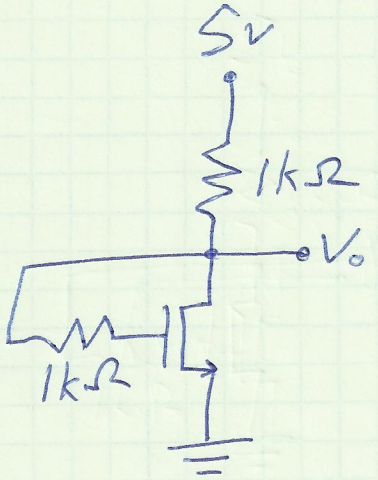
Question 1



assume cut-off

$i_D = 0 \rightarrow V_{GS} = 5v > V_t$

not cut-off

assume saturation

$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_T)^2$

$i_D = \frac{1}{2} \cdot 1 \cdot (V_{GS} - 1)^2$

$V_{GS} = V_{DS} = 5v - 1k \cdot i_D$

$5 - V_{DS} = \frac{1}{2}(V_{DS} - 1)^2$

$10 - 2V_{DS} = V_{DS}^2 - 2V_{DS} + 1$

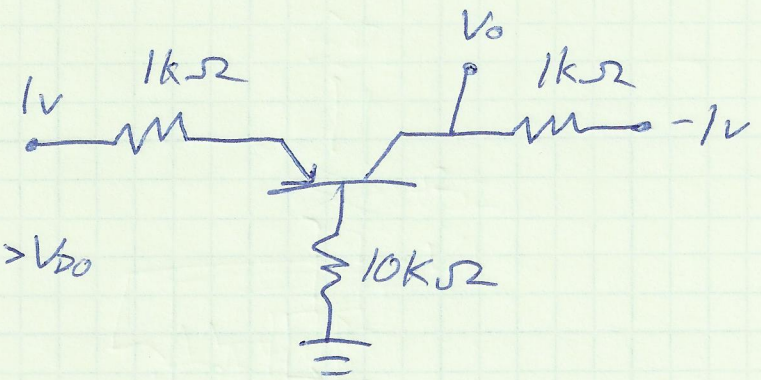
$V_{DS}^2 = 9$

$V_{DS} = \pm 3$, but $-3v$ is unphysical

$\boxed{V_o = 3V}$

$V_{DS} = V_{GS} > V_{GS} - V_T \rightarrow$ transistor must be in saturation mode

Question 2



assume cut-off

$i_B = 0, i_C = 0 \rightarrow V_{EB} = 1V > V_{DO}$

not in cut-off

assume active

$$1V - 1k\cdot(\beta+1)i_B - 0.7V - 10k\cdot i_B = 0$$

$$0.3V - 111k\, i_B = 0$$

$$i_B = \frac{0.3V}{111k} = 2.7\mu A$$

$$i_C = \beta i_B = 0.27mA$$

$$1V - 1k\cdot 0.27mA - V_{EC} - 1k\cdot 0.27mA + 1V = 0$$

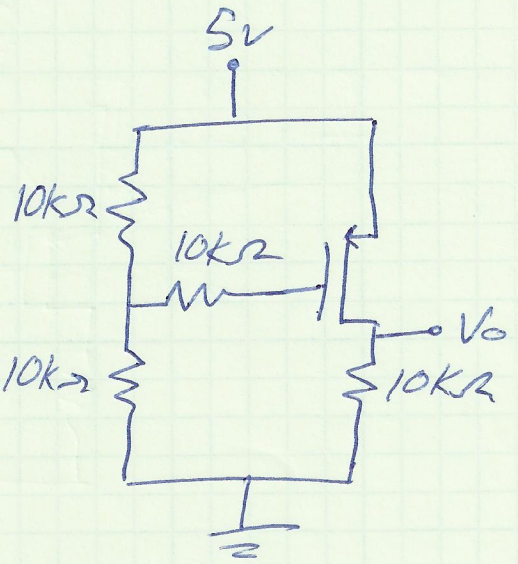
$$2 - 2\cdot 0.27 = V_{EC} = 1.46V > V_{DO}$$

→ transistor is in active mode

$$V_o = -1V + 1k\cdot 0.27mA$$

$$\boxed{V_o = -0.73V}$$

Question 3



$V_G = \frac{5}{2} = 2.5v$

$V_{SG} = 5 - 2.5 = 2.5v > |V_t|$

transistor not in cut-off

assume saturation

$i_D = \frac{1}{2} k_p' \frac{W}{L} (V_{SG} - |V_t|)^2$

$i_D = \frac{1}{2} \cdot 1mA \cdot (2.5-1)^2 = 1.1mA$

$V_{SD} = 5v - 10k \cdot 1.1mA = 5 - 11 = -6 volts \rightarrow$ unphysical

transistor not in saturation

assume triode

$i_D = \frac{1}{2} k_p' \frac{W}{L} [2V_{SD}(V_{SG} - |V_t|) - V_{SD}^2]$

$5v - V_{SD} - 10k \cdot i_D = 0$

$\frac{5 - V_{SD}}{10} = \frac{1}{2} \cdot 1 \cdot [2V_{SD} \cdot 1.5 - V_{SD}^2]$

$10 - 2V_{SD} = 30V_{SD} - 10V_{SD}^2$

$10V_{SD}^2 - 32V_{SD} + 10 = 0$

unphysical

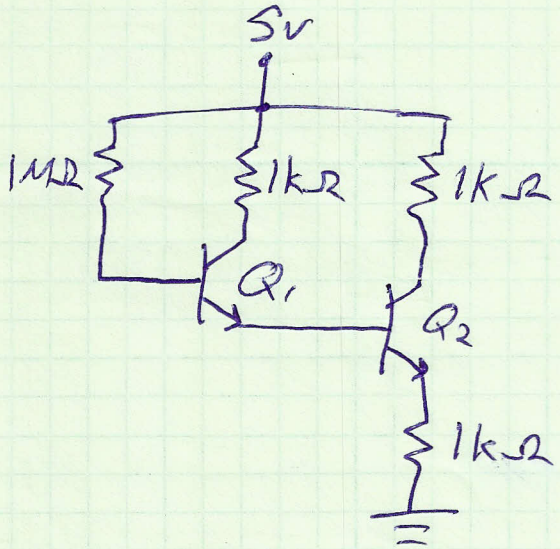
$V_{SD} = \frac{32 \pm \sqrt{32^2 - 400}}{20} = 0.35v \text{ or } 2.85v$

$V_o = 5v - 0.35v$

$\boxed{V_o = 4.65v}$

transistor is in triode mode because we have ruled out cut-off and saturation

Question 4



cut-off for both transistors is unlikely because if $i_{B1}=0$, $i_{B2}=0$, then $V_{BE1}+V_{BE2}=5V>V_{D0}$

assume Q_1 and Q_2 active

$5-1M\cdot i_{B1}-0.7-0.7-1k\cdot i_{C2}=0$, $i_{C2}=\beta i_{B2}=\beta i_{C1}=\beta^2 i_{B1}$

$5-1M\, i_{B1}-1.4-1k\cdot\beta^2 i_{B1}=0$

$i_{B1}=\dfrac{5-1.4}{1M}=0.33\mu A$

$i_{C1}=\beta i_{B1}=33\mu A=i_{B2}$

$i_{C2}=\beta i_{B2}=3.3mA$

$V_{CE2}=5-1k\cdot 3.3mA-1k\cdot 3.3mA=-1.6v \longrightarrow$ unphysical

assume Q_2 in saturation

$i_{C2}=\dfrac{5v-0.2v}{2k}=2.4mA$

$V_{E2}=1k\cdot 2.4mA=2.4v$

$V_{E1}=V_{E2}+V_{D0}=2.4v+0.2v$

$V_{E1}=3.1v$

$V_O=V_{E2}+V_{CE2}=2.4v+0.2v$

$\boxed{V_O=2.6v}$

$i_{B1}=\dfrac{5v-0.7v-3.1v}{1M}=1.2\mu A$, $i_{C1}=\beta i_{B1}=120\mu A$

$V_{CE1}=5v-3.1v-1k\cdot 120\mu A=1.78v>V_{D0}$

so Q_1 is in active mode

$\dfrac{i_{C2}}{i_{B2}}=\dfrac{2.4mA}{120\mu A}=20<\beta$ so Q_2 is in saturation mode