Reading:

Chap 12.1-12.6 Hambley.
Chap 3.3 of Rabaey

Problems:

*Chap 12*: 12.15, 12.24, 12.30, 12.37, 12.40, 12.47 (midband refers to the frequencies at which the capacitors are short), 12.51

Additional Problems:

**Problem 1**

The circuit above has the following parameters:
$V_{DD} = 5V$, $R_1 = 20k\Omega$, $R_2 = 30k\Omega$, $R_S = 1k\Omega$, $R_D = 4k\Omega$, $V_{Th}(M_1) = 0.5V$

a) Find the value of $V_G$. 
b) From the $I_D$ vs. $V_{GS}$ curve below, find the values of $I_{DQ}$, $V_{GSQ}$.

c) From the values of $I_{DQ}$, $V_{GSQ}$ and $V_T$, draw the $I_D$ vs. $V_{DS}$ curve for $M_1$. **Assume** $\lambda = 0$. Annotate $V_{GSQ}$, $I_{DQ}$ and the point where $M_1$ enters saturation.

d) From the $I_D$ vs. $V_{DS}$ curve you drew, find the value of $V_{DSQ}$.

e) Is $M_1$ in saturation?

f) Find $V_o$.

**Problem 2**

Consider the Common Source amplifier above. $C_{gs}$ is the capacitance between the gate and the source of the NMOS.

\[
\begin{align*}
V_{DD} &= 15 \text{ V} \\
V_{Tn} &= 1 \text{ V} \\
\mu_n C_{ox} &= 100 \frac{\mu A}{V^2} \\
\frac{W}{L} &= 20 \\
\lambda &= 0 \\
R_1 &= 4 \text{ M}\Omega \quad R_2 = 1 \text{ M}\Omega \quad R_D = 2K\Omega \quad R_L = 20K\Omega \quad R_s = 10K\Omega \quad C_{gs} = 5 \text{ fF} (1 \text{ fF} = 10^{-15} \text{ F})
\end{align*}
\]
a. What is $I_{DSQ}$ and $V_{DSQ}$?

*Hint: All the capacitors, including $C_{gs}$, are open circuit for DC analysis.*

b. Draw the small signal model for the circuit and find the $v_g/v_{in}$.

*Hint: All the capacitors except for $C_{gs}$ are short circuit for the small signal analysis. Do include $C_{gs}$ in your small signal analysis.*

c. Find the small signal transfer function, $\frac{v_{out}}{v_{in}}$. Draw the bode plot for the transfer function.

**Problem 3**

![Circuit Diagram]

The circuit shown is biased so that both transistors are in saturation. M1 is an N-MOS and M2 is a P-MOS. The source terminals are indicated by the arrows.

a. Draw the small-signal model of the P-MOS transistor in saturation. (It should be very similar to an N-MOS, differing only by signs). Give expressions for $g_{m2}$ and $r_{d2}$ in terms of the MOSFET parameters and large-signal current.
b. Draw the small-signal model of the whole circuit.

c. Find the voltage gain of this circuit in terms of $g_{m1}$, $g_{m2}$, $r_{d1}$, and $r_{d2}$.

Problem 4

Find the transfer function of the following amplifier.
Use $R_1 = 10k$, $C_1 = 0.01\mu F$, $R_2 = 1k$, $C_2 = 0.001\mu F$, and $G_m = 0.01S$. 