Final Exam for Physics 4051, Fall 2005

50 points - closed book – calculators allowed - show your work – 3 hours

You have some selection in the problems you solve. Note the selections carefully.

You must solve either problem 1.1. or problem 1.2. If you solve both then you will be graded on the first one appearing in your notes.

1.1 (7 Points) Given the circuit shown in Figure 1:

a) With the resistor $R_{Load}$ removed, derive equations for the Thevenin voltage and Thevenin resistance across AB.

b) Make a sketch of the equivalent circuit.

c) With $V_1 = 10$ Volts, $V_2 = 20$ Volts, $R_1 = 10k\Omega$ and $R_2 = 30k\Omega$, find the numerical values for $V_{Th}$ and $R_{Th}$.

d) Using the values given in 1c) calculate the current through $R_{Load} = 7.5k\Omega$.

![Figure 1](image1.png)

1.2 (7 Points) You have bought the most powerful sound system on the market but find that the lights in your house dim each time you turn it on. You want to measure how much electrical power the system uses and find that with the sound system on, the household voltage drops from 110 V to 100 V (RMS). From your physics class, you remember that a typical output impedance of a household circuit is 1 Ohm.

a) What is the input impedance of your sound system?

b) How much current (RMS) does it draw?

You must solve either problem 2.1. or problem 2.2. Same rules as before apply.

2.1 (7 Points) The circuit in Figure 2 represents a typical scope probe ($R_1$ and $C_1$) and a scope input ($R_2$ and $C_2$).

a) Calculate the impedance for a resistor $R$ in parallel with a capacitor $C$.

b) Assume $R_1C_1 = R_2C_2$. Calculate the transfer function $(|V_{out}/V_{in}|)$ for the circuit on the right.

c) What is the frequency dependence of the transfer function calculated in part b?

![Figure 2](image2.png)
2.2 (7 Points) Consider the circuit in Figure 3:

a) Assume \( V_{in} = V_0 \cos(\omega t) \). What is the (time-dependent) current \( I \) flowing to ground that you would measure?

b) If \( L = 40 \mu \text{H} \) and \( C = 5 \times 10^{-10} \text{F} \), at what frequency (in Hz) does the current \( I \) vanish?

You must solve either problem 3.1. or problem 3.2. Same rules as before apply.

3.1 (7 Points)
Assume that the transistor in Figure 4 operates in unsaturated regime and that it has \( h_\beta = \beta = 100 \) and a base-emitter drop of 0.6 V. You may use appropriate approximations; i.e., your results should be accurate to within 5%.

a) For \( V_0 \) very small (\( V_0 << 2.6 \text{ V} \)), find the following DC voltages and currents: \( V_1, V_2 \) and \( I_2 \).

b) Using the information previously stated, calculate the DC values \( I_3 \) and \( V_3 \).

c) Calculate the AC voltage gain of the circuit, i.e., find \( V_4/ V_0 \) for \( V_0 \) small.

3.2 (7 Points)
Analyze the circuit in figure 5: (Use appropriate approximations to obtain voltages to 0.1V and the currents to 10%, assume \( \beta = h_\beta = 50 \))

a) Determine the values for \( R_1 \) and \( R_2 \) such that the voltage at the base is 4.0V and that the current that flows into the base (\( I_B \)) is about 1% of \( I_E \).

b) With no sources or loads connected, what are the values of \( I_B, I_E, I_C, V_E \) and \( V_C \)?

c) An AC signal is coupled to the input through a large capacitor \( C \). What is the voltage gain of output1? Of output2?

d) What is the input impedance of the circuit as shown at \( f >> 0 \)?

e) Find the capacitance \( C \) required to place the lower frequency -3dB point at 10Hz.
4. (7 Points)
Assume that the op-amp in Figure 6 is ideal and that its supply voltages are +/- 15 VDC.

Before time \( t = 0 \) seconds, the switch S1 was closed, for all practical purposes, for an infinite amount of time. At time \( t = 0 \) seconds the switch S1 is opened. Determine the \( V_{\text{out}} \) at the following instances:
   a) at \( t = -1 \) seconds
   b) at \( t = 0 \) seconds.
   c) at \( t = +1 \) seconds
   d) at \( t = +5 \) seconds.
(To ensure your answer is correct, you may want to sketch for your own sake \( V_{\text{out}} \) vs. \( t \)).

![Figure 6]

5. (8 Points) In lecture you learnt how a parallel-encoded (“flash”) analog to digital converter works. A simplified two-bit version with an analog input range from 0 to 4 V is shown in Figure 7.

It contains a series of voltage dividers to set the various threshold voltages for the comparators and a decoder chip that converts the information from the comparators into the corresponding binary signal. Design the logic circuitry for the decoder chip which outputs a two bit binary value that corresponds to the truncated (analog) input voltage. For example, an analog input voltage of 2.0 V and less than 3.0 V will always result in a binary output of: 10.

a) Write down the truth table for the decoder chip and the Boolean logic expressions for \( Q_0 \) and \( Q_1 \) in terms of the comparator outputs, \( C_{\text{Out}2} \), \( C_{\text{Out}1} \) and \( C_{\text{Out}0} \). (You may assume that the comparator outputs are TTL level and that if the analog input voltage exceeds a comparator’s threshold voltage (V-), its output will go HI.)

b) Implement it using only standard 1 and 2-input gates such as NOT, AND, NAND, OR, NOR and XOR gates and draw a circuit diagram.

![Figure 7]
6. **(7 Points)** Figure 8 shows a pseudo random bit generator.

![Figure 8](image)

Assume that it has been initialized with: \(Q_3 = \text{HI}, Q_2 = \text{LO}, Q_1 = \text{HI}\) and \(Q_0 = \text{LO}\). Determine the decimal equivalent of its outputs \(Q_3\) (MSB), \(Q_2\), \(Q_1\) and \(Q_0\) (LSB) during the next 4 cycles.

7. **(7 Points)** Consider the analog signal:

\[x_a(t) = 3 \cos 2000 \pi t + 5 \sin 6000 \pi t + 10 \cos 12000 \pi t\]

a) What is the Nyquist frequency for this signal?

b) Assume that we sample this signal using a sampling rate, \(F_s = 5000\) samples/sec. Which frequencies will appear in the sampled data?

c) Write an expression for the discrete time signal obtained after sampling?