ENGR-2300
Electronic Instrumentation
Quiz 1
Fall 2012

Name ________________________

Section ___

Question I (25 points) ____________
Question II (25 points) ____________
Question III (25 points) ____________
Question IV (25 points) ____________

Total (100 points) ______________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.
I. Resistive circuits (25 points)

a) Find the voltage $V_{\text{out}}$ in the circuit above. (4 pts)

$$V_{\text{out}} = \frac{R_2}{R_1 + R_2} V_{\text{in}} = \frac{1}{1000} \times 900 = .9V \ (\text{PSpice gives 900mV})$$

b) Find the total resistance of the circuit above, seen from the 130V voltage source, (i.e. all resistors inside the dashed region) (5 pts)

$$R_{\text{total}} = 1k + 1k \ || (1k + 1k \ || 2k) = 1k + 1k \ || (1k + 2/3k) = 1k + \frac{\frac{5}{3}k}{1 + \frac{5}{3}} = \frac{13}{8}k$$

$$R_u = (2/3)k ; \ R_h = 1k \ || (1k + 2/3k) = \frac{5}{3}k ;$$
c) Find the voltages at the points A, B and C. (6 pts)

\[ V_A = 50V \quad V_B = 20V \quad V_C = 10V \]

From the answer to d, the voltage drop across R16 is 1k times 80mA or 80V so that \( V_A = 130 - 80 = 50V \)

\( V_C = \frac{V_B}{2} \) from the voltage divider. \( V_B \) is also determined from a voltage divider. Thus,

\[ \frac{2}{5} \cdot 50 = 20V \text{ and } V_C = \frac{20}{2} = 10V. \]

\[ \frac{2}{5} \cdot 50 = 20V \text{ and } V_C = \frac{20}{2} = 10V. \]

d) Find the current drawn from the 130V DC voltage source. (4 pts)

\[ I_{IN} = \frac{130}{\left( \frac{13k}{8} \right)} = 80mA \]

The previous circuit is modified as shown below.

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e) Find the voltages at the points A, B, C, D, E, F, G, H, I. (6 pts)

Note that this circuit is symmetric so that A, B, C are the same as before; D, E, F are all zero; G, H, I are the negative of A, B, C.
PSpice Solutions:
II. Filters & Transfer Functions (25 points)

a) Find the transfer function $\frac{V_{out}}{V_{in}}$ for the resistive circuit shown above. Note that output is measured across R3. (2 pts)

$V_{out} = V_{in} \cdot \frac{5}{20} = \frac{V_{in}}{4}$

b) Write the input voltage $V_{in}$ and the output voltage $V_{out}$ as sinusoidal functions with offsets for the given operating conditions. That is write the voltages in the form $V_{in} = A + B \sin \omega t$ and $V_{out} = C + D \sin \omega t$ (2 pts)

$V_{in} = 10 + 5 \sin \omega t \quad V_{out} = 2.5 + 1.25 \sin \omega t$

The previous circuit is modified by replacing the third resistor with an inductor. For simplicity, the offset voltage has also been set to zero.
c) Find the transfer function \( \frac{V_{out}}{V_{in}} \) for the new circuit. Write it first in general form \( H(j\omega) \) in terms of \( \omega, R_1, R_2, \) and \( L_1 \) and then plug in the given numerical values. (4 pts)

\[
H(j\omega) = \frac{j\omega L_1}{(R_1 + R_2 + j\omega L_1)} = \frac{j\omega 0.1}{(15k + j\omega 0.1)}
\]

*Can also replace* \( \omega = 2\pi f = 2000\pi \)

d) Simplify the transfer function for low frequencies and for high frequencies. (4 pts)

\[
H_{low}(j\omega) = \frac{j\omega L_1}{(R_1 + R_2)}
\]

\[
H_{high}(j\omega) = \frac{j\omega L_1}{(j\omega L_1)} = 1
\]

e) What kind of filter response would best represent this circuit? (Please circle one.) (2 pts)

i) Low Pass  ii) Band Pass  iii) High Pass  iv) Band Reject

f) What kind of filter response would best represent this circuit if the positions of the inductor and resistor \( R_2 \) are reversed? (Please circle one.) (2 pts) *Hint: Sketch the new circuit diagram.*

i) Low Pass  ii) Band Pass  iii) High Pass  iv) Band Reject

*There is also some attenuation at low frequencies, but high frequencies are rejected.*
The inductor is now replaced by a capacitor.

\[ V_{out} = \frac{1}{j\omega C} \left( \frac{1}{R_1 + R_2 + \frac{1}{j\omega C}} \right) = \frac{1}{1 + j\omega C1(R_1 + R_2)} = \frac{1}{1 + j(1.5 \times 10^{-6})} \]

h) Determine the corner frequencies \( f_c \) for both the circuit with the inductor (at the output) and the circuit with the capacitor. Find the numerical values, not just the general expression. (2 pts)

Inductor \( f_c \): \( \frac{R}{2\pi L} = 23.873 \text{Hz} \)

Capacitor \( f_c \): \( \frac{1}{2\pi RC} = 1061 \text{Hz} \)

Thus, 1kHz is near the corner for RC and way below the corner for RL

h) On the following page are the input and output voltages for the three circuit configurations considered in this problem (output across resistor, output across inductor and output across capacitor). Label which plot goes with which circuit and explain your answer. (3 pts)

The resistor case is obvious because of the offsets. The RC case has the largest output voltage because 1kHz is near the corner. The RL case has the very small output voltage because the source frequency is so much less than the corner.
III – Signals, Transformers and Inductors (25 points)

a) Given the circuit above, assume an ideal transformer with full coupling. With $R_s = 10\Omega$ and $R_L = 1k\Omega$ and $L_2/L_1=100$, find $V_{in}$, $V_{out}$, and the power in $R_L$. (6 pts)

$$Z_{in} = \frac{R_L}{a^2} = \frac{1k}{100} = 10 \text{ thus } V_{in} \text{ will be half of } V_{AML} \text{ or } 6V. \text{ Vout will be } 10X \text{ larger than } V_{in} \text{ or } 60V. \text{ The power in RL is } V_{out}^2 / R_L = 60^2 / 1000 = 3.6W \text{ which should be the same as the power delivered to the transformer input } = \frac{6^2}{10} = 3.6W. \text{ (While this is not mentioned in the solutions to previous semesters’ quizzes, the answer is actually } \frac{1}{2} \text{ of this value because the RMS voltage is supposed to be used instead of the amplitude. However, for a ballpark number, this approach is fine.)}$$

b) For which of the following choices for $L_2$ will the transformer work at the given frequency, but not a 100Hz? (4 pts)

$1\mu H \ 10\mu H \ 100\mu H \ 1mH \ 10mH \ 100mH \ 1H$

The primary and the secondary legs of the circuit must be dominated by inductance to work as a transformer. Thus $\omega L >> R / (2\pi f) = 1000 / (2\pi 10000) = .016$ so for the given values, only $100mH$ and $1H$ are large enough. $100mH$ will not work at $100Hz$. $1H$ will be marginal.

$$f = \frac{1000}{(2\pi 100)} = 1.6$$

c) If $L_1$ is set equal to $L_2$ (everything else remains as in 1), what are the new values for $V_{in}$, $V_{out}$, and the power in $R_L$? (6 pts)

$$Z_{in} = \frac{R_L}{a^2} = \frac{1k}{1} = 1000 \text{ thus } V_{in} \text{ will be most of } V_{AML} \text{ or } \sim 12V. \text{ Vout will be the same. The power in RL is } V_{out}^2 / R_L = 12^2 / 1000 = 144mW.$$  

d) If $L_2 = L_1 = 1H$, for which of the following frequencies will the transformer work? (4 pts)

$60Hz \ 100Hz \ 1kHz \ 10kHz \ 30kHz \ 100kHz$

$$f >> R / (2\pi L) = 1000 / 2\pi = 167Hz$$
e) Out of curiosity, you decide to build a 1H inductor by winding wires on a 4m long, hollow cardboard cylinder with a radius of 10cm. Assuming the ideal formula gives a reasonably accurate result for this geometry, how many turns of wire will you need if $\mu = \mu_0 = 4\pi \times 10^{-7}$ H/m? (4 pts)

$$L = \frac{\mu N^2 \pi r^2}{d} = \frac{(4\pi \times 10^{-7}) N^2 \pi (0.1)^2}{4} \text{ or } N = 10000$$

Assuming that you wind the coil with standard 12 gauge wire (diameter = 2mm), how much wire will you need? Note that this wire costs roughly $1 per meter. (1 pt)

2mm diameter means 2000 turns per layer or 5 total layers. Each of the turns has a circumference of $2\pi$ times 10cm or the total length is about 6300 meters.

**PSpice Solution for Original Transformer Configuration:**
IV – Instrumentation, PSpice, Components, Troubleshooting & Concepts (25 points)

Shown above is the pinout diagram for the Mobile Studio. Shown also at the right are the 10 input/output connections we have used so far in the course. The insert in the figure is a photo of the relevant part of the Mobile Studio board.
a) Shown above are four possible parameter selections for Channel 1 and wire connections. If you wish to measure a time varying voltage on Channel 1, using wires to connect to some points on your circuit, which of the 4 choices is correct? Explain your answer. (6 pts)

Setup A because we need to select the single ended measurement and connect A1+ and GND to the circuit being measured.
b) Shown below are two Mobile Studio measurements of sine waves. Which of the two waves has a frequency of 10kHz? Label the correct plot and explain your answer. (5 pts) *The first one has 5 cycles in .5ms so it will have 10 cycles in 1ms, which is 10kHz*
c) You are to build the following circuit that you have analyzed using PSpice and test it using the Mobile Studio. (4 pts)

\[\text{VOFF} = 0\, \text{V} \quad \text{VAMPL} = 0.5\, \text{V} \quad \text{FREQ} = 4\, \text{kHz} \quad \text{AC} = 0.5\, \text{V}\]

\[\text{R} = 2.2\, \text{k}\, \Omega \quad \text{Rload} = 10\, \text{k}\, \Omega \quad \text{C} = 1\, \mu\text{F}\]

i) Shown below are the components used to build the circuit. Label which one is R, Rload and C. While the figure is in black and white, there is still sufficient information to answer this question. They are shown in the order they are used.

\[\begin{array}{c}
\text{Resistor} \\
\text{Resistor} \\
\text{Capacitor}
\end{array}\]

ii) The voltage source shown at the left is realized using the Mobile studio. Which of the two connections for the Mobile Studio must be used to provide the voltage source for this circuit?

\[\text{AWG1 and GND or AWG2 and GND}\]

In PSpice, you set up a circuit and perform a time domain simulation. You have carefully created all of the circuit components and correctly specified the simulation profile, but the simulation does not run. You get the following warning: Your design does not contain a Ground (0) net. You may not be able to run analog simulation on this design. You look at your circuit and cannot understand the warning because you have included a ground. What do you think could be wrong with your circuit? (4 pts)

The wrong ground was used. One needs the ground that specifies zero for PSpice.
d) Which of the three figures above shows an inductor? (3 pts)

All 3. The one on the left is a coil for Beakman’s Motor. The one on the right is from our parts kit.

e) When does a real physical inductor behave like a resistor? When does it behave like an inductor? When does it behave like neither? (3 pts)

Inductor when $\omega L >> R$, Resistor when $R >> \omega L$, neither when the two impedances are similar in size.