left(\frac{101}{100}\right)\left(\exp\left(\frac{V_{eb}}{0.925V}\right) - 1\right)$

Solve, $\boxed{V_{eb} = 0.678\,V}$ $\boxed{V_{cb} = 0V}$