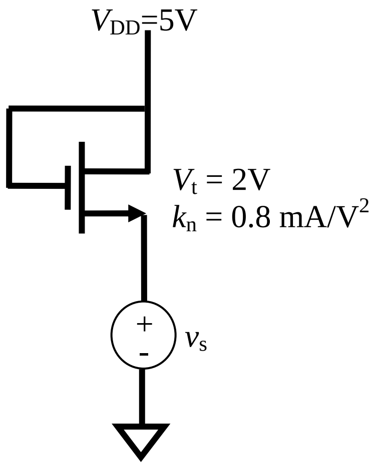
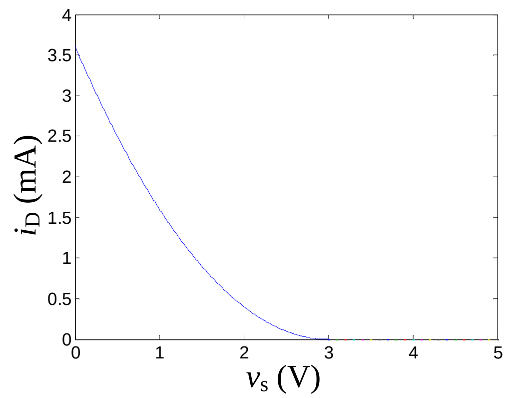
Homework 6 solutions:

5.25:





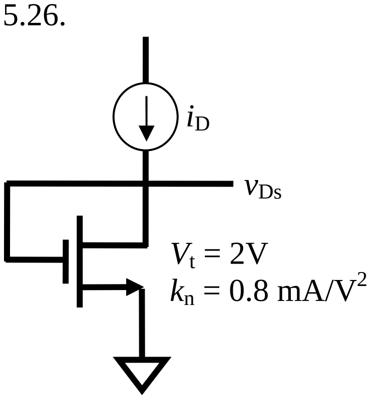
$$i_D = \frac{1}{2}k_n(v_{GS} - V_t)^2,\ v_{GS} = V_{DD} - v_s$$

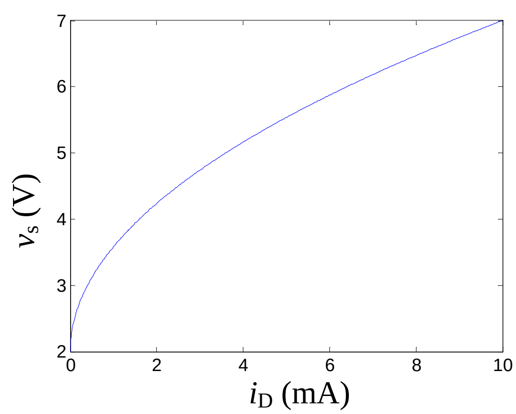
therefore, $i_D = \frac{1}{2}k_n(V_{DD} - V_t - v_s)^2 = 0.4(3 - v_s)^2$

For $v_s \le (V_{DD} - V_t)$, that is $v_s \le 3V$, $i_D > 0$

For $v_s > (V_{DD} - V_t)$, that is $v_s > 3V$, $i_D = 0$,

5.26.



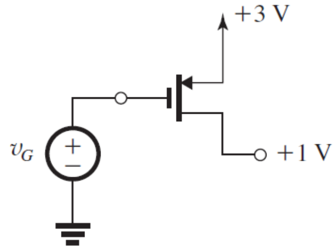


$v_{GS} = v_{DS}$, for iD > 0, NMOS must be operate in saturation:

$$i_D = \frac{1}{2}k_n(v_{GS} - V_t)^2 = \frac{1}{2}k_n(v_{DS} - V_t)^2$$

$$v_{DS} = \sqrt{\frac{2i_D}{k_n}} + V_t = \sqrt{\frac{i_D}{0.4}} + 2$$

5.41

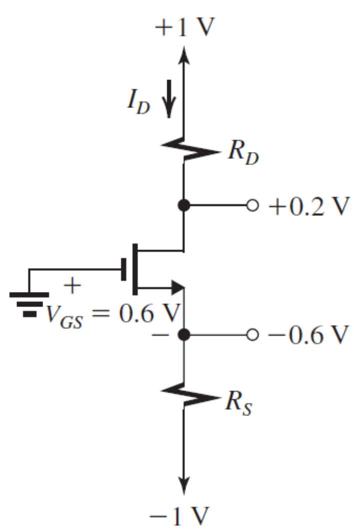


$V_{tp} = -0.5$ V

$v_G = +3 \text{ V} \rightarrow 0 \text{ V}$

As v_G reaches +2.5 V, the transistor begins to conduct and enters the saturation region, since v_{DG} will be negative. The transistor continues to operate in the saturation region until v_G reaches 0.5 V, at which point v_{DG} will be 0.5 V, which is equal to $|V_{tp}|$, and the transistor enters the triode region. As v_G goes below 0.5 V, the transistor continues to operate in the triode region.

5.45



Since $V_{DG} > 0$, the MOSFET is operating in saturation. Thus

$$I_D = \frac{1}{2}k_n(V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 4 \times (0.6 - 0.4)^2$$

$$= 0.08 \text{ mA}$$

$$R_D = \frac{1 - V_D}{I_D} = \frac{1 - 0.2}{0.08} = \frac{0.8}{0.08} = 10 \text{ k}\Omega$$

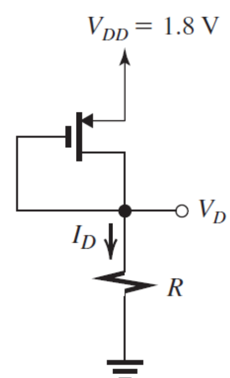
$$R_S = \frac{-0.6 - (-1)}{I_D} = \frac{-0.6 + 1}{0.08} = 5 \text{ k}\Omega$$

For I_D to remain unchanged from 0.08 mA, the MOSFET must remain in saturation. This in turn can be achieved by ensuring that V_D does not fall below V_G (which is zero) by more than V_t (0.4 V). Thus

$$1 - I_D R_{D\text{max}} = -0.4$$

$$R_{D\text{max}} = \frac{1.4}{0.08} = 17.5 \text{ k}\Omega$$

5.49



$I_D = 180\ \mu\text{A}$ and $V_D = 1$ V

$$R = \frac{V_D}{I_D} = \frac{1}{0.18} = 5.6 \text{ k}\Omega$$

Transistor is operating in saturation with $|V_{OV}| = 1.8 - V_D - |V_t| = 1.8 - 1 - 0.5 = 0.3$ V:

$$I_D = \frac{1}{2}k'_p\frac{W}{L}|V_{OV}|^2$$

$$180 = \frac{1}{2} \times 100 \times \frac{W}{L} \times 0.3^2$$

$$\Rightarrow \frac{W}{L} = 40$$

$$W = 40 \times 0.18 = 7.2\ \mu\text{m}$$