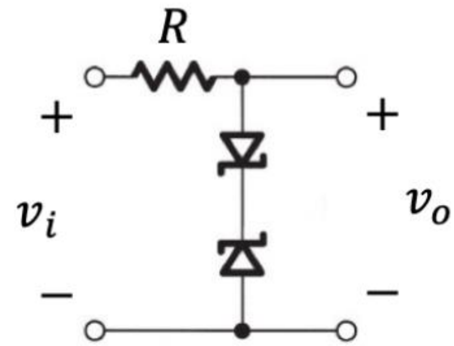
Problem1:

(a)



(1) $V_{D1} = on, V_{D2} = Zener\ region$

(2) $V_{D1} = Zener\ region, V_{D2} = on$

(3) $V_{D1} = off, V_{D2} = off$

(b)

Case1: $\boldsymbol{V_{D1} = on, V_{D2} = Zener}$

$V_{D1} = V_{Do}, V_{D2} = -V_Z$

$V_o = V_{D1} - V_{D2} = V_{D0} + V_Z = 0.7 + 2.3 = 3V$

$V_i = V_R + V_o = iR + V_0 = iR + 3V$

$\rightarrow i = \dfrac{V_i - 3V}{R} \geq 0$

$\rightarrow V_i - 3V \geq 0$

$\rightarrow V_i \geq 3V$

So, when $V_i \geq 3V$, $V_o = 3V$

Case2: $\boldsymbol{V_{D1} = Zener, V_{D2} = on}$

$V_{D1} = -V_Z, V_{D2} = V_{Do}$

$V_o = V_{D1} - V_{D2} = -V_Z - V_{Do} = -2.3 - 0.7 = -3V$

$V_i = V_R + V_o = iR + V_0 = iR - 3V$

$\rightarrow i = \dfrac{V_i + 3V}{R} \leq 0$

$\rightarrow V_i + 3V \leq 0$

$\rightarrow V_i \leq -3V$

So, when $V_i \leq -3V$, $V_o = -3V$

Case3: $\boldsymbol{V_{D1} = off, V_{D2} = off}$

$-2.3V < V_{D1} < 0.7V, \ -2.3V < V_{D2} < 0.7V$

$V_o = V_i - V_R = V_i - iR = V_i \quad \because i = 0\ (no\ current\ flows)$

$V_i = V_R + V_o = iR + V_{D1} - V_{D2} = 0 + V_{D1} - V_{D2}$

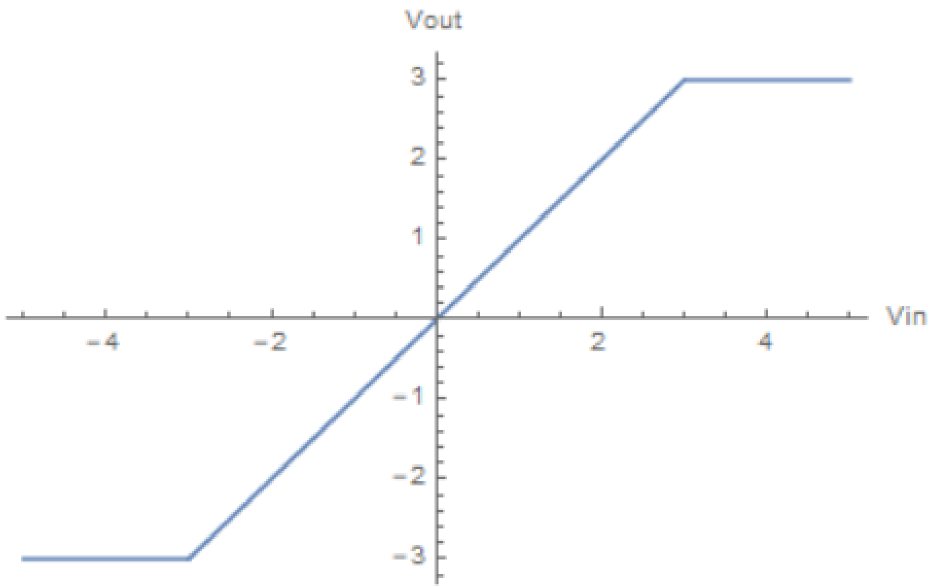
$\because \quad -2.3V < V_{D1} < 0.7V,$

$and - 0.7V < -V_{D2} < 2.3V$

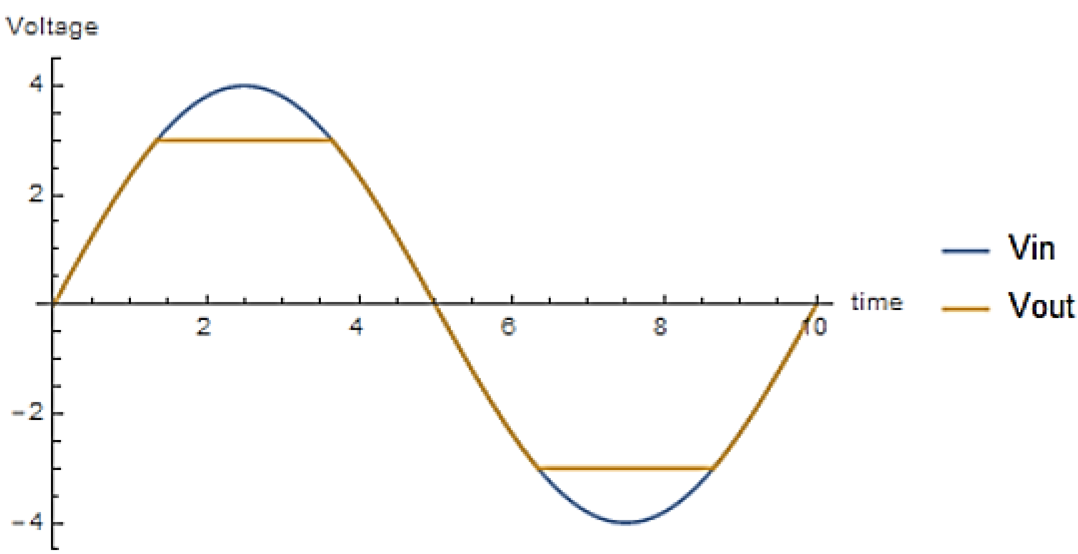
$\therefore -3V < V_{D1} - V_{D2} < 3V$

$\rightarrow -3V < V_i < 3V$

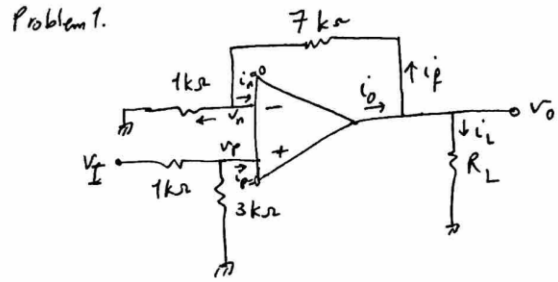
So, when $-3V < V_i < 3V$, $V_o = V_i$



(c)



Problem2:



a) ideal op-amp : $i_n = i_p = 0$, negative feedback is present $\Rightarrow v_n = v_p$

KCL at the inverting node:

$$\frac{v_n}{1k} + \frac{v_n - v_o}{7k} = 0 \longrightarrow \frac{v_o}{7k\Omega} = \left(\frac{1}{1k} + \frac{1}{7k}\right) v_n$$

$$\longrightarrow V_o = \left(1 + \frac{7k\Omega}{1k\Omega}\right) v_n$$

$$\xrightarrow[v_n = v_p]{} \quad v_o = \frac{3}{4}(1 + 7) v_I = 6\ v_I$$

$$v_p = \frac{3k\Omega}{3k\Omega + 1k\Omega} \times v_I$$

$$\longrightarrow \boxed{V_o = 6\ v_I}$$

b) checking the positive peak of $v_I = 2V$:

@ $V_I = 2V$: $V_o = 6 \times 2 = 12V < V_{sat}$ $\Rightarrow$ we are not limited by the saturation voltage for the max positive v_I.

@ $V_I = 2\,V$: $\quad i_o = i_L + i_f$

$i_L = \dfrac{v_o}{R_L} = \dfrac{12V}{1k\Omega} = 12\,mA$, $\quad i_f = \dfrac{v_o}{8k\Omega} = \dfrac{12V}{8k\Omega} = 1.5\,mA$

$i_o = 12\,mA + 1.5\,mA = 13.5\,mA < 25\,mA \longrightarrow$ we are not limited by the max output current for the max positive v_I.

checking the negative peak of $v_I = -3\,V$:

@ $V_I = -3\,V \longrightarrow V_o = 6 \times (-3) = -18V$ and $|-18V| > |V_{sat}|$

$\Rightarrow$ we are limitted by the saturation voltage for the max negative v_I.

Cannot go below $V_{sat} = -16V$

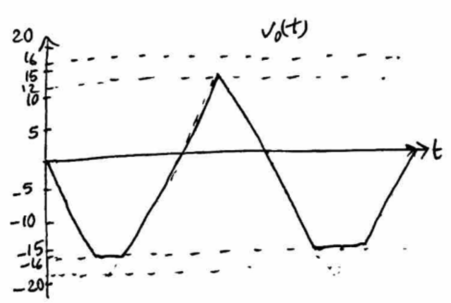
Ch $\Rightarrow v_{out}$

checking for the max output current at $V_{out} = -16\,V$:

$i_o = i_L + i_f$, $\quad i_L = \dfrac{V_o}{R_L} = \dfrac{-16V}{1k} = -16\,mA$

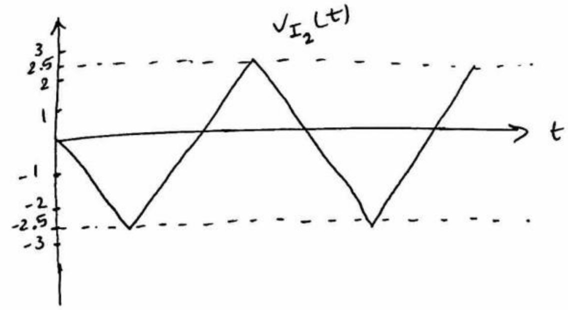
$i_f = \dfrac{-16V}{8k\Omega} = -2\,mA \longrightarrow i_o = -16mA - 2mA = -18\,mA$

$|i_o| < |i_{omax}|$



c)

i)



ii)

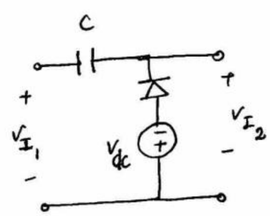
The max positive and negative values of v_I are 2.5V and -2.5V

For $|v_I| = 2.5V \longrightarrow |v_o| = 2.5 \times 6 = 15V$

$$\left|i_{o_{max}}\right| = \frac{|v_{o_{max}}|}{R_{L_{min}}} + \frac{|v_{o_{max}}|}{8k\Omega} = \frac{15V}{R_{L_{min}}} + \frac{15V}{8k\Omega} = \frac{15V}{R_{L_{min}}} + \underset{(mA)}{1.875} = 25mA$$

$$\frac{15V}{R_{L_{min}}} = 23.125mA \longrightarrow R_{L_{min}} \simeq 649\,\Omega$$

iii)



Assume using a diode with $v_{D_0} = 0.7V$

$v_{I_2} = v_{I_1} + (v_p - v_{DC} - v_{D_0})$

$v_{I_2} = v_{I_1} + 0.5V$

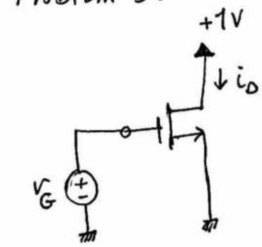
$\longrightarrow v_p - v_{DC} - v_{D_0} = 0.5V$

$3V - v_{DC} - 0.7V = 0.5V$

$\boxed{v_{DC} = 1.8V}$

Problem3:

Problem 3.



a&b) when $v_G < v_t \longrightarrow$ Mos is off $i_D = 0$

$V_G = V_{GS}$, $V_D = V_{DS} = 1V$

when

$V_{GS} - V_t \leqslant V_{DS} \longrightarrow$ Mos is in saturation

$0.5V \leqslant V_G \leqslant 1V + 0.5V \rightarrow 0.5V \leqslant V_G \leqslant 1.5V$ Mos is in saturation

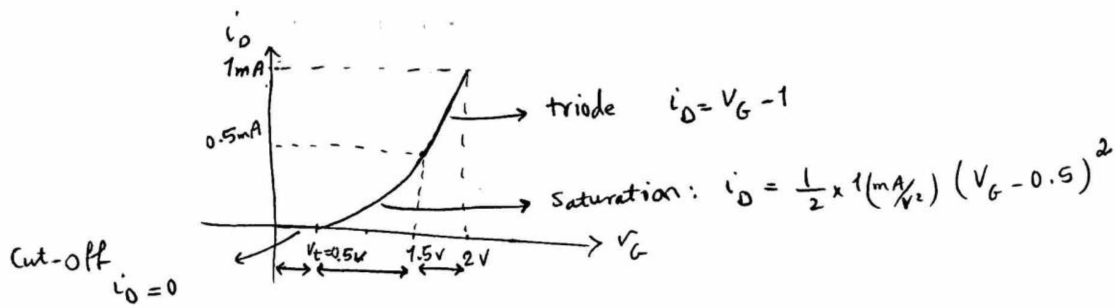
$$i_D = \frac{1}{2} k_n \left(V_{GS} - V_t\right)^2 = \frac{1}{2} \times 1 \left(mA/V^2\right) \times \left(V_G - 0.5\right)^2$$

when

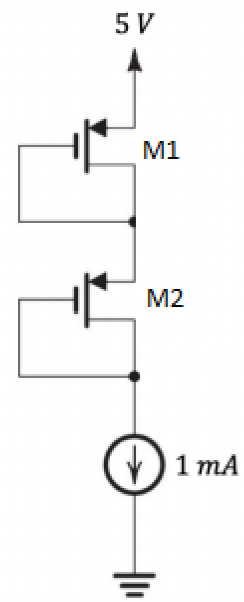
$v_G > 1.5v \longrightarrow$ Mos is in triode:

$$i_D = \frac{1}{2} k_n \left(2V_{ov} V_{DS} - V_{DS}^2\right) = \frac{1}{2} \times 1\, mA/V^2 \left(2 \times (V_G - 0.5) - 1\right)$$

$$i_D = V_G - 1$$



Problem4:



Both MOS are in saturation since $V_{DG1} = V_{DG2} = 0 < |V_t|$.

Here, $V_{G1} = V_{D1} = V_{S2}, V_{G2} = V_{D2}$ and $I_{D1} = I_{D2} = I_D = 1mA$.
Then,

$$V_{OV1} = V_{OV2} \Rightarrow 4 - V_{S2} = V_{S2} - V_{D2} - 1 = \sqrt{\frac{2I_D}{\mu C_{ox}\frac{W}{L}}} = 1\,V$$

(a)

$$V_{G1} = V_{D1} = V_{S2} = 3V$$

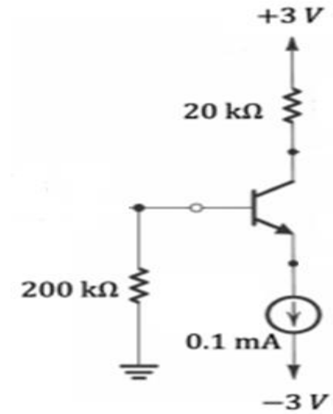
$$V_{G2} = V_{D2} = 1V$$

(b) As same current is flowing through the MOSs', V_{S2} remains same. Then

$$R = \frac{V_{S2}}{I_D} = 1k\Omega$$

Problem5:

$\beta = 100, V_{Do} = 0.7\,V, V_T = 25\,mV$



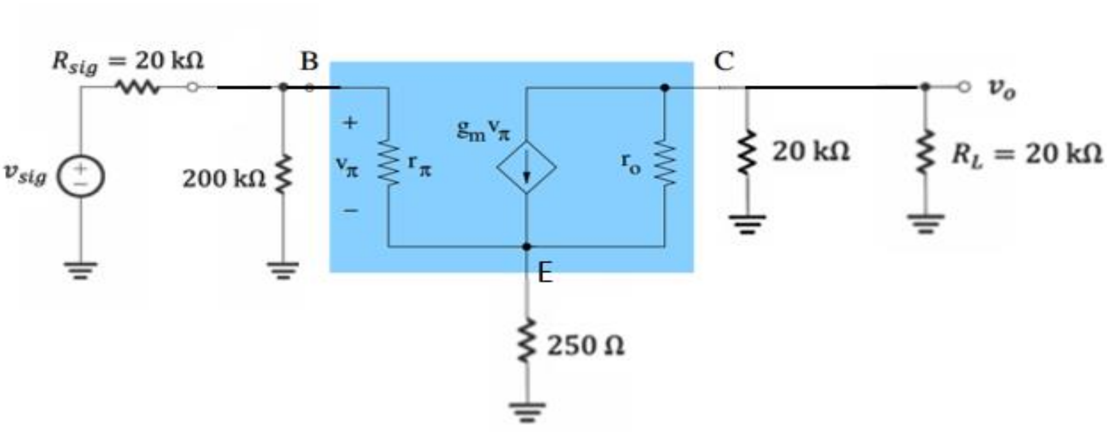
(a) Due to current source, $I_E = 0.1\,mA$
Assuming BJT is in active mode.
Then, $V_{BE} = V_{Do} = 0.7\,V$ and

$$I_C = \frac{\beta}{\beta+1} I_E = I_E - I_B = 99.01\,\mu A$$
$$I_B = \frac{I_C}{\beta} = \frac{I_E}{\beta+1} = I_E - I_C = 0.99\,\mu A$$
$$V_B = -I_B \times 200k = -0.198\,V \approx -0.2\,V$$
$$V_E = V_B - V_{BE} = -0.898\,V \approx -0.9\,V$$
$$V_C = 3 - I_C \times 20k = 1.0198\,V \approx 1.02\,V$$

Now,
$$V_{CE} = 1.92V \Rightarrow Correct\ assumption$$

(b) Small signal parameters:
$$g_m = \frac{I_C}{V_T} = 3.9604\frac{mA}{V} \approx 3.96\frac{mA}{V}$$
$$r_\pi = \frac{\beta}{g_m} = 25.25\,k\Omega$$
$$r_o = \frac{|V_A|}{I_C} = \frac{\infty}{I_C} = \infty\,\Omega$$

(c) Small signal equivalent circuit:



(d) CE with R_E amplifier.

$$R_i = R_B \parallel \left[R_E + r_\pi + \frac{\beta R_E}{1 + \frac{[R_E + R_C \parallel R_L]}{r_o}} \right] = 200k \parallel [101 \times 0.25k + 25.25k\,] = 40.32\,k\Omega$$
$$R_o = R_C \parallel \left[r_o\left(1 + g_m(r_\pi \parallel R_E)\right)\right] = 20\,k\Omega$$
$$A_{vo} = \frac{-R_C}{R_E + \left(1 + \frac{R_C}{r_o}\right)\frac{R_E + r_\pi}{\beta}} = \frac{-20k}{0.25k + \frac{0.25k + 25.25k}{100}} = -39.6\,V/V$$
$$A_v = A_{vo} \times \frac{R_L}{R_o + R_L} = -19.8$$

$$A = A_v \times \frac{R_i}{R_i + R_{sig}} = -13.235$$

(e) $v_{b,max} = 10\ mV$

$$v_{sig,max} = v_{b,max} \times \frac{R_i + R_{sig}}{R_i} = v_{b,max} \times \frac{A_v}{A} = 14.96\ mV$$

$$v_{o,max} = v_{sig,max} \times |A| = v_{b,max} \times |A_v| = 198\ mV$$