NAME ____SOLUTIONS_____

MIDTERM EXAM 1 - SOLUTIONS

(Closed book)

ECE 342

July 2nd, 2020

9:00 a.m. – 9:50 a.m.

Instructions : This examination consists of 7 multiple choice questions. Select the most nearly correct answer for each question. You are allowed to use a calculator.

Note 1. It is suggested that you answer the questions you consider easiest first.

Note 2. Choose only ONE answer per problem. Points will be taken off for multiple answers.

Formula Sheet

DIODE

$$I_D = I_S(e^{V_D/V_T} - 1)\text{, where } V_T = \frac{k_B T}{q} = 26 \text{ mV}$$

NMOS	PMOS
Cut-off $V_{GS} < V_{tn}$, $I_D = 0$ Triode Region (Linear) $V_{GS} > V_{tn}$ & $V_{DS} < V_{DSP} = V_{GS} - V_{tn}$ $I_D = \frac{W}{L}\mu_n C_{ox}\left((V_{GS} - V_{tn})V_{DS} - \frac{V_{DS}^2}{2}\right)$ Active Region (Saturation) $V_{GS} > V_{tn}$ & $V_{DS} \geq V_{DSP} = V_{GS} - V_{tn}$ $I_D = \frac{W}{L}\frac{\mu_n C_{ox}}{2}(V_{GS} - V_{tn})^2\left[1 + \lambda V_{DS}\right]$	Cut-off $V_{SG} < \lvert V_{tp}\rvert$, $I_D = 0$ Triode Region (Linear) $V_{SG} > \lvert V_{tp}\rvert$ & $V_{SD} < V_{SDP} = V_{SG} - \lvert V_{tp}\rvert$ $I_D = \frac{W}{L}\mu_p C_{ox}\left((V_{SG} - \lvert V_{tp}\rvert)V_{SD} - \frac{V_{SD}^2}{2}\right)$ Active Region (Saturation) $V_{SG} > \lvert V_{tp}\rvert$ & $V_{SD} \geq V_{SDP} = V_{SG} - \lvert V_{tp}\rvert$ $I_D = \frac{W}{L}\frac{\mu_p C_{ox}}{2}(V_{SG} - \lvert V_{tp}\rvert)^2\left[1 + \lvert\lambda\rvert V_{SD}\right]$

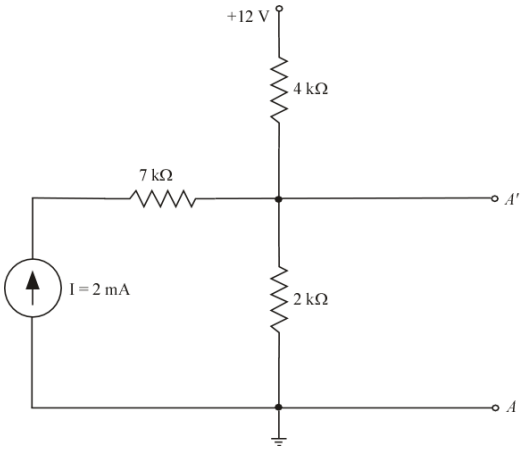
Body Effect

$$V_t = V_{to} + \gamma\left(\sqrt{\lvert V_{SB}\rvert + 2\phi_F} - \sqrt{2\phi_F}\right)$$

Small Signal Characteristics (NMOS):

$$g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L}I_D}\,; \quad r_{ds} = \frac{\lvert V_A\rvert}{I_D} = \frac{1}{\lambda I_D}$$

Consider the circuit shown below



1. The Thévenin equivalent voltage across the terminals *A'*-*A* is (1 point)

(a) $V_{th} = 1.33$ V

(b) $V_{th} = 3.33$ V,

(c) $V_{th} = 6.66$ V

(d) $V_{th} = 8$ V

(e) $V_{th} = 12$ V

$$2+\frac{12-V_x}{4}=\frac{V_x}{2}\Rightarrow 2+3=V_x\left(\frac{1}{2}+\frac{1}{4}\right)\Rightarrow 5=\frac{3V_x}{4}$$

$$V_X=\frac{20}{3}V\Rightarrow V_{th}=\frac{20}{3}V,\quad V_{TH}=6.66\text{ V}$$

(c) is correct answer

2. The Thévenin equivalent impedance across the terminals *A'*-*A* is (1 point)

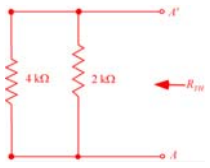
(a) $Z_{th} = 1.33$ kΩ

(b) $Z_{th} = 2$ kΩ

(c) $Z_{th} = 4$ kΩ

(d) $Z_{th} = 6.66$ kΩ

(e) $Z_{th} = 7.22$ kΩ

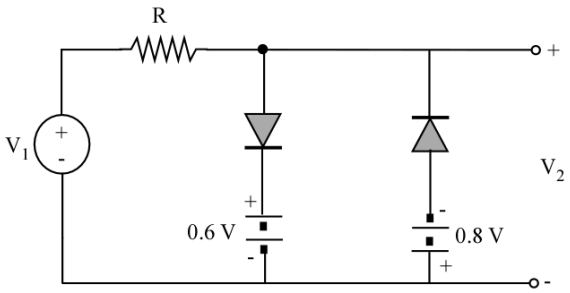


$$R_{TH}=4\ k\Omega\,||\,2\ k\Omega=\frac{4}{3}\ k\Omega$$

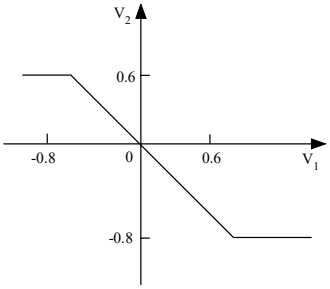
$$R_{TH}=1.333\ k\Omega$$

(a) is correct answer

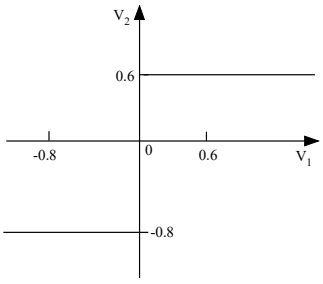
3. In the circuit shown, the diodes are ideal. Indicate the correct plot for V_2 versus V_1. (3 points)



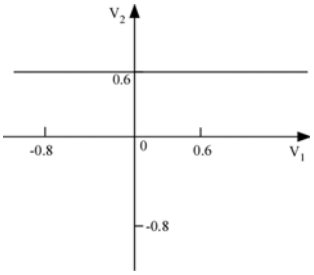
(a)



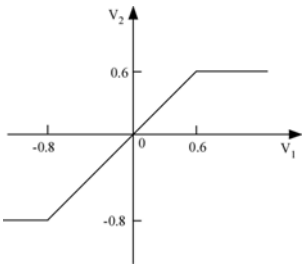
(b)



(c)



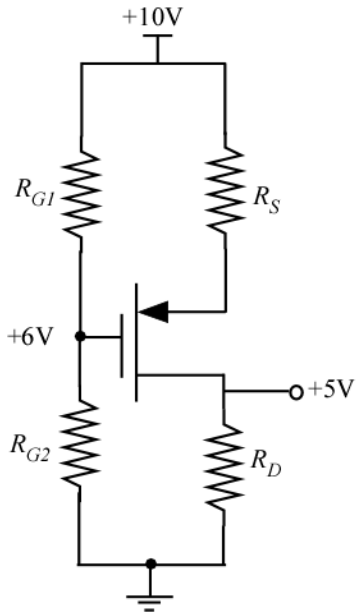
(d)



(e) None of the above

(d) is correct answer

The circuit shown below uses an enhancement-type PMOS transistor with V_t = -1.5V, $k_p'(W/L)$ = 1 mA/V^2, and $\lambda = 0$. Also, R_{G1} = 4 MΩ. The desired drain current is 0.5 mA and the drain voltage is +5V. Find values for R_{G2}, R_S and R_D.



4. What is the value of R_{G2}? (1 point)

(a) 2 MΩ
(b) 3 MΩ
(c) 4 MΩ
(d) 6 MΩ
(e) 8 MΩ

$$R_{G2} = \frac{V_G}{\frac{(V_{DD} - V_G)}{R_{G1}}} = \frac{6}{\frac{(10-6)}{4}} = 6M\Omega$$

(d) is correct answer

5. What is the value of R_D? (1 point)

(a) 2 kΩ
(b) 5 kΩ
(c) 10 kΩ
(d) 15 kΩ
(e) 20 kΩ

$$R_D = \frac{V_D}{I_D} = \frac{5}{0.5} = 10\,k\Omega$$

(c) is correct answer

6. What is the value of the source voltage, V_S? (2 points)

(a) 4.5 V
(b) 5.5 V
(c) 6.5 V
(d) 7.5 V
(e) 8.5 V

$$I_D = 0.5 = \frac{1}{2} \times 1 \times (V_{GS} + 1.5)^2 = \frac{1}{2}(V_{GS}^2 + 3V_{GS} + 2.25)$$

$$1 = V_{GS}^2 + 3V_{GS} + 2.25 \Rightarrow V_{GS}^2 + 3V_{GS} + 1.25 = 0$$

Good root is: V_{GS} = -2.5 V. Other root (-0.5 V) is rejected since its magnitude is less than the magnitude of the threshold voltage

$$V_{GS} = -2.5\,V \Rightarrow V_S = 8.5\,V$$

(e) is correct answer

7. What is the value of R_S? (1 point)

(a) 1 kΩ
(b) 3 kΩ
(c) 5 kΩ
(d) 6 kΩ
(e) 9 kΩ

$$R_S = \frac{(V_{SS} - V_S)}{I_D} = \frac{(10 - 8.5)}{0.5} = 3\,k\Omega$$

(b) is correct answer