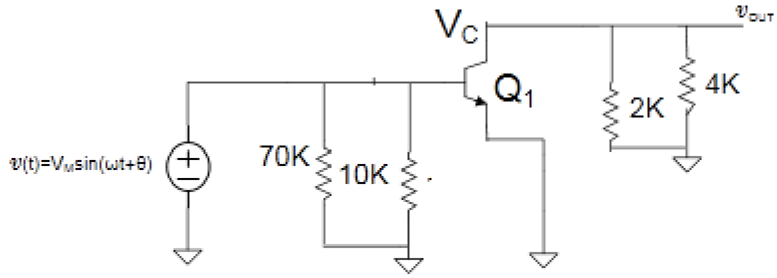
Problem 1:

a)



$$V_B = 32 * \left(\frac{10}{10+70}\right) k = 4V$$
$$I_{CQ} = \frac{4-0.6}{2k} = 1.7 \text{ mA}$$
$$V_{CQ} = 32 - (2k)(I_{CQ})$$
$$V_{CQ} = 28.6V$$
$$V_{outq} = 0V$$

$$A_V = -gm(R_L) = -\frac{I_{CQ}}{V_t} * R_L = -\frac{1.7 \text{ mA}}{25.9 \text{ mV}} * 1.33k$$

$$A_V = -87.3$$

j) $V_{out} = A_V V_{in} = -87.3 * 0.001 \sin(2000\pi t + \theta)$

$$V_{out} = -0.0873 \sin(2000\pi t + \theta)$$

Problem 2:

$$V_{out} = 10 - \left(10000 * i_{DQ}\right)$$
$$I_{DQ} = 350 * 10^{-6} * \left(\frac{8}{2*4}\right) * (0 - (-2) - 0.5)^2$$
$$I_{DQ} = 788\mu A$$
$$V_{out} = 2.125V$$

$$A_V = -g_{m1}R_1 = -\left(\mu C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)\right)R_1 = 350 * 10^{-6} * \left(\frac{8}{4}\right) * (1.5) * 10000 = -10.5$$

Problem 3:

$$I_{DQ} = \mu C_{ox}\left(\frac{W}{2L}\right)\left(V_{gs} - V_T\right)^2$$
$$I_{Dss} = -g_m * V_{in}(t)$$
$$g_m = \mu C_{ox}\left(\frac{W}{L}\right)\left(V_{gs} - V_T\right) = \frac{1.05\ \text{mA}}{\text{V}}$$
$$V_{out} = I_{Dss} * 20k$$
$$V_{out} = -0.525\ \sin(2\pi * 1000t)$$

Problem 4:

a) $I_D = \mu C_{ox}\left(\frac{W}{2L}\right)\left(V_{gs} - V_T\right)^2 = 0.394\ \text{mA}$

$$V_{ds} \geq V_{gs} - V_T$$
$$V_{ds} \geq 0.5$$
$$\rightarrow R_1 = \frac{4 - (-1.5)}{0.000394} = 13.97\ \text{k}\Omega$$

b) $A_V = -gmR_1 = -(0.004725)(4656) = -22$

c) $\frac{4 - V_D}{4656} = 0.000394$

$$V_{DQ} = 2.17\text{V}$$
$$V_D = V_{DQ} + A_V V_{in}(t)$$
$$V_D = 2.17 + 0.022\sin(5000t + 75^o)\ V$$

Problem 5:

a)

$$A_V = -g_{m1}R_1 = -\left(\mu C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)\right)R_1 = -8$$
$$\rightarrow \frac{W}{L} = 2.286$$

b)

Assume M_1 is in saturation

$$I_D = \mu C_{ox}\left(\frac{W}{2L}\right)(V_{GS} - V_T)^2 = \frac{4V - V_{outQ}}{R_1}$$

$V_{outQ} = 2.0\ \text{V}$

Verify: $V_{DS} = 3V > 0.5V = V_{GS} - V_T \rightarrow$ it is in saturation

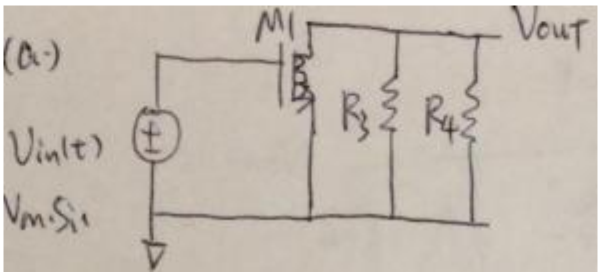
Problem 6:

Because M_2 is diode connected it can be modeled as $G_L = g_m + g_{02}$, because we can assume $g_{02} \approx 0$ we can say $G_L = g_m$. From this we can create the gain

$$A_V = -\frac{g_{m1}}{g_{m2}}$$

$$V_{out} = A_V V_{in} = -\frac{g_{m1}}{g_{m2}} V_m \cos(\omega t + \theta)$$

Problem 7:



b)

Assuming M_1 is working in saturation (W=8, L=12)

$$I_D = \mu C_{ox}\left(\frac{W}{2L}\right)(V_{gs} - V_T)^2 = \frac{V_{DD} - V_D}{R_3}$$

$I_D = 262.5\ \mu A$

$V_{DQ} = 2.375V$

$V_{OutQ} = 0V$

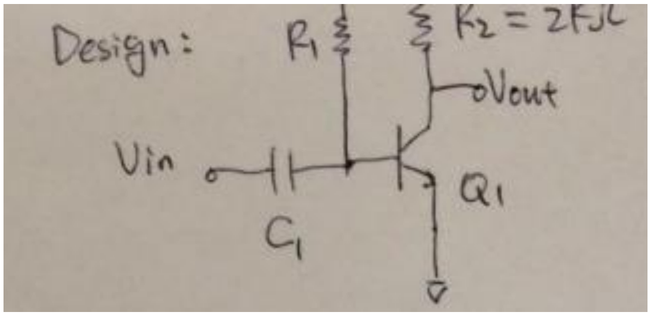
c) $A_V = -g_m(R_3||R_4) = \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right) I_D} * \frac{R_3 * R_4}{R_3 + R_4}$

$A_V = -2.92$

d) $V_{out} = A_v V_{in}(t)$

V_{out} =-58.4 $\sin(\omega t + \theta)\ mV$

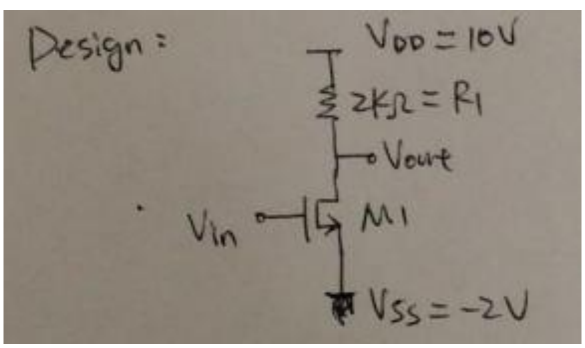
Problem 8:



$$A_V = -\frac{I_{CQ}R_2}{V_t} = -5$$
$$I_{CQ} = \frac{5 * 0.026}{2k\Omega} = 65\ \mathrm{uA}$$
$$I_{BQ} = \frac{I_{CQ}}{\beta} = 0.65\ \mu\mathrm{A}$$
$$\rightarrow R_1 = \frac{(10 - 0.6)\mathrm{V}}{0.65 * 10^{-6}\mathrm{A}} = 14.46\ \mathrm{M}\Omega$$

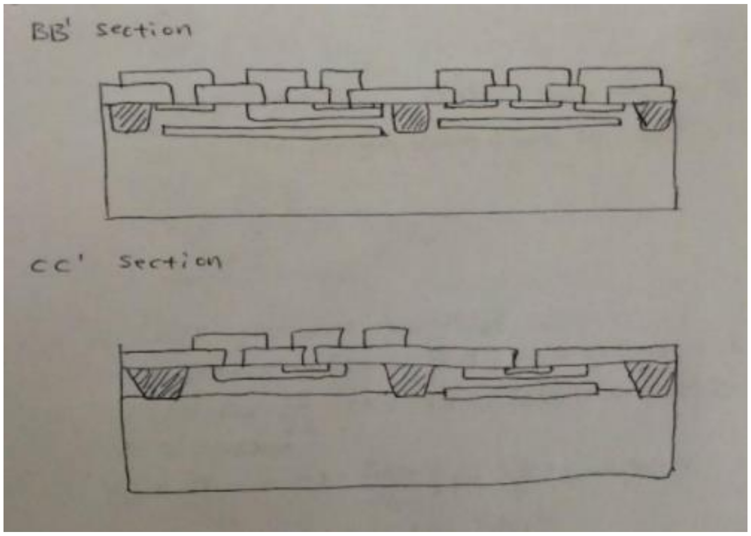
The emitter area has almost no effect on the gain of this circuit, so choose a convenient value of A_E such as $100\mu^2$

Problem 9:



$$A_V = -g_m R_1 = -10,\quad R1\ is\ 10K, not\ 2K$$
$$g_m = \frac{\mu_n C_{OX} W}{L}\left(V_{gs} - V_T\right)$$
$$\frac{W}{L} = \frac{10}{1}, W = 10\mu,\ \ L = 1\mu$$
$$I_D = \ \mu C_{ox}\left(\frac{W}{2L}\right)(V_{GS} - V_T\ )^2$$
$$I_D = 0.5\ \mathrm{mA}$$

Problem 10:



Problem 11:

a)

For saturation, $V_{BE} = 0.7\,V,\ V_{CE} = 0.2\,V, \rightarrow\ I_B = \frac{5-0.7}{1000} = 4.3\,mA \rightarrow I_C < \beta * I_B = 430\,mA$

$V_F = 0.2 = 5 - I_C * R_{PU} \rightarrow\ R_{PUMin} = \dfrac{4.8}{0.429} = 11.19\,\Omega$

b)

Using p-base diffusion size of Resistors is,

$\frac{1000+11.19}{160} = 6.32\lambda^2 \rightarrow Area_{BJT} \rightarrow (3600 + 6.32)\lambda^2 = 901.58\,\mu m^2$

From the design rules we get $Area_{MOS} \cong 57\,\mu m^2$