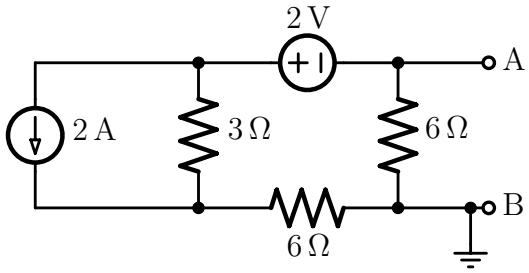
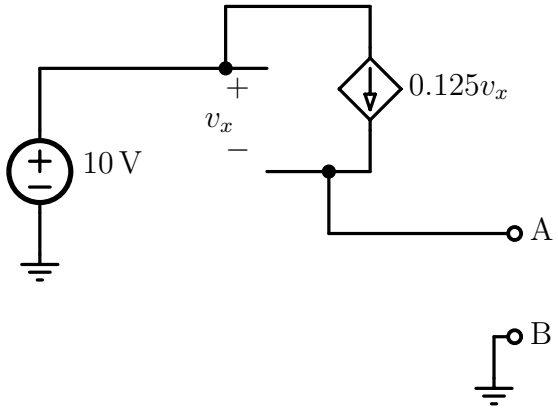
Problem Set 1

Q1. Find the voltage source equivalent and current source equivalent circuits for the following circuits between the nodes A and B. Use I_{sc} for the short circuit output current, V_{oc} for the open circuit output voltage and R_{th} for the output resistance.

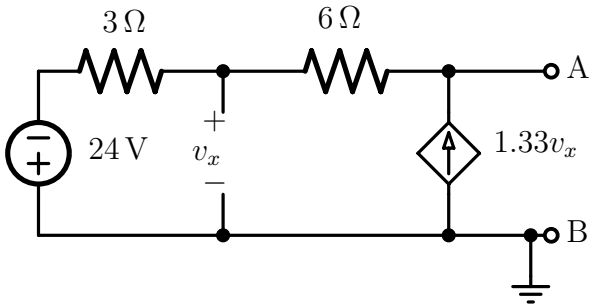
(a)



(b)



(c)



Q2. An NMOS transistor that is operated with a small v_{DS} is found to exhibit a resistance r_{DS}. By what factor will r_{DS} change in each of the following situations?

(a) Overdrive is multiplied by a factor of 2.
(b) The device is replaced with another fabricated in the same technology but width multiplied by a factor of 2.
(c) The device is replaced with another fabricated in the same technology but with both the width and length are multiplied by a factor of 2.
(d) The device is replaced with another fabricated in a more advanced technology for which the oxide thickness is multiplied by a factor of 0.5 and both W and L are each multiplied by a factor of 0.5 (assume μ_n remains unchanged).

Q3. An NMOS transistor with $k_n = 1\,\text{mA/V}^2$ and $V_t = 1\,\text{V}$ is operated with V_{GS} =2.5 V. At what value of V_{DS} does the transistor enter the saturation region? What value of I_D is obtained in saturation?

Q4. With the knowledge that $\mu_p \approx 0.4\,\mu_n$, what must be the relative width of n-channel and p-channel devices if they are to have equal drain currents when operated in the saturation mode with overdrive voltages of the same magnitude?

Q5. An NMOS transistor is fabricated in a 0.8-μm process having $k'_n = 130\,\mu\text{A/V}^2$ and $V'_A = 20\,\text{V}/\mu\text{m}$ of channel length. If $L = 1.6\,\mu\text{m}$ and $W = 16\,\mu\text{m}$, find V_A and λ. Find the value of I_D that results when the device is operated with an overdrive voltage of 0.5 V and $V_{DS} = 2\,\text{V}$. Also, find the value of r_o at this operating point. If V_{DS} is increased by $1V$, what is the corresponding change in I_D?

Q6. A p-channel transistor for which $|V_t| = 1\,\text{V}$ and $|V_A| = 50\,\text{V}$ operates in saturation with $|V_{GS}| = 3\,\text{V}$, $|V_{DS}| = 4\,\text{V}$, $i_D = 3\,\text{mA}$. Find the corresponding signed values for V_{GS}, V_{SG}, V_{DS}, V_{SD}, V_t, λ, and $k'_p(W/L)$.

Q7. For the NMOS amplifier below, replace the transistor with its T equivalent circuit, assuming $\lambda = 0$. Derive the expressions for the voltage gains v_s/v_i and v_d/v_i.