Problem 1:

$$R_{in} = \frac{v_1}{i_1}|v_2 = 0 \rightarrow h_{11} \rightarrow R_{in} = \frac{1}{y_{11}} = 1000$$

$$R_{out} = \frac{v_2}{i_2}|v_1 = 0 \rightarrow g_{22} \rightarrow R_{out} = \frac{1}{y_{22}} = 10$$

$$A_v = \frac{v_2}{v_1}|i_2 = 0 \rightarrow g_{21} \rightarrow A_v = \frac{-y_{21}}{y_{22}} = 0$$

$$A_{vr} = \frac{v_1}{v_2}|i_1 = 0 \rightarrow h_{12} \rightarrow A_{vr} = \frac{-y_{12}}{y_{11}} = 1$$

Problem 2:

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_{o1} + R_L} * A_{v1} * \frac{R_{in1}}{R_{in1} + R_S} = 1.90$$

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_{o2} + R_L} * A_{v2} * \frac{R_{in2}}{R_{in2} + R_S} = 32$$

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_{o2} + R_L} * A_{v2} * \frac{R_{in2}}{R_{in2} + R_{o1}} * A_{v1} * \frac{R_{in1}}{R_{in1} + R_S} = 228.3$$

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_{o1} + R_L} * A_{v1} * \frac{R_{in1}}{R_{in1} + R_{o2}} * A_{v2} * \frac{R_{in2}}{R_{in2} + R_S} = 424.5$$

Choose option 4

Problem 3:

a)

$$R_{in} = \frac{v_1}{i_1}|v_2 = 0 \rightarrow \frac{v_{in}}{v_{in}}\left(R_1 \middle|\middle| R_2 \middle|\middle| R_\pi\right) = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_\pi}}$$

$$R_{out} = \frac{v_2}{i_2}|v_1 = 0 \rightarrow \frac{v_{out}}{v_{out}} R_4 = R_4$$

$$A_v = \frac{v_2}{v_1}|i_2 = 0 \rightarrow \frac{-g_m * v_{in} * R_4}{v_{in}} = -g_m R_4$$

$$A_{vr} = \frac{v_1}{v_2}|i_1 = 0 \rightarrow \frac{v_{in}}{R_4(i_2 + g_m v_{in})}$$

b)

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{R_{o1}+R_L} * A_{v1} * \frac{R_{in1}}{R_{in1}+R_S} = \frac{R_L}{R_4+R_L} * -g_m R_4 * \frac{R_{in1}}{R_{in1}+0} = \frac{R_L * R_4}{R_4+R_L} * -g_m = -g_m(R_4||R_L)$$

c)

We have seen from previous homework and in class that the small signal gain of this amplifier is $-g_m(R_4||R_L)$, so both methods result in the same gain.

Problem 4:

a)

$$I_{out} = \frac{100\ mV}{1000} = 100\ \mu A$$

$$V_{out} = \frac{1k}{10k+1k} * V_{in} \rightarrow\ V_{in} = 1.1\ V$$

$$Power\ transfer\ ratio = \frac{V_{out}I_{out}}{V_{in}I_{in}} = \frac{0.1 * 100\mu}{1.1 * 100\mu} = 0.091$$

$$Attenuation\ ratio = \frac{V_{out}}{V_{in}} = 0.091$$

b)

$$V_{out} = \frac{R_L}{R_o+R_L} * A_v * \frac{R_{in}}{R_{in}+R_S} * V_{in} \rightarrow\ V_{in} = 0.111\ V$$

$$Power\ transfer\ ratio = \frac{\frac{V_{out}^2}{R_L}}{\frac{V_{in}^2}{R_S+R_{in}}} = 89.3$$

$$Attenuation\ ratio = \frac{V_{out}}{V_{in}} = 0.901$$

c)

$$I_{in} = 0 \rightarrow V_{out} = V_{in} = 0.100\ V$$

$$Power\ transfer\ ratio = \frac{\frac{V_{out}^2}{R_L}}{V_{in} * 0} = inf$$

$$Attenuation\ ratio = \frac{V_{out}}{V_{in}} = 1$$

Problem 5:

a) Choose $V_{GTMax} = 0.8\,V \; and \; I_{GT} = 200\ \mu A$

$$\rightarrow R_{GG} = \frac{20 - 0.8}{200\ \mu} = 96k\Omega$$

b) $I_F = \frac{50-.8}{60} = .820\ A, V_F = 0.8 \rightarrow P = 0.82 * .8 = 0.656\ W$

c) $V_{GT} = .8,\ I_G = \frac{10-0.8}{96k} = 95.8\ \mu A \rightarrow P = 76.7\ \mu$

Problem 6:

a)

Upper portion of potentiometer = 500*(1 - 0.1) = 450

Lower portion of potentiometer = 500*0.1 = 50

$$V_{TM} = 1.6\,V,\ \ V_{GT} = V_{AC}\left(\frac{50}{500 * 2}\right) = 3\sin(2\pi * 60 * t)$$

$$\rightarrow V_F = \begin{cases} 1.6\,V;\ \frac{T}{4} + nT < t < \frac{T}{2} + nT, \frac{3T}{4} + nT < t < (n+1)T \\ Vcc; \quad otherwise \end{cases}$$

b)

$$V_{RMS} = \frac{60 - 1.6}{\sqrt{2}} = 41.30, \rightarrow\ I_L = \frac{V_{RMS}}{R_L} = 1.38\ A$$

$$P = V * I_L = 1.6 * 2.208$$

c)

Quadrants 1 and 3

Problem 7:

Turn on voltage is 0.8 V so at 2π/8 we need, $0.8 = \frac{R_1}{R_1 + 10000} * 170\sin\left(\frac{\pi}{4}\right) \rightarrow\ R_1 = 70\ \Omega$

Problem 8:

$V_{GS} = 0 \ and \ V_{DS} > V_{GS} - V_P \rightarrow V_{out} = I_{DSS} * 6k = 0.6 \ V$

Problem 9:

a)

$V_{GSH} = 50 \ mV, assume \ V_{DS} > V_{GS} - V_P$

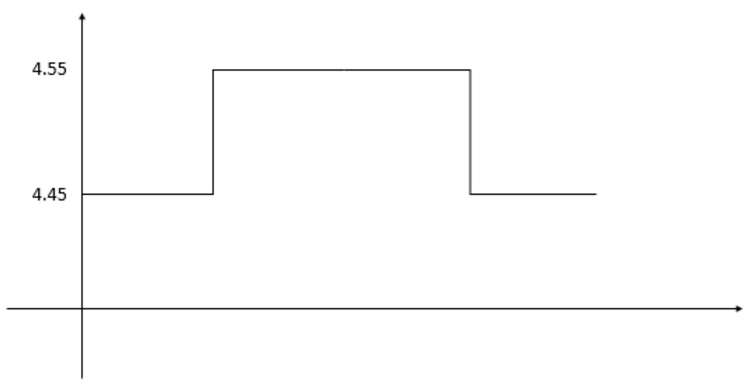
$V_{out1} = 5 - \ I_D * 5k = 5 - I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 * 5k = 4.45$

$Verify \rightarrow \ V_{DS} > V_{GS} - V_P \rightarrow 4.45 > 1.05$

$V_{GSL} = -50 \ mV, assume \ V_{DS} > V_{GS} - V_P$

$V_{out1} = 5 - \ I_D * 5k = 5 - I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 * 5k = 4.55$

$Verify \rightarrow \ V_{DS} > V_{GS} - V_P \rightarrow 4.55 > 1.05$



b)

$V_{in} < V_{GSMax} = \ 0.3 \ V$

Problem 10:

$I = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{out} - V_{TN})^2 = \ I_{DSS} * \left(1 - \frac{V_{in}}{V_P}\right)^2$

$\rightarrow \frac{100 * 10^{-6}}{2} * \left(\frac{W}{8\mu}\right)(5 - 3 - 0.75)^2 = 100 * 10^{-6} * \left(1 - \frac{-0.5}{-1}\right)^2 \rightarrow W = 2.56 \ \mu m$

Problem 11:

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = -2 * \frac{I_{DSSP}}{-V_P}\left(1 - \frac{V_{GS}}{V_P}\right)(1 - \lambda V_{DS}) \approx = 2 * \frac{I_{DSSP0}}{V_P}\left(\frac{W}{L}\right)\left(1 - \frac{V_{GS}}{V_P}\right)$$

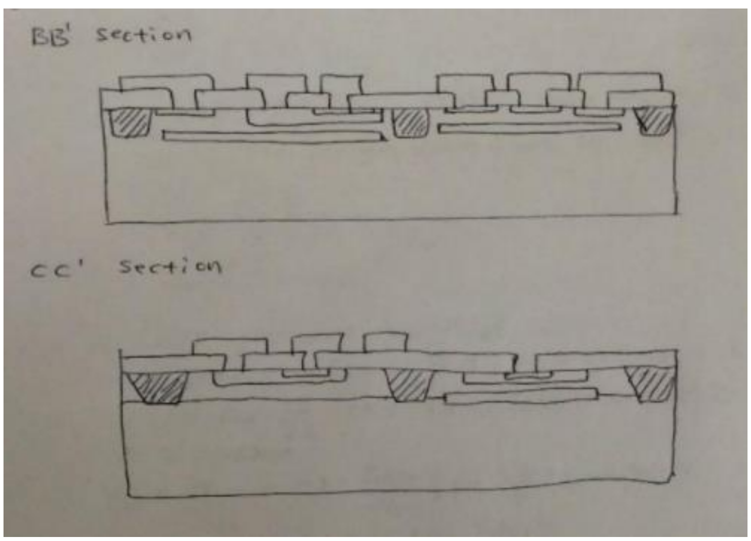
$$g_o = \frac{\partial I_D}{\partial V_{DS}} = \lambda * I_{DSSP}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

Problem 12:

$$I_{DQ} = \frac{30\mu * 10}{15} * \left(1 - \frac{0}{1}\right)^2 = \frac{V_{outQ} - (-5)}{50k} \rightarrow V_{outQ} = -4\,V, I_{DQ} = 20\,\mu A$$

$$g_m = \frac{2}{V_P}\frac{I_{DQ}}{\left(1 - \frac{V_{GS}}{V_P}\right)} \rightarrow A_V = \frac{V_{out}}{V_{in}} = -g_m * 50k = 2$$

Problem 13:



Problem 14:

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 $Area_{MOS} \cong 57\,\mu m^2$