1. (19 pts) a) Find and draw the Thévenin equivalent of the circuit shown. The load resistor is \( R_L \).

b) Find and draw the Norton equivalent of the same circuit.

c) Find the load current using your Thévenin equivalent circuit.

\[
\begin{align*}
\text{V}_S &= 24 \text{ V} \\
R_1 &= 60 \text{ } \Omega \\
R_2 &= 120 \text{ } \Omega \\
R_3 &= 80 \text{ } \Omega \\
R_L &= 100 \text{ } \Omega
\end{align*}
\]

2. (12 pts) a) Find the s-type transfer function of the circuit shown. Consider \( I_C \) as the "output".

You MUST show work to get credit. Simplify your expression for \( H(s) \) so that the denominator is a simple polynomial.

\[
H(s) = \frac{I_C(s)}{I_{in}(s)} = ?
\]

b) How many poles does this transfer function have?

c) How many zeroes does this transfer function have?

If it has 1 or more, express them (probably in terms of \( R_1, R_2, L \) and \( C \)).

3. (15 pts) a) Find: \( V_1 \) & \( I_2 \)

b) How much power does the 2-V battery supply to the circuit?

4. (21 pts) The transformer shown in the circuit below is ideal. It is rated at 220/110 V, 200 VA, 60 Hz

Find the following:

a) The primary current (magnitude).

\[ |I_1| = ? \]

b) The primary voltage (magnitude).

\[ |V_1| = ? \]

c) The secondary voltage (magnitude).

\[ |V_2| = ? \]

d) The power supplied by the source.

\[ P_S = ? \]

e) Is this transformer operating within its ratings? Show your evidence.
5. (22 pts) Assume that diode $D_1$ does **NOT** conduct. Assume that diodes $D_2$ and $D_3$ **DO** conduct.

a) Stick with these assumptions even if your answers come out absurd. Find the following:

- $V_{D1} = \_\_\_\_$
- $I_{R3} = \_\_\_\_$
- $I_{D2} = \_\_\_\_$

b) Based on the numbers above, was the assumption about $D_1$ correct? Circle one: yes no

   How do you know? (Specifically show a value which is or is not within a correct range.)

c) Based on the numbers above, was the assumption about $D_2$ correct? Circle one: yes no

   How do you know? (Specifically show a value which is or is not within a correct range.)

d) Based on the numbers above, was the assumption about $D_3$ correct? Circle one: yes no

   How do you know? (Specifically show a value which is or is not within a correct range.)

5. continued

   e) Based on your answers to parts b), c) & d), Circle one:

      i) The real $I_{R3} < I_{R3}$ calculated in part a.

      ii) The real $I_{R3} > I_{R3}$ calculated in part a.

      iii) The real $I_{R3} = I_{R3}$ calculated in part a.

6. (16 pts) A voltage waveform (dotted line) is applied to the circuit shown. **Accurately draw the output waveform ($v_o$) you expect to see.** Label important times and voltage levels.
7. (34 pts) You have two input voltages to work with. A 1V battery and the waveform (at right).

\[ V_B := 1 \text{V} \]

The problems below are op-amp design problems. The answer should be a schematic of a circuit showing the values of all the parts. Use reasonable resistor values (in the 100Ω to 1 MΩ range). Also show how one or both of the sources are hooked up to your circuit. Most circuits won’t need both.

(a) Design a circuit which will output the waveform at right.

(b) Design a circuit which will output the waveform at right.

(c) What power supply or supplies are being used with your op-amps?

(d) Design a circuit which will output the waveform at right.

(e) Design a circuit which will output the waveform at right. Hint: Think nonlinear.
8. (31 pts) A couple of transistors are used to control the current flow through an inductive load.

a) The switch is open, as shown. What is the minimum $V_2$ needed to insure that transistor $Q_2$ is in saturation.
\[ \beta_2 = 25 \quad V_2 = ? \]

b) Find the power dissipated in transistor $Q_2$ with this $V_2$. $P_{Q2} = ?$

c) What if the voltage $V_2$ was too low so that the base voltage of transistor $Q_2$ was only $8V$, how much power would be dissipated in transistor $Q_2$?
\[ \text{IF} \quad V_{B2} := 8 \cdot V \quad P_{Q2} = ? \]

d) The transistor $Q_2$ was selected to be able to handle the power found in part b) (with a 2x factor of safety). What would happen with the $V_2$ of part c)?

$V_2$ is NOT too low for the remainder of the problem, that is, use the $V_2$ found in part a).

e) When the switch is closed, you would like transistor $Q_1$ to saturate.
What minimum $\beta_1$ would be required to achieve saturation?

Use the $\beta_1$ for the remainder of the problem.

f) The diode in this circuit conducts a significant current: (circle one)

- A) never.
- B) when the switch closes.
- C) whenever the switch is closed.
- D) always.
- E) when the switch opens.
- F) whenever the switch is open.

g) What is the maximum diode current you expect when the switch is cycled. (Answer 0 if it never conducts.)

h) This circuit design is: (circle one)

- A) incredibly fantastic.
- B) a very good design.
- C) dumb.
- D) not a good design.

Why?
9. (10 pts) Find the resonant frequency (or frequencies) of the circuit shown (in cycles/sec or Hz).

\[
\begin{align*}
L_1 &= 6\text{ mH} \\
C_1 &= 4\mu\text{F} \\
C_2 &= 6\mu\text{F} \\
L_2 &= 9\text{ mH}
\end{align*}
\]

10. Do you want your grade and scores posted on my door and on the Internet? If your answer is yes, then provide some sort of password or alias: ______________________________

The grades will be posted on my door in alphabetical order under the alias that you provide here. I will not post grades under your real name. The Internet version will be a pdf file which you can download. Both will show the homework, lab, and exam scores of everyone who answers here.

Answers

1. a) $16\text{ V}$ b) $133.3\text{ mA}$ c) $120\Omega$

2. a) $72.7\text{ mA}$

3. a) $8\text{ V}$ b) $3\text{ mA}$

4. a) $937\text{ mA}$ b) $93.7\text{ V}$ c) $46.85\text{ V}$

d) $87.8\text{ W}$ e) NO $I_{1\text{max}} = 909\text{ mA} > I_1$

5. a) $1\text{ V}$ b) $20\text{ mA}$ c) $13\text{ mA}$ d) $0$ e) $I_{D2} = 13\text{ mA} > 0$ f) $I_{D3} = 20\text{ mA} > 0$ g) iii)

6. a) $20.3\text{ V}$ b) $0.98\text{ W}$ c) $9.86\text{ W}$ d) $Q_2$ will burn out. e) $93.5$ f) B g) $4.9\text{ A}$

h) C D There are good ways to do this same thing without the extra requirement of $V_2$, and this extra voltage makes the transistor $Q_2$ more vulnerable to failure (see part d)).

9. $411\text{ Hz}$