Department of Computer Science and Engineering (CSE)
BRAC University

Practice Problem Set 5

CSE251 - Electronic Devices and Circuits

MOSFET CIRCUITS

S-Model, SR-Model, Real MOSFET Model, Logic Function Implementation, Method of Assumed States, and Multistage Circuits

[Course Description, COs, and Policies](#)

[Midterm and Final Questions](#)

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Problem 1

- Give a switch-MOSFET implementation of the following logic functions. A, B, C, D, E, and F are Boolean inputs.

I. $f = A.B.C + D.E$

II. $f = \overline{A.B.(C + D)}$

III. $f = A.B + \bar{A}.\bar{B}$

IV. $f = \overline{A.C} + \overline{B + C}$

V. $f = (A.B + C).D$

VI. $f = A.B + C.D$

VII. $f = A.B.C + D$

VIII. $f = (A + B).(C + D)$

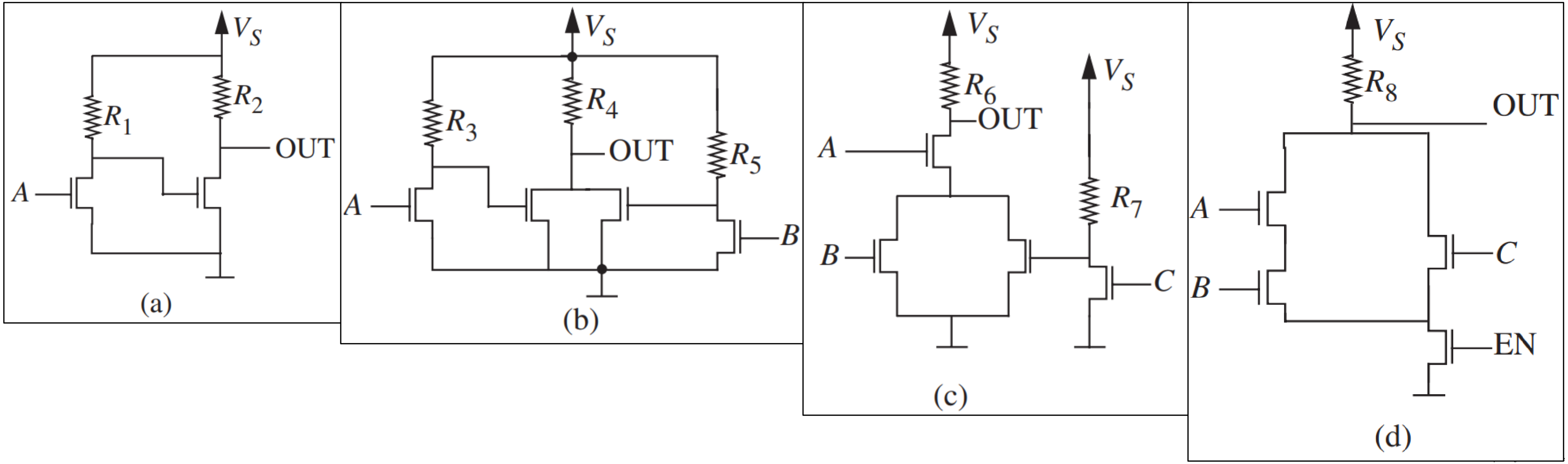
IX. $f = (A.B + C).D.(E + F)$

X. $f = A \oplus B$

XI. $f = \overline{C.(A + B)}.(A + \bar{B} + C)$

Problem 2

- Write a Boolean expression that describes the function of each of the circuits below.



Problem 3

- Draw voltage transfer characteristics (VTC) for the following logic gates implemented using MOSFETs. Use S −Model.

  I. Inverter

  II. 2-input NAND Gate

  III. 2-input NOR Gate

  IV. 3-input AND Gate or $f = A.B.C$

  V. 3-input OR Gate or $f = A + B + C$

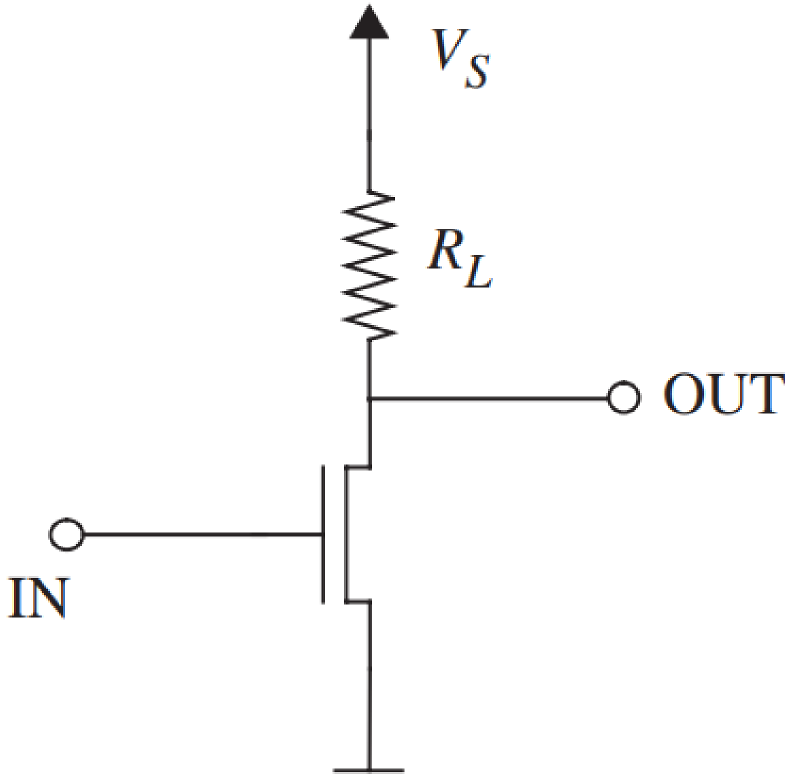
Problem 4

- The MOSFET in the following inverter circuit has a threshold voltage $V_{Tn} = 2\ V$ and $R_{ON} = 8\ k\Omega$. For the circuit, $V_S = 5\ V$. Draw the $OUT\ vs.\ IN$ (VTC) graph by modeling the MOSFETs using

  I. S –Model and

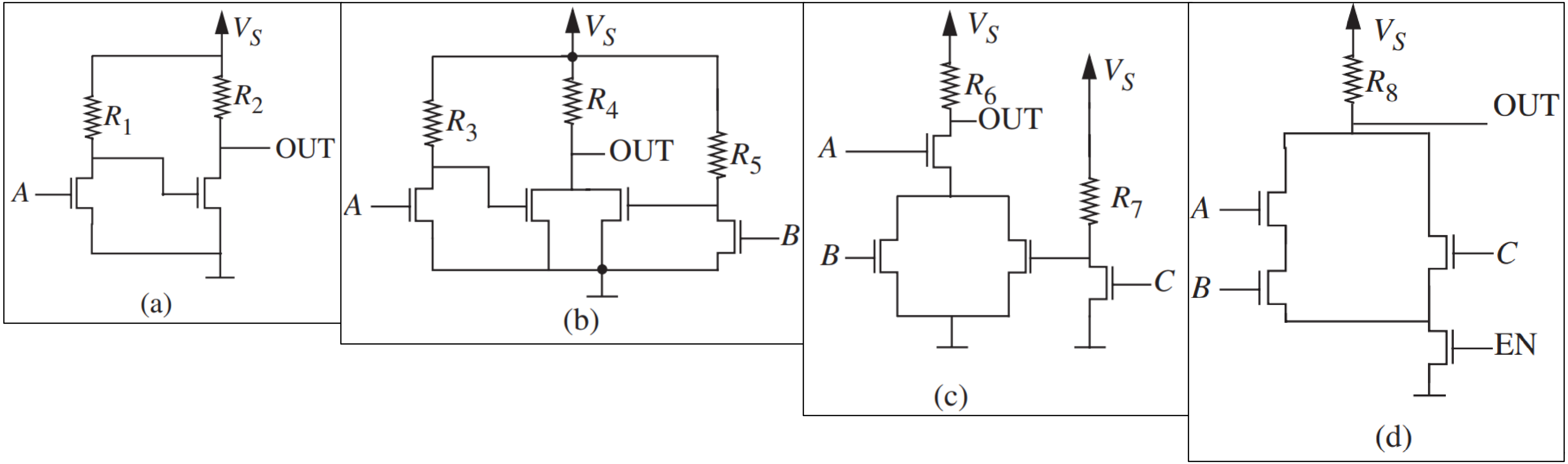
  II. SR –Model with $R_L = 10\ k\Omega$.

  III. SR –Model with $R_L = 40\ k\Omega$.



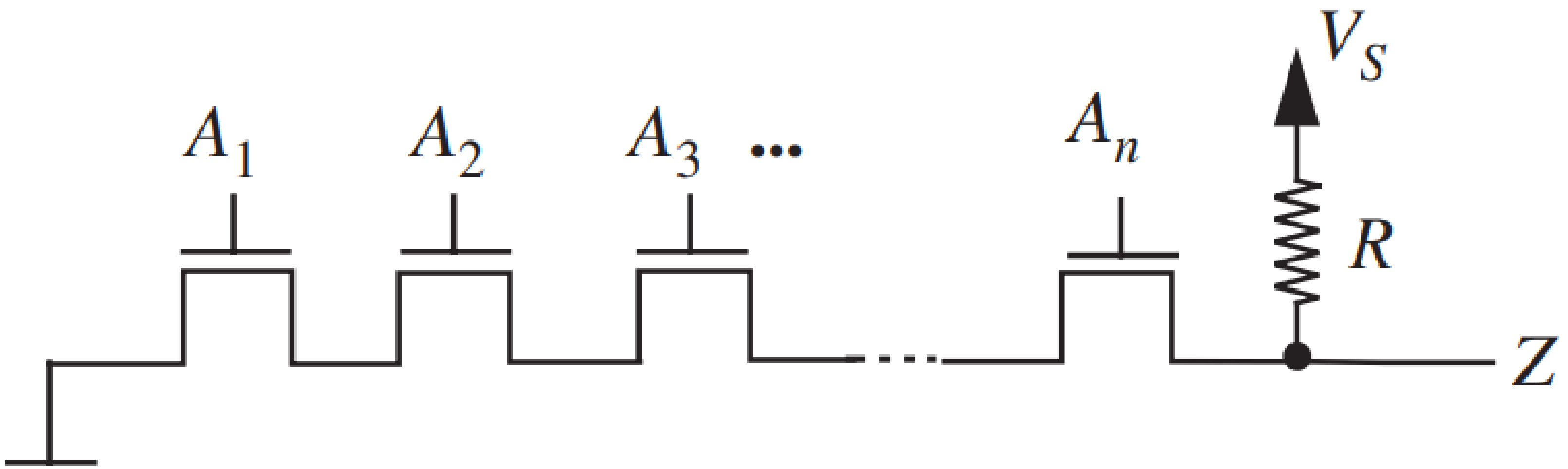
Problem 5

- The static discipline of an electronic system is such that, an input or output will be considered "low" if it remains below $0.5\,V$. Determine minimum values for the resistors R_1 through R_8 in terms of R_{ON}, so that each circuit satisfies the static discipline of the system. Here, $V_S = 5\,V$.



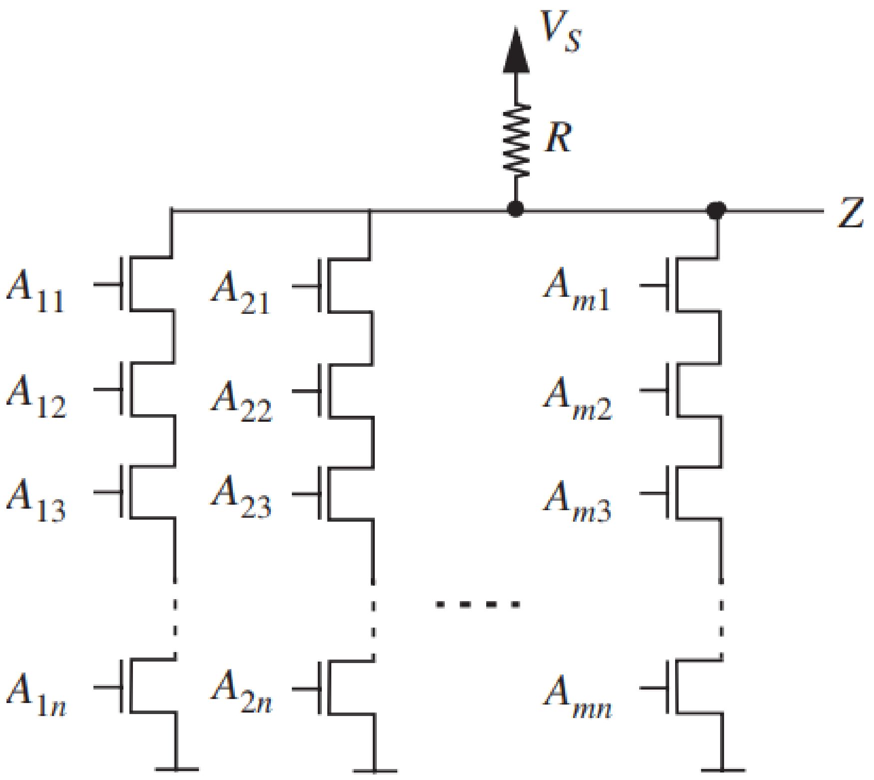
Problem 6

- The static discipline of an electronic system is such that, an input or output will be considered "low" if it remains below $0.5\ V$. Consider the N-input NAND gate circuit shown below. In the design, $\mathrm{V_S} = 5\ \mathrm{V}$, $R = 100\ k\Omega$, and $R_{ON} = 2\ k\Omega$. Determine the maximum value of N, that is, the maximum number of MOSFETs that can be connected so that the circuit satisfies the static discipline.



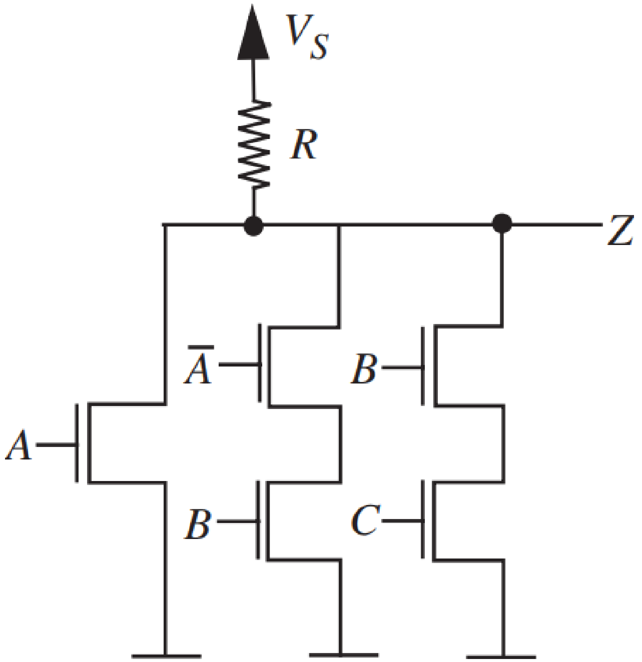
Problem 7

- The static discipline of an electronic system is such that, an input or output will be considered "low" if it remains below $0.5\ V$. Consider the following logic circuit where, $V_S = 5$ V and $R_{ON} = 1\ k\Omega$. Design the circuit so that the circuit satisfies the static discipline for $m = 10$ and $n = 25$.

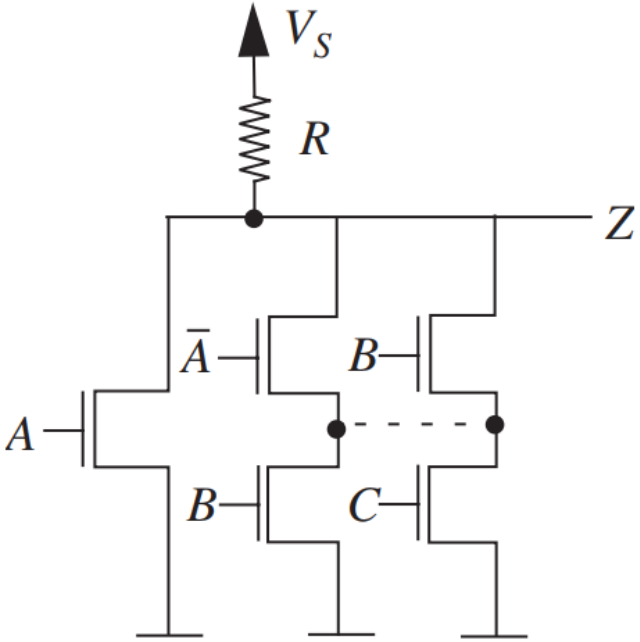


Problem 8

- Write a Boolean expression that describes the function of the circuit in figure (a). What will be the expression if a manufacturing error results in a short circuit as indicated by the dashed line in (b).



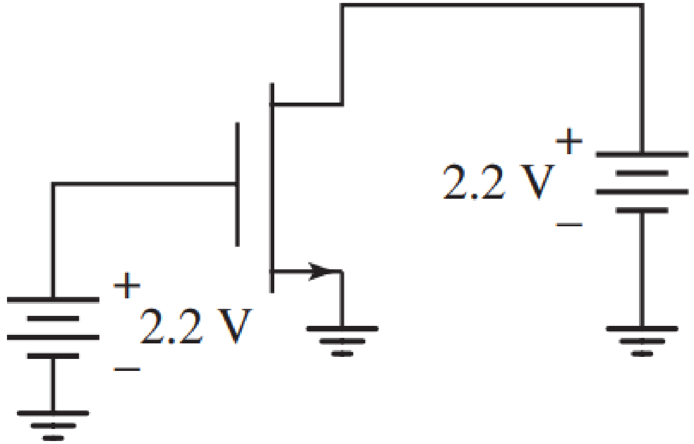
(a)



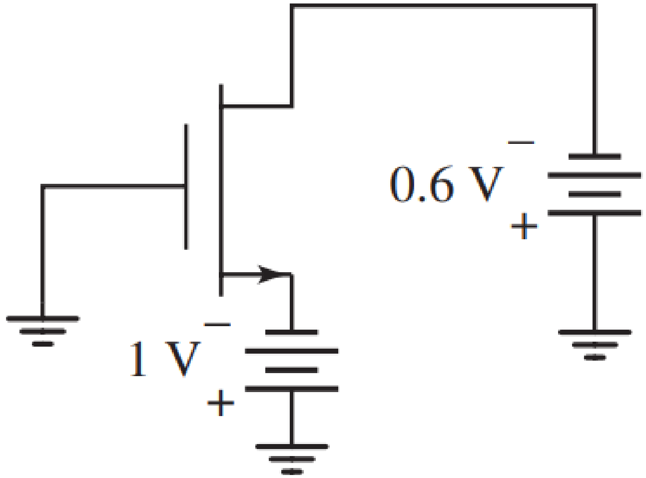
(b)

Problem 9

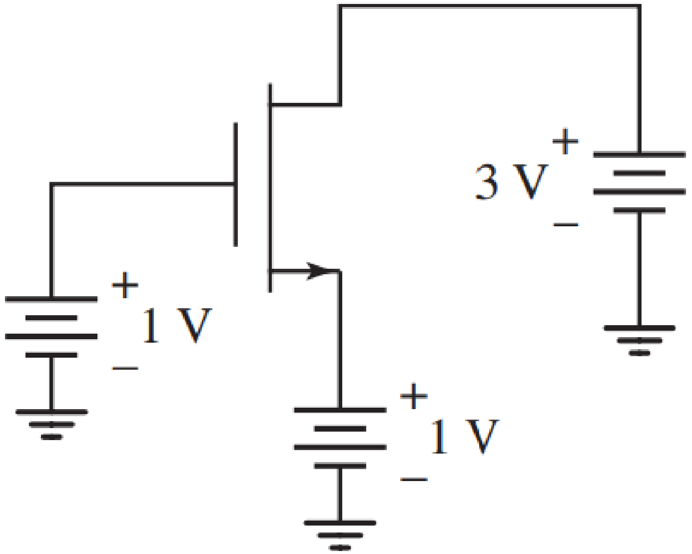
- The threshold voltage for each of the NMOS transistors in the following circuits is $V_{Tn} = 0.4\ V$. Determine the operating region of the transistor in each circuit.



(a)



(b)



(c)

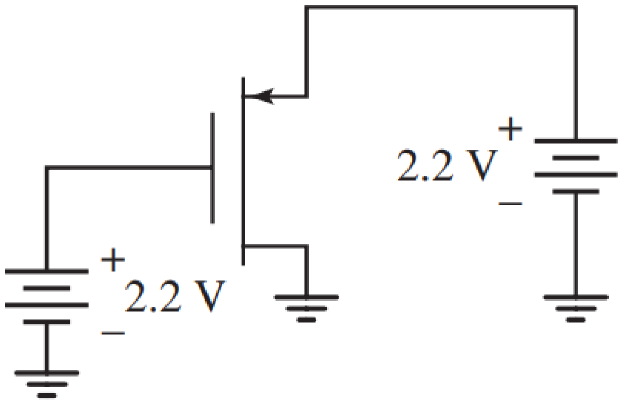
Ans: ***Saturation***

Ans: ***Triode***

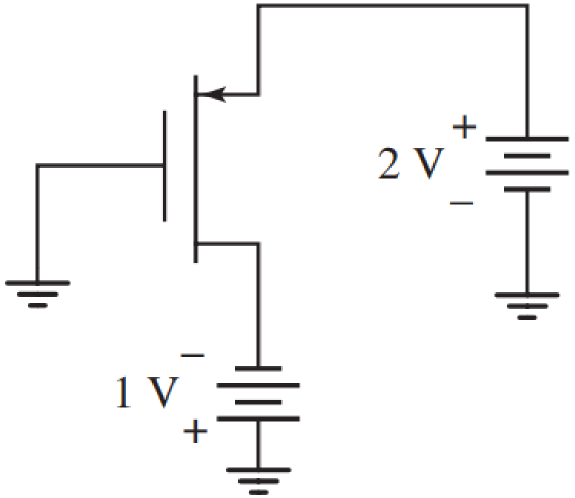
Ans: ***Saturation***

Problem 10

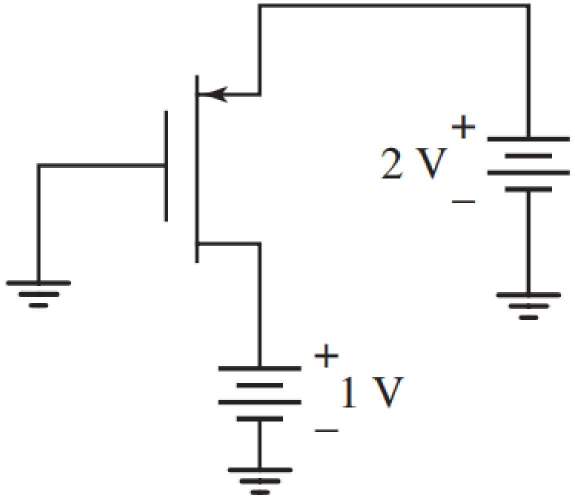
- The threshold voltage for each of the PMOS transistors in the following circuits is $V_{Tp} = -0.4\ V$. Determine the operating region of the transistor in each circuit.



(a)



(b)



(c)

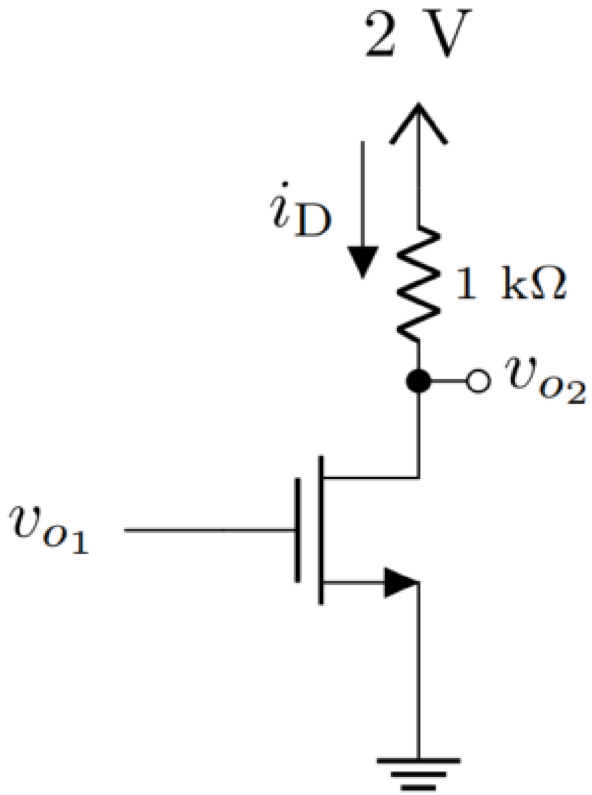
Ans: ***Saturation***

Ans: ***Saturation***

Ans: ***Triode***

Problem 11

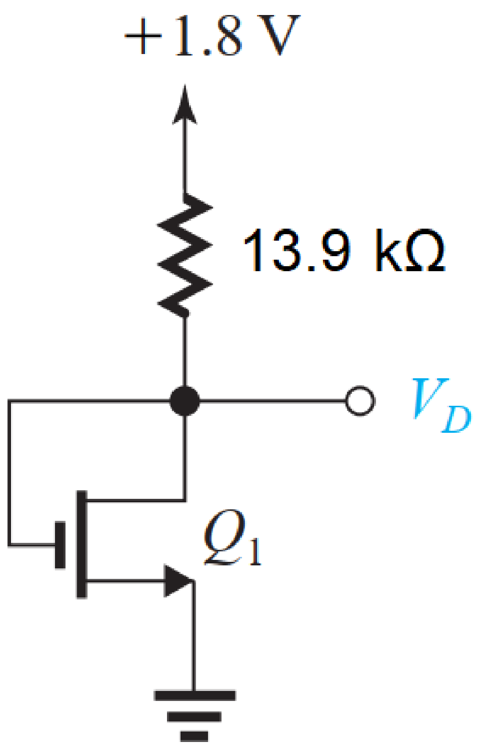
- The transistor in the following circuit has parameters $V_{Tn} = 0.2\ V$ and $k_n = k_n' \frac{W}{L} = 4\ {}^{mA}/_{V^2}$. If $v_{O_1} = 2\ V$, determine i_D and v_{O_2}.



Ans: $\boldsymbol{v_{O_2} = 0.26\ V; i_D = 1.74\ mA}$

Problem 12

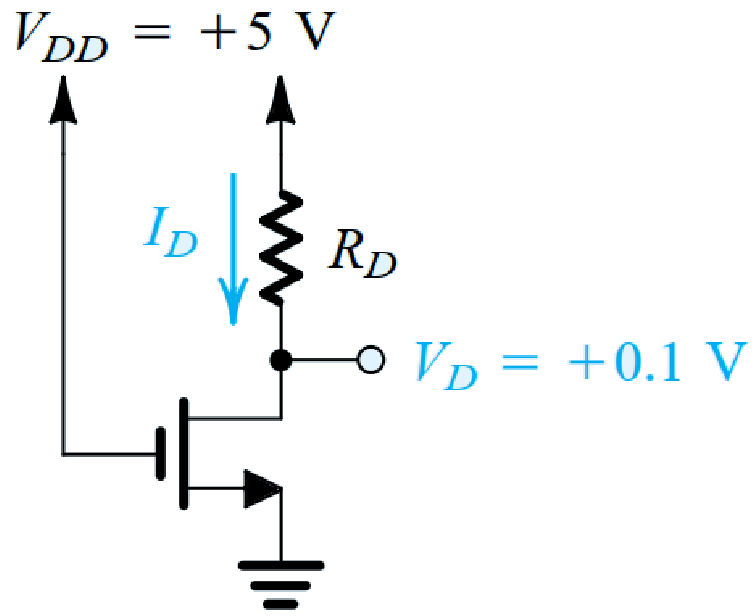
- The transistor in the following circuit has parameters $V_{Tn} = 0.5\ V$ and $k_n = k_n' \frac{W}{L} = 1.6\ {}^{mA}/_{V^2}$. Determine V_D.



Ans: $\boldsymbol{V_D = 0.79\ V}$

Problem 13

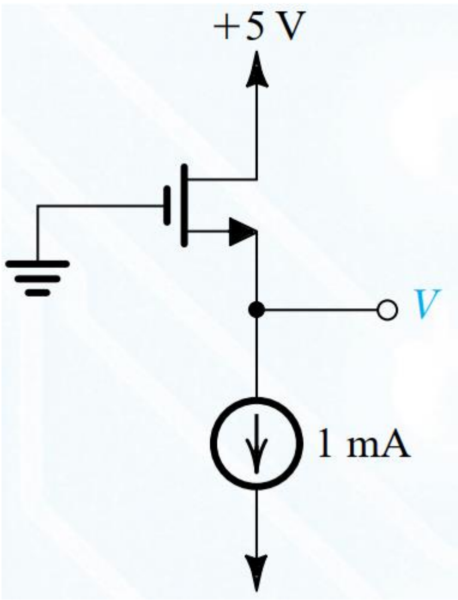
- Design the circuit, that is, determine the values of R_D, so that the transistor operates at $V_D = 0.1\,V$. The NMOS transistor has $V_{Tn} = 1\,V$ and $k_n = k_n' \frac{W}{L} = 1\ {}^{mA}/_{V^2}$.

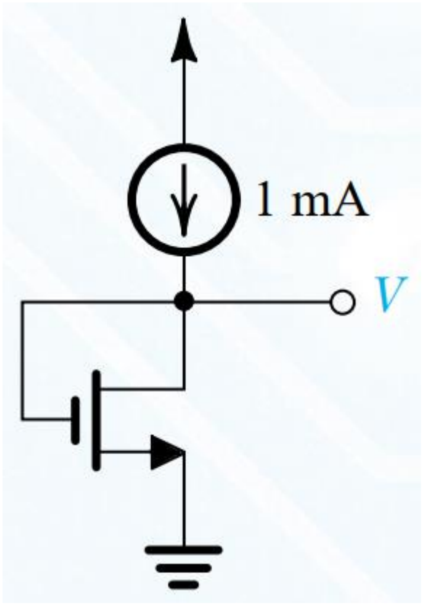


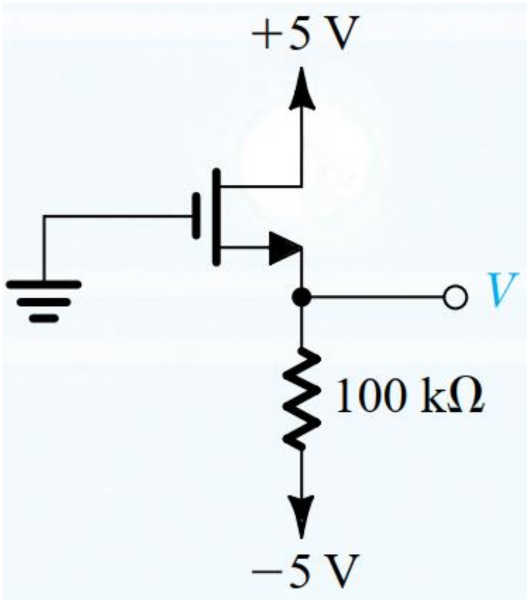
Ans: $\boldsymbol{I_D = 0.395\ mA; R_D = 12.4\ k\Omega}$

Problem 14

- The transistors in the following circuits has $V_{Tn} = 0.8\,V$ and $k_n = k_n' \frac{W}{L} = 0.5\ {}^{mA}/_{V^2}$. Determine V in each circuit.







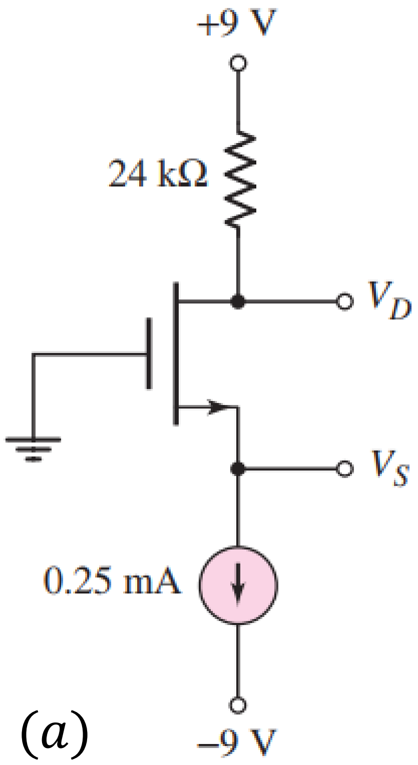
Ans: $\boldsymbol{V = 2.8\,V}$ (a)

Ans: $\boldsymbol{V = 2.8\,V}$ (b)

Ans: $\boldsymbol{V = 1.19\,V}$ (c)

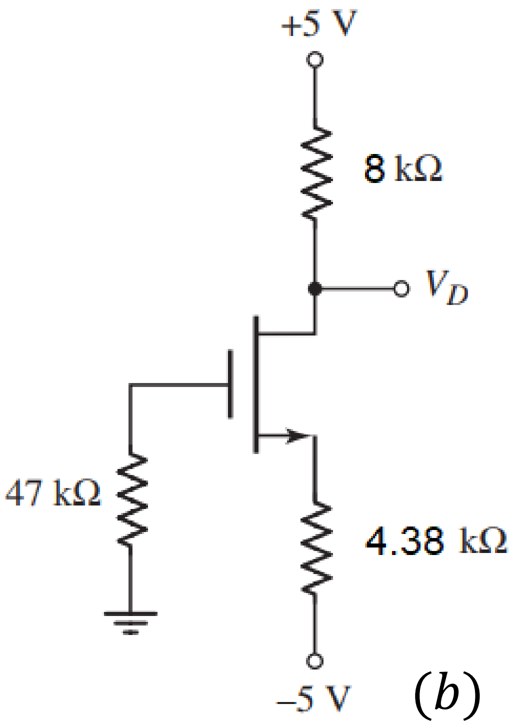
Problem 15

- The transistors in the following circuits has parameters $V_{Tn} = 0.6\,V$ and $k_n = k_n' \frac{W}{L} = 200\ {}^{\mu A}/_{V^2}$. Determine V_D and V_S.



(a)

Ans: $\boldsymbol{V_D = 3\ V, V_S = 2.18\ V}$

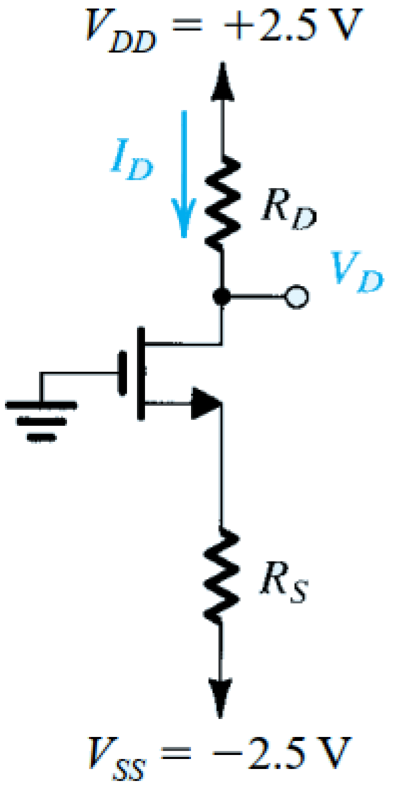


(b)

Ans: $\boldsymbol{V_D = 1.03\ V, V_S = 2.83\ V}$

Problem 16

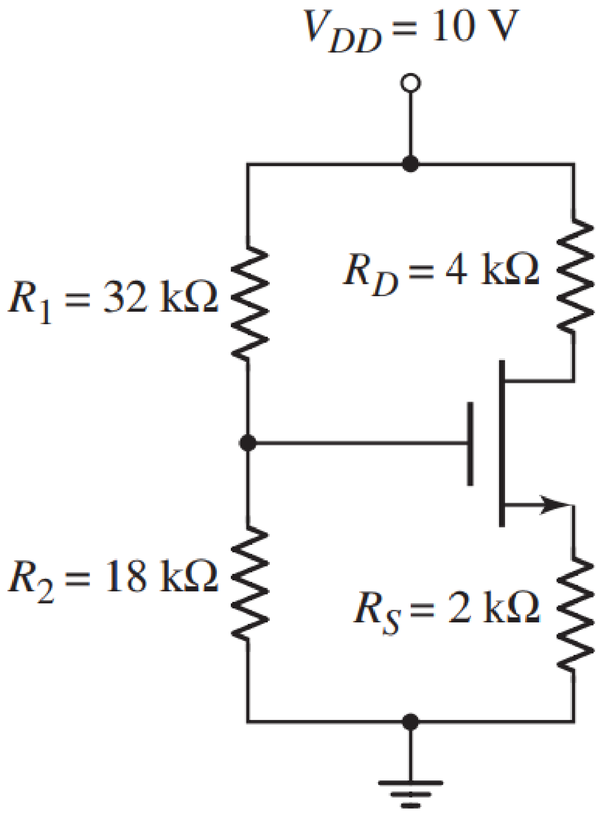
- Design the circuit, that is, determine the values of R_D and R_S, so that the transistor operates at $I_D = 0.4\, mA$ and $V_D = 0.5\, V$. The transistor has $V_{Tn} = 0.7\, V$ and $k_n = k_n' \frac{W}{L} = 3.2\ {}^{mA}/_{V^2}$.



Ans: $\boldsymbol{R_D = 5\ k\Omega, R_S = 3.25\ k\Omega}$

Problem 17

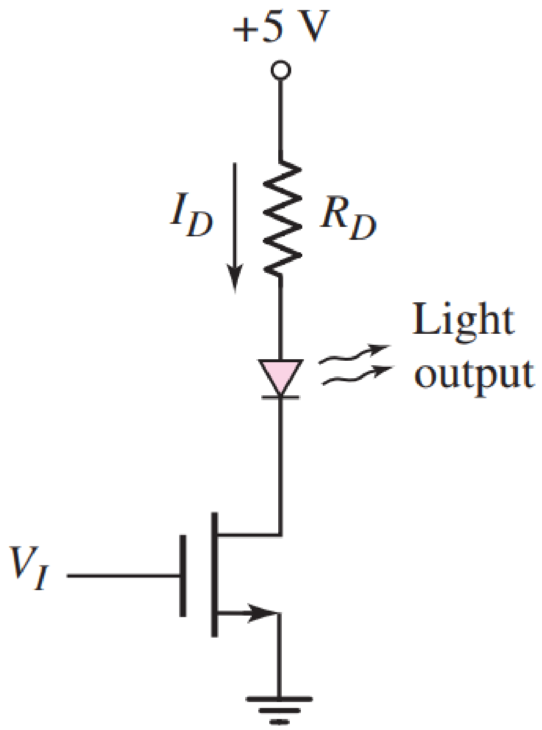
- The transistor in the following circuit has parameters $V_{Tn} = 0.8\,V$ and $k_n = k'_n \frac{W}{L} = 0.5\ {}^{mA}/_{V^2}$. Determine the voltages across the transistor.



Ans: $\boldsymbol{V_G = 3.6\,V, V_D = 7.54\,V, V_S = 1.23\,V}$

Problem 18

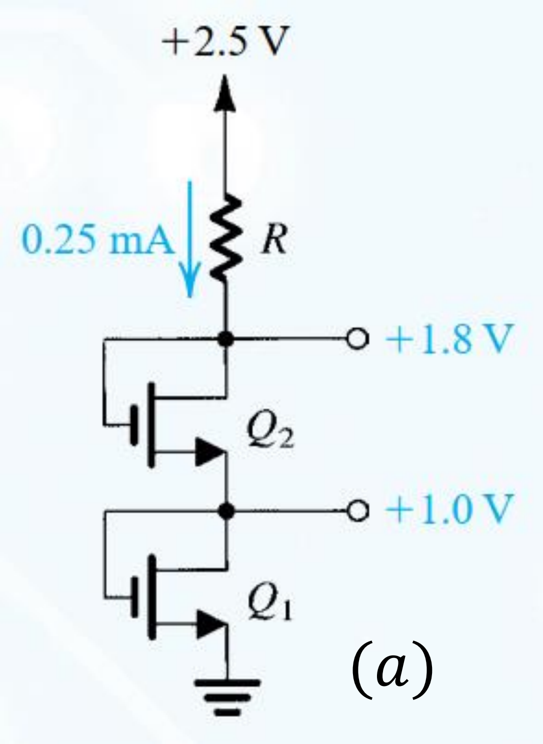
- The transistor in the following circuit is used to turn the LED on and off. The transistor parameters are $V_{Tn} = 0.6\,V$ and $k_n' = 80\ {}^{\mu A}/_{V^2}$. The diode cut-in voltage is $V_{D_o} = 1.6\,V$. Design R_D and transistor width-to-length $\left(\frac{W}{L}\right)$ ratio such that $I_D = 12\,mA$ for $V_I = 5\,V$ and $V_{DS} = 0.15\,V$.



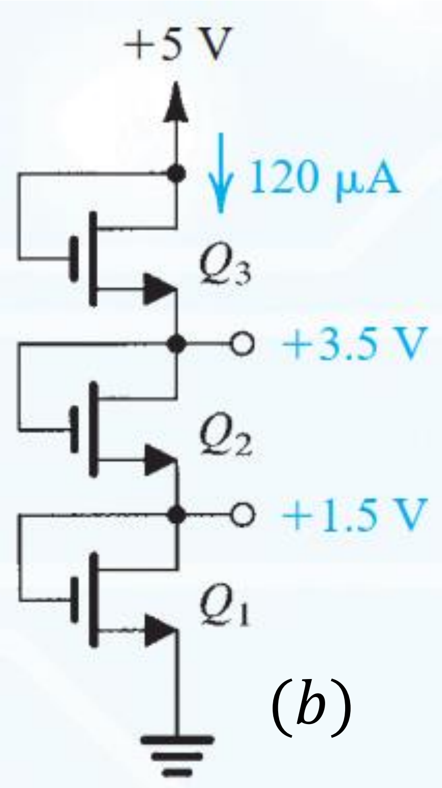
Ans: $\boldsymbol{R_D = 0.27\ k\Omega}$, $\boldsymbol{\left(\frac{W}{L}\right) = 15.5}$

Problem 19

- The transistors in the following circuits has parameters $V_{Tn} = 0.5\,V$, $k_n' = \mu_n C_{oc} = 250\ {}^{\mu A}/_{V^2}$, and $L = 0.25\,\mu m$. Determine the required values of gate width for each of the transistors.



(a)



(b)

Ans: $(\mathbf{a})\ \boldsymbol{W_{Q_2} = 2.77\ \mu m, W_{Q_1} = 1\ \mu m};\ (\boldsymbol{b})\ \boldsymbol{W_{Q_3} = 0.12\ \mu m, W_{Q_2} = 0.053\ \mu m, W_{Q_1} = 0.12\ \mu m}$

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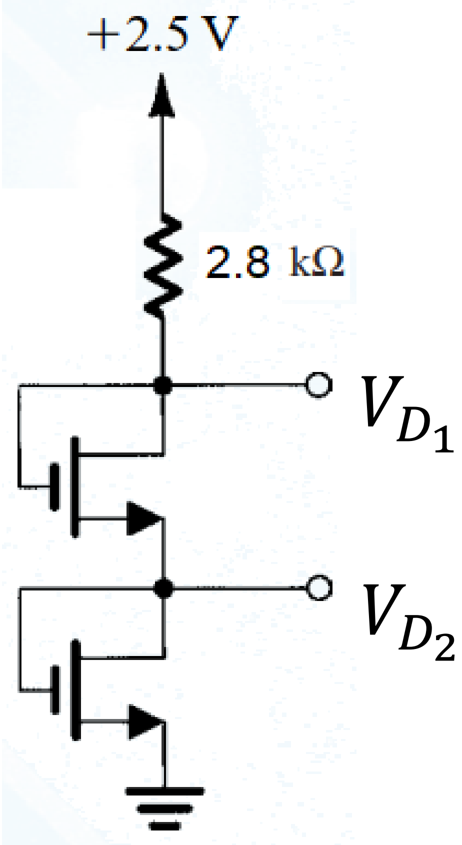
Problem 20

- For the transistors in the following circuit, $V_{Tn} = 1\ V$ and $k_n = k_n' \frac{W}{L} = 5\ {}^{mA}/_{V^2}$. Determine V_{D_1} and V_{D_2}.

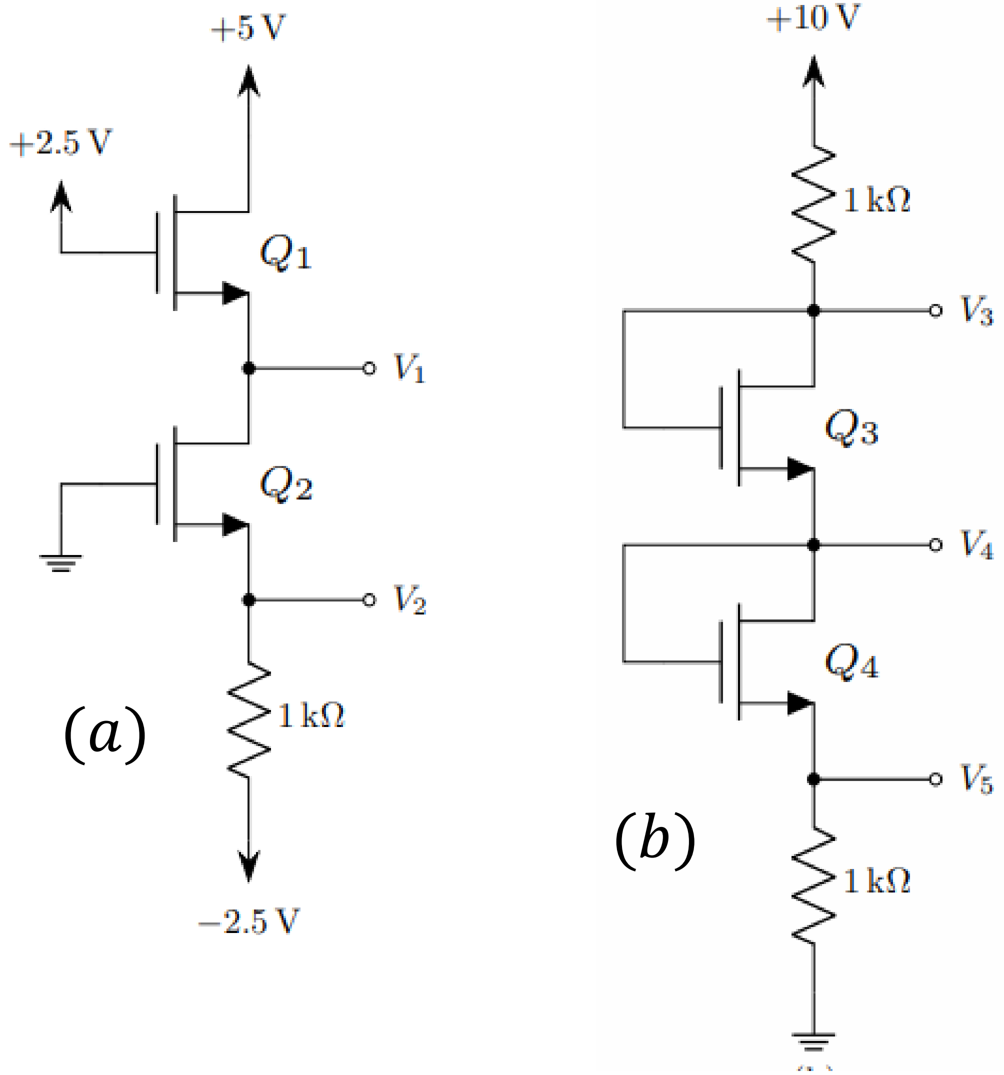


Ans: $\boldsymbol{V_{D_1} = 2.32\ V, V_{D_2} = 1.16\ V}$

Problem 21

- For the transistors in the following circuits, $V_{Tn} = 1\ V$ and $k_n = k'_n \frac{W}{L} = 2\ {}^{mA}/_{V^2}$. Determine V_1 through V_5.

[Hint: Form simultaneous equations consisting of voltage variables for circuit in (b).]

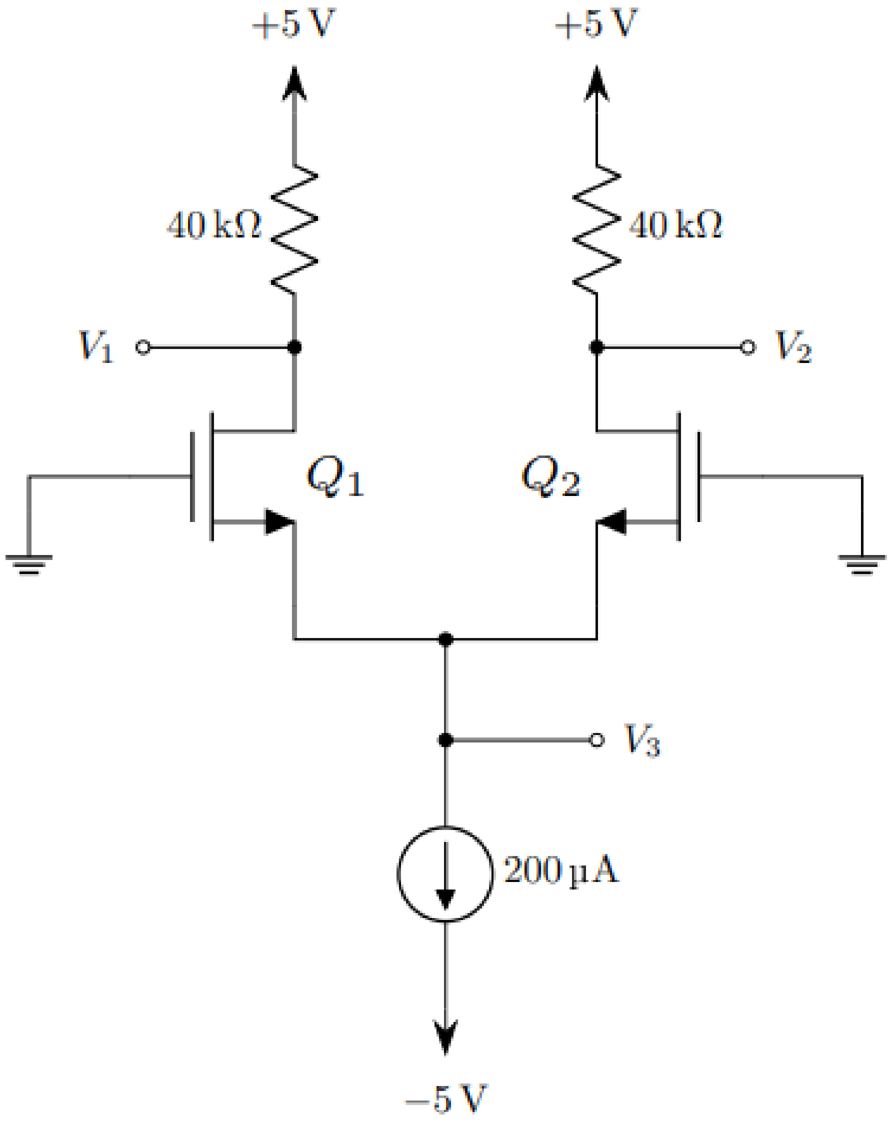


Ans: $(\boldsymbol{a})$ $\boldsymbol{Both\ in\ sat, V_1 = 4.5625\ V, V_2 = 0.75\ V}$

Ans: $(\boldsymbol{b})$ $\boldsymbol{All\ in\ sat, V_3 = 7.55\ V, V_4 = 5\ V, V_5 = 2.45\ V}$

Problem 22

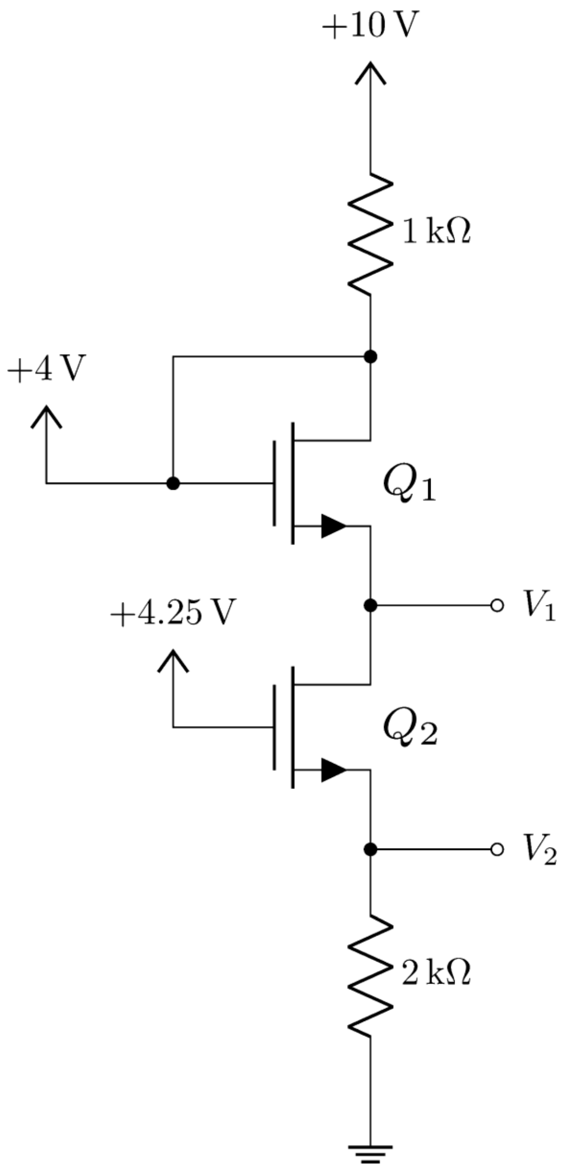
- For the transistors in the following circuits, $V_{Tn} = 1\ V$, $k_n' = 10\ {}^{\mu A}/_{V^2}$, and $\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = 20$. Determine V_1 through V_3.



Ans: $\boldsymbol{V_1 = V_2 = 1\ V, V_3 = 0\ V}$

Problem 23

- For the transistors in the following circuits, $V_{Tn} = 1\ V$ and $k_n = k'_n \frac{W}{L} = 100\ ^{\mu A}/_{V^2}$. Determine V_1 and V_2.



Ans: $\boldsymbol{Both\ in\ sat, V_1 = 5.95\ V, V_2 = 0.295\ V}$