Physics 536 - Second Exam
March 28, 2007

1. Consider the circuit shown below:

Assume that the voltage drop across the diodes is 0.7 volts when they are forward biased.
(a) What is $v_{out}$ when $v_{in} = 1$ V?
(b) What is $v_{out}$ when $v_{in} = -1$ V?
(c) What is $v_{out}$ when $v_{in} = 5$ V?
(d) What is $v_{out}$ when $v_{in} = -5$ V?

2. Draw the following operational amplifier circuits and give an expression for the gain in terms of any resistors that may be present in each circuit:
   (a) An voltage follower,
   (b) An inverting amplifier,
   (c) An non-inverting amplifier.
3. Consider the FET amplifier circuit:

![FET amplifier circuit diagram]

Assume that the drain current is described by the formula

$$I_D = I_{DSS} \left(1 + \frac{V_{GS}}{|V_P|}\right)^2$$

in which $I_{DSS} = 10 \text{ mA}$ and $V_P = -2 \text{ V}$.

(a) Calculate the value of $V_{GS}$ that will produce a quiescent current of $I_D = 2.5 \text{ mA}$.

(b) What is the transconductance at this operating point? Recall that

$$g_m = \frac{\partial I_D}{\partial V_{GS}}.$$  (2)

(c) Assuming that $R_{in}$ is very large but maintains the gate at a potential of 0 volts, what value of $R_S$ will yield the value of $V_{GS}$ determined in part (a)?

(d) The voltage gain of the amplifier is given by

$$G = \frac{-R_D}{1/g_m + R_S}.$$  (3)

What value of $R_D$ will give a small signal voltage gain of $-6$?

(e) What is the output impedance of this amplifier circuit?
4. For an NPN transistor that is correctly biased, the emitter will be at a potential that is $V_{be}$ lower than the base: $V_e = V_b - V_{be}$.

(a) If the base of a PNP transistor is at a potential $V_b$, what is the potential of its emitter?

(b) Consider the following circuit:

Assuming that $V_{be}$ is the same for both transistors, calculate the current, $I_1$, that flows through $Q_1$ in terms of $v_1$ and the current, $I_2$, that flows through $Q_2$ in terms of $v_2$. Assume that the voltages $v_1$ and $v_2$ allow both transistors to operate in the active region.

(c) By considering the current conservation rule, what current will flow through the resistor, $R_L$?