Student Number & Name: ______________________________

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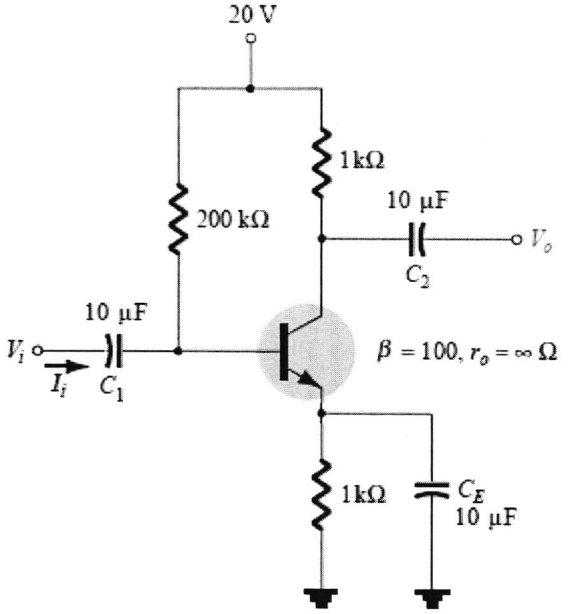
ES2032 Electronics Final

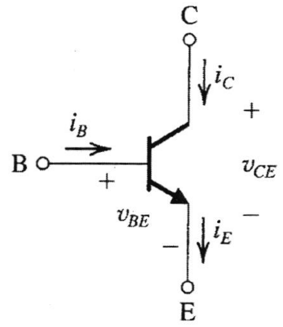
June 12, 2019

1) For the network, find the DC currents I_B, I_E, and the DC voltage V_{CE}.



Hint: npn transistor equations in active mode are:

$i_C = \beta i_B \qquad v_{BE}=0.7$



$$20 = 200K \cdot I_B + 0.7 + 1K \cdot \underbrace{101 \cdot I_B}_{I_E}$$

$\Rightarrow I_B = 0.064\ mA$

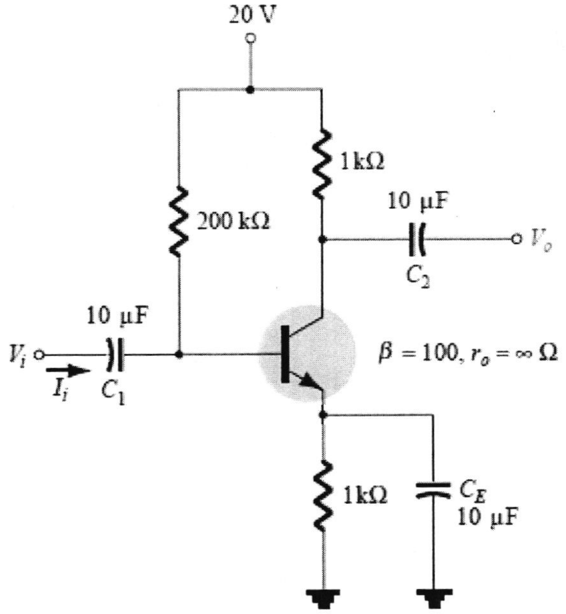
$\Rightarrow I_E = 6.48\ mA$

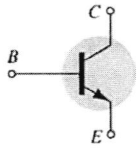
$$20 = 1K \cdot \underbrace{100 \cdot I_B}_{I_C} + V_{CE} + 1K \cdot I_E$$

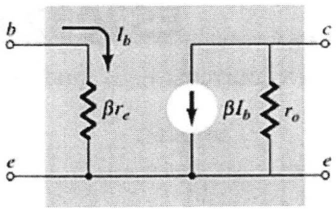
$\Rightarrow V_{CE} = 7.1\ V.$

Note: Total time allowed is 100 min. No calculators. Please show all your work and write legibly.

2) For the network shown, assume $r_e = 4\ \Omega$. Draw the ac equivalent network, and find the voltage gain V_o/V_i.



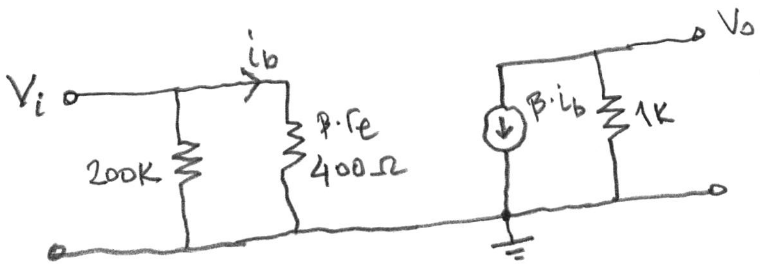




r_e model

$$I_e = (\beta + 1) I_b$$

$$r_e = \frac{26\,\text{mV}}{I_e}$$

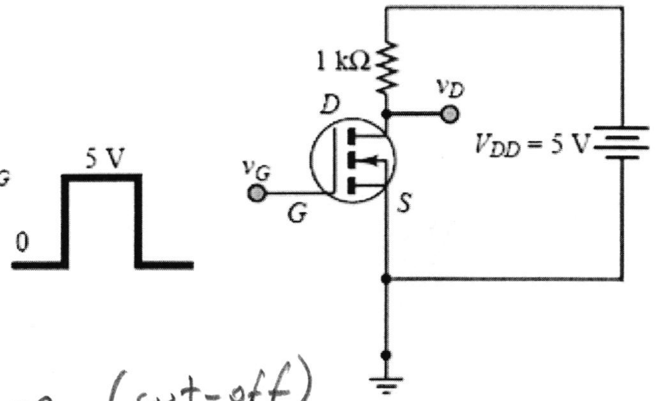


$$i_b = \frac{V_i}{\beta \cdot r_e}$$

$$V_o = -1K \cdot \beta \cdot i_b$$

$$\Rightarrow \frac{V_o}{V_i} = -\frac{1K}{r_e} = -250$$

3) The NMOS transistor shown in the figure has $V_{GS(Th)} = 2.5$ V, $k = 1$ mA/V^2. If v_G is a pulse with 0 V to 5 V, find the voltage levels of the pulse signal at the drain output. (That is; find v_D for $v_G = 0$ and for $v_G = 5$ V)



For $V_G = V_{GS} = 0 \Rightarrow I_D = 0$ (cut-off)

$V_D = 5 - 1K \cdot I_D = 5$

For $V_G = V_{GS} = 5$ V :

Assume saturation first: $I_D = K \cdot (5-2.5)^2 = 6.25$ mA

$\Rightarrow V_D = V_{DS} = 5 - 1K \cdot I_D = -1.25$ V

which is impossible ($V_{DS} < V_{GS} - V_{GS(Th)}$)

Assume Ohmic region:

$I_D = k \cdot [2(5-2.5)V_D - V_D^2]$

and from the circuit $I_D = \frac{5-V_D}{1K}$

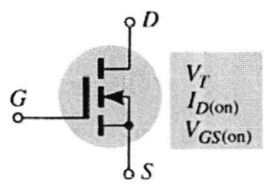
$\Rightarrow 5 - V_D = 5V_D - V_D^2$

$\Rightarrow V_D = 1$ (the other root, 5, is not valid.)

$I_D = 4$ mA .

- If $V_{GS} < V_{GS(Th)}$, the NMOS is in cut-off, $I_D = 0$. Otherwise:
  - If $V_{DS} < V_{GS} - V_{GS(Th)}$, the NMOS is in Triode (Ohmic) region, in this case:
    $$I_D = k\left[2\left(V_{GS} - V_{GS(Th)}\right)V_{DS} - V_{DS}^2\right]$$
  - If $V_{DS} >= V_{GS} - V_{GS(Th)}$, the NMOS is in Saturation region, in this case:
    $$I_D = k\left(V_{GS} - V_{GS(Th)}\right)^2$$

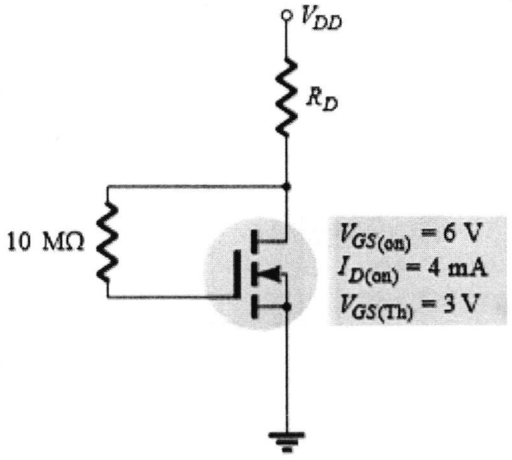
$I_G = 0$ A, $I_D = I_S$



$I_D = k(V_{GS} - V_{GS(Th)})^2$

$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$

4) For the network shown, we need $V_{DS} = V_{DD}/2$, and $I_D = 1$ mA. Determine V_{DD} and R_D.



$$k = \frac{4\text{mA}}{(6-3)^2} = \frac{4}{9}\ \text{mA/V}^2$$

Since $V_{DS} = V_{GS}$, NMOS is in saturation.

$$I_D = k \cdot (V_{GS} - V_{GS(Th)})^2$$

$$1 = \frac{4}{9}(V_{GS} - 3)^2$$

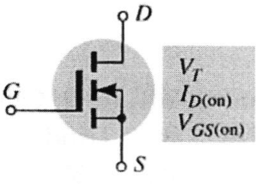
$$\Rightarrow V_{GS} = V_{DS} = 4.5\ \text{V}.$$

$$\Rightarrow V_{DD} = 2 \cdot 4.5 = 9\ \text{V}.$$

$$R_D = \frac{V_{DD} - V_{DS}}{I_D} = \frac{9-4.5}{1} = 4.5\ \text{k}\Omega$$

- If $V_{GS} < V_{GS(Th)}$, the NMOS is in cut-off, $I_D = 0$. Otherwise:
  - If $V_{DS} < V_{GS} - V_{GS(Th)}$, the NMOS is in Triode (Ohmic) region, in this case: $I_D = k[2(V_{GS} - V_{GS(Th)})V_{DS} - V_{DS}^2]$
  - If $V_{DS} >= V_{GS} - V_{GS(Th)}$, the NMOS is in Saturation region, in this case: $I_D = k(V_{GS} - V_{GS(Th)})^2$

$I_G = 0$ A, $I_D = I_S$



$$I_D = k(V_{GS} - V_{GS(Th)})^2$$

$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$