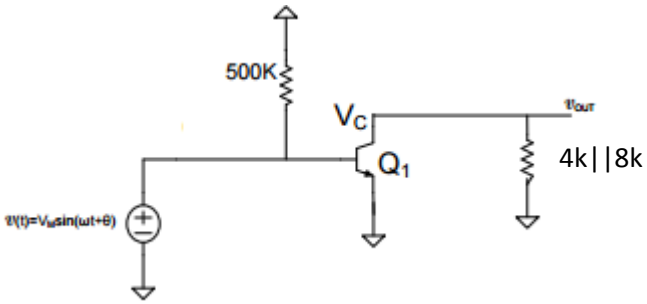
Problem 1

a)



b) $V_{cq} = 10V - (2k * I_{cq})$

$I_{cq} = \frac{\beta(10 - 0.6)}{500k} = 1.88\ mA$

$V_{cq} = 10V - (4k * 1.88m)$

$V_{cq} = 2.48V$

$V_{outq} = 0$

c)

$v_{out} = (-g_m v_{IN}) * (\frac{1}{g_o} // R_L)$

$A_v = \frac{v_{OUT}}{v_{in}} = -g_m\ (\frac{1}{g_o} || RL)$

d)

Approximate gain, $A_V = -g_m R_L$

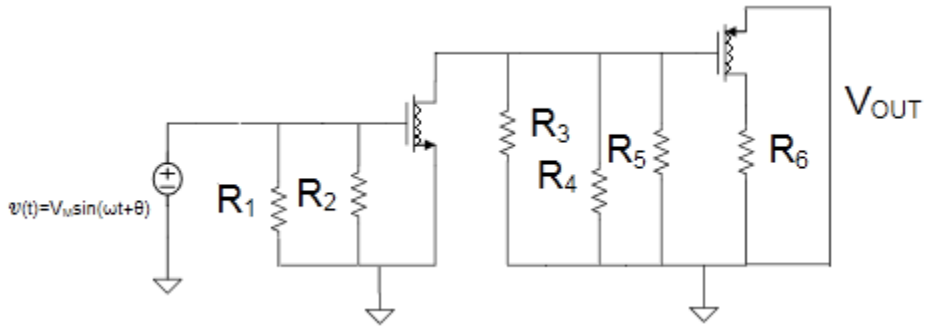
$A_V = -g_m(4k||8k) = -gm(2.6667k)$

$gm = \frac{I_Q}{V_t} = \frac{\beta(10 - 0.6)}{500k * 0.0259} = 0.0726V$

$A_V = -0.0726 * 2666.7$

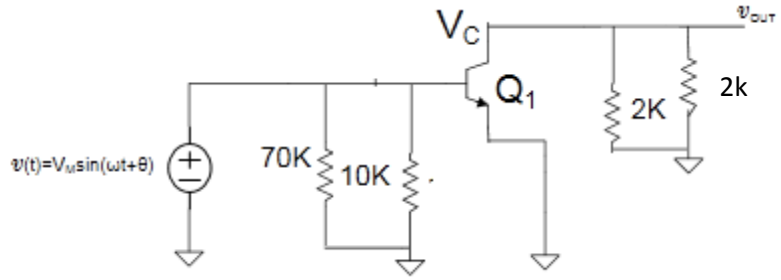
$A_V = -193.60$

Problem 2



Problem 3

a)



b) $V_B = 32 * \left(\frac{10}{10+70}\right) k = 4V$

$I_{CQ} = \frac{4 - 0.6}{2k} = 1.7\ mA$

$V_{CQ} = 32 - (2k)(I_{CQ})$

$V_{CQ} = 26.6V$

$V_{outq} = 0V$

c)

$v_{out} = (-g_m v_{IN}) * (\frac{1}{g_o} // R_L)$

$A_v = \frac{v_{OUT}}{v_{in}} = -g_m(\frac{1}{g_o} // R_L) \approx -g_m R_L$

d)

$A_v = \frac{I_{cq}R}{2v_t} = \frac{1000 * 0.0017}{2 * 0.0259} = 32.81\frac{V}{V}$

Problem 4

a)

$$y_{11} = \frac{dI_1}{dV_1} = V_2^2, \qquad y_{12} = \frac{dI_1}{dV_2} = 2V_1V_2$$
$$y_{21} = \frac{dI_2}{dV_1} = 0.04V_1V_2e^{2V_1^2V_2}, \qquad y_{22} = \frac{dI_2}{dV_2} = 0.02V_1^2e^{0.2V_1^2V_2}$$

b)

$$y_{11} = 1^2 = 1, \qquad y_{12} = 2(5)(1) = 10$$
$$y_{21} = 0.04(5)(1)e^{2(5^2)1} = 29.68, \qquad y_{22} = 0.02(5^2)e^{2(5^2)1} = 74.21$$

c)

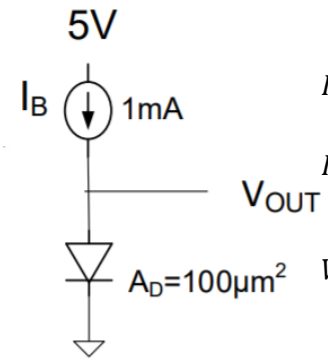
$$I_{1Q} = V_1V_2^2 = 5(1^2) = 5$$
$$I_2 = 0.02V_1^2e^{0.2V_1^2V_2} = 0.02(5^2)e^{2(5^2)1} = 14.8413$$

d)

$$i_1 = 1(1mV_{RMS}) + 10(2mV_{RMS}) = 21mV_{RMS}$$
$$i_2 = 29.68(1mV_{RMS}) + 74.21 = 178.10mV_{RMS}$$

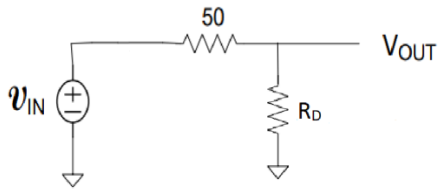
Problem 5

a.) DC equivalent circuit



$$I_{DQ} = 1mA, \qquad V_t = (8.615 * 10^{-5}) * (300) = 25.85mV$$
$$I_{DQ} = J_SA_De^{\frac{V_D}{Vt}} \rightarrow V_D = V_{OUT} = V_t * \ln\left(\frac{I_{DQ}}{J_SA_D}\right)$$
$$V_{OUT} = V_t(25.85mV) * \ln\left(\frac{1mA}{\frac{0.5fA}{\mu m^2} * 100\mu m^2}\right) = 0.613\ V$$

b.)



c.) $R_D = \frac{V_t}{I_{DQ}} = \frac{25.85mV}{1mA} = 25.85\ \Omega$

$$v_{out} = \frac{R_D}{R_D + 50\Omega} v_{in}$$

$$A_v = \frac{v_{out}}{v_{in}} = \frac{R_D}{R_D + 50\Omega} = \frac{25.85\Omega}{25.85\Omega + 50\Omega} = 0.34\ V/V$$

d.) $R_D = \frac{25.85mV}{5mA} = 5.17\ \Omega$

$$A_v = \frac{5.17\Omega}{5.17\Omega + 50\Omega} = 0.094\ V/V$$

Problem 5

$$I_2 = J_s A_{D2} e^{\frac{V_{OUT}}{Vt}} = \frac{0.5fA}{\mu m^2} * 100\mu m^2 * e^{\frac{V_{out}}{25.85mV}}$$

$$I_{D1} = \frac{0.5fA}{\mu m^2} * 300\mu m^2 * e^{\frac{V_{out}}{25.85mV}}$$

$$I_B = 1mA = I_{D1} + I_2$$

Solve system of equations

$I_2 = 250\ \mu A$

$V_{out} = 0.577\ V$

Problem 6

$$R_{ch} = \frac{L}{\mu_n C_{OX}(W)(V_{GS} - V_T)^2}$$

$$R_{ch(0)} = \frac{4}{350 * 10^{-6}(2 - 0.5)^2} = 5079.36$$

$$R_{ch(0.25)} = \frac{4}{350 * 10^{-6}(2.25 - 0.5)^2} = 3731.77$$

$$A_{V_0} = -\frac{15000}{5079.36} = 2.9531$$

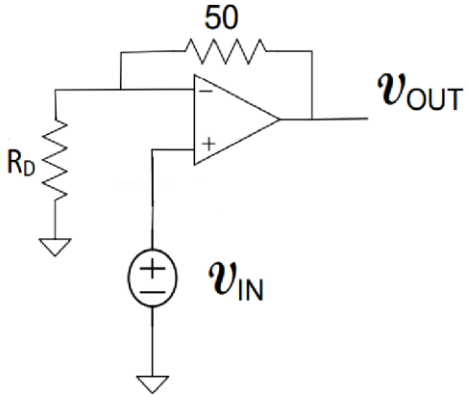
$$A_{V_{(0.25)}} = -\frac{15000}{3731.77} = 4.0195$$

$V_{0-p} = 4 * (2.9531)$ to $4 * (4.0195)$

$V_{0-p} = 11.812V$ to $16.078V$ sin wave.

Problem 7

a.) Small signal equivalent circuit



$$R_D = \frac{V_t}{I_{DQ}} = \frac{25.85mV}{1mA} = 25.85\ \Omega$$

$$A_v = 1 + \frac{50\ \Omega}{R_D} = 1 + \frac{50\ \Omega}{25.85\ \Omega} = 2.93\ V/V$$

b.) $R_D = \frac{25.85mV}{10mA} = 2.59\ \Omega$

$$A_v = 1 + \frac{50\ \Omega}{2.59\ \Omega} = 20.34\ V/V$$

Problem 8

MOSFET:

$$V * (g_m + g_o) = I \rightarrow R_{eq} = \frac{1}{(g_m + g_o)} \cong \frac{1}{g_m}$$

$$g_m = \sqrt{2 * \mu_n C_{ox} \left(\frac{W}{L}\right) * I_D} \rightarrow assume\ \left(\frac{W}{L}\right) = 6$$

$R_{eq} = 912.87\ \Omega$

BJT:

$$V * (g_m + g_\pi + g_o) = I \rightarrow R_{eq} = \frac{1}{(g_m + g_\pi + g_o)} \cong \frac{1}{g_m}$$

$$g_m = \frac{I_{CQ}}{V_t} = \frac{1\ mA}{26\ mV}$$

$R_{eq} = 26\ \Omega$

Problem 9

a) For the MOSFET to be in saturation $V_{DS} \geq V_{GS} - V_T$

$V_{out} + 2 \geq 2 - 0.5 \rightarrow V_{out} \geq -0.5$

$I_D = \frac{\mu_n C_{OX} W}{2L}(V_{GS} - V_T)^2 = \frac{4 - V_{out}}{R_1}$

$100 * 10^{-6} * \left(\frac{18}{2 * 2}\right) * (2 - 0.5)^2 = \frac{4 - V_{out}}{R_1}$

$V_{out} = 4 - 0.0010125 * R_1 \geq 0.5V$

$\rightarrow R_1 \leq 3456.79\Omega$

b) $\frac{R_1}{3} = 1152.26$

$A_v = \frac{2I_{DQ}R}{V_{SS} + V_T} = \frac{2(0.0010125)(1152.26)}{-1.5} = -1.556$

c)

$V_{out}(t) = 1.556\sin(500t + 75^o)$

Problem 10

$V_{out} = (A_V V_M)\cos(\omega t + \theta)$

$A_V = -g_m\,(\frac{1}{g_o}||RL)$

$V_{out} = (-g_m R_L * V_M)\cos(\omega t + \theta)$

Problem 11

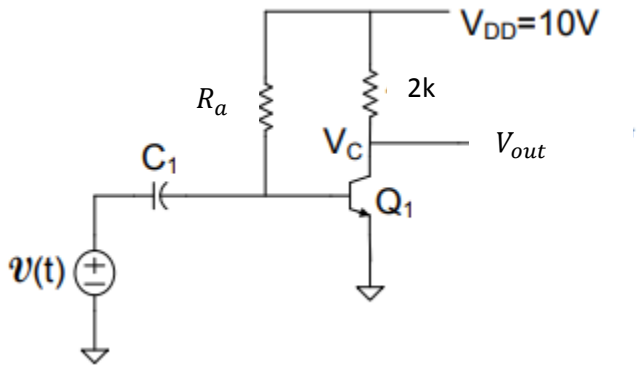
$\left(100 * 10^{-6}\left(\frac{10}{4}\right)(2 - 0.5)^2\right) = \left(30 * 10^{-6}\left(\frac{6}{2}\right)(5 - V_{out} - 0.5)^2\right) \rightarrow V_{out} = 2V$

$-g_m R_L = \frac{2I_{DQ}R_L}{V_{GS} - V_T} = \frac{2\left(\mu_n C_{OX}\left(\frac{W}{2L}\right)(V_{GS} - V_T)\right)\left(\frac{L}{\mu_P C_{OX}(W)(V_{GS} - V_T)^2}\right)}{2 - 0.5}$

$= \frac{2\left(100 * 10^{-6}\left(\frac{10}{4}\right)(2 - 0.5)^2\right)\left(\frac{1}{30 * 10^{-6}(6)(2 - 0.5)^2}\right)}{2 - 0.5} = \frac{2(0.0005625)(2469)}{1.5} = 1.85\frac{V}{V}$

$V_{out} = 1.85V_M\cos(\omega t + \theta)$

Problem 12



The gain for a BJT is

$$A_V = -\frac{I_{CQ}R_L}{V_t} = -\frac{I_{CQ}(2000)}{0.0259} = -5$$

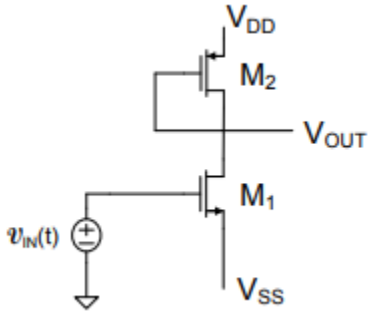
so there is only one real unknown, R_a,

$$-\frac{5(0.0259)}{2000} = I_{Cq} = 0.00006475$$

$$I_{BQ} = \frac{I_{CQ}}{100} = 64.75nA$$

$$\frac{10}{R_a} = 64.75nA \rightarrow \boxed{R_a = 154.4M\Omega}$$

Problem 13



$$A_V = \frac{-2I_{DQ}R_L}{V_{GS} - V_T}$$

Start by giving $I_{DQ} = 1mA$, $V_{SS} = -2V$, and $\boxed{L_1 = 10\mu}$, so

$$I_D = 300 * 10^{-6} * \frac{W}{2} * (2 - 0.5)^2 = 1mA \rightarrow \boxed{W_1 = 29.6\mu}$$

$$A_V = \frac{-2I_{DQ}R_L}{V_{GS} - V_T} = \frac{-2(0.001)R_L}{1.5} = -10 \rightarrow R_L = 7500\Omega$$

Then using $V_{DD} = 15V$ and $V_{out} = 15 - (1mA)(7.5k) = 7.5V$ set $\boxed{L_1 = 100\mu}$

$$R_L = \frac{10}{70 * 10^{-6}(W_2)(7.5 - 0.5)^2} = 7500 \rightarrow \boxed{W_2 = 3.8\mu}$$