1. (10 pts) Find the resonant frequency (or frequencies) of the circuit shown (in cycles/sec or Hz).

2. (25 pts) The switch has been closed (making contact) for a long time and is switched open (as shown) at time \( t = 0 \).
   a) Find the complete expression for \( v_C(t) \).
   b) What is \( v_C \) when \( t = \tau \)? \( v_C(\tau) = ? \)
   c) At time \( t = \tau \) the switch is closed again. Find the complete expression for \( v_C(t') \), where \( t' \) starts at \( t = \tau \).

3. 9 pts) \( Z := |Z| e^{j40\text{-deg}} \) We don't know its magnitude, but its phase angle is \( +40^\circ \). \( \omega := \frac{3000}{\text{rad/sec}} \).
\( Z \) is made of a 100\( \Omega \) resistor in series with one other part. What is the part? Give type and value.

4. (24 pts) An inductor is used to completely correct the power factor of a load. Find the following:
   a) The power consumed by the load. \( P_L = ? \)
      Hint 1: Since \( L \) corrects the power factor, its \( Q \) must exactly cancel the load's \( Q \) and the source provides only \( P \) and no \( Q \).
      Hint 2: If hint 1 doesn't make sense to you, you don't know AC power well enough to do part a) -- so skip to part b).
      If you can't find this power, mark an x here _____ and assume \( P_L = 550\text{W} \) for the rest of the problem.
   b) The power supplied by the source. \( P_S = ? \)
   c) The source current (magnitude and phase). \( I_S = ? \)
   d) The load can be modeled as 2 parts in series.
      Draw the model and find the values of the parts.
   e) The inductor, \( L \), is replaced with a 50 mH inductor.
      i) The new source current \( |I_S| \) is greater than that calculated in part c).
      ii) The new source current \( |I_S| \) is the same as that calculated in part c).
      iii) The new source current \( |I_S| \) is less than that calculated in part c).
5. (15 pts) a) Find the s-type transfer function of the circuit shown after time $t = 0$. Consider $I_2$ as the "output".

You MUST show work to get credit. Simplify your expression for $H(s)$ so that the denominator is a simple polynomial with no coefficient before the highest-order $s$ term in the denominator.

$$H(s) = \frac{I_2(s)}{I_{in}(s)} = ?$$

b) How many zeroes does this transfer function have?

If it has 1 or more, express them (probably in terms of $R_1$, $R_2$, $R_3$, $L$ and $C$).

c) How many poles does this transfer function have?

If it has 1 or more, express them (probably in terms of $R_1$, $R_2$, $R_3$, $L$ and $C$).

6. (22 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. (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 maximum $R_2$ can be if transistor $Q_2$ is in saturation.

$$\beta_2 = 30 \quad R_2 = ?$$

b) Find the power dissipated in transistor $Q_2$ with this $R_2$.

$$P_{Q2} = ?$$

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

$$\beta_{1min} = ?$$

Assume at least this $\beta_1$ for the remainder of the problem.

d) What if the voltage $V_2$ was too low so that the base voltage of transistor $Q_2$ was only 6V, how much power would be dissipated in transistor $Q_2$?

$$\text{IF } V_{B2} := 6\text{-V} \quad P_{Q2} = ?$$
7. continued

(f) 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 d)?

$V_2$ is NOT too low for the remainder of the problem, that is, use the original $V_2 = 10\cdot V$

(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 as many as apply and don’t forget to say why)

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

Why?

Use constant-voltage-drop models for the diodes and LEDs on this exam.

8. (24 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:

$V_{D1} = \underline{\hspace{2cm}}$

$I_{D2} = \underline{\hspace{2cm}}$

$I_{D3} = \underline{\hspace{2cm}}$

$V_A = \underline{\hspace{2cm}}$

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

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

c) Was the assumption about $D_2$ correct? yes  no (circle one)

How do you know? (Show a value & range.)

d) Was the assumption about $D_3$ correct? yes  no (circle one)

How do you know? (Show a value & range.)

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

Justify your answer.

i) The real $I_{R1} < I_{R1}$ calculated in part a.

ii) The real $I_{R1} = I_{R1}$ calculated in part a.

iii) The real $I_{R1} > I_{R1}$ calculated in part a.
10. (18 pts) The same input signal (at right) is connected to several op-amp circuits below. Sketch the output waveform for each circuit. Clearly label important voltage levels on each output. If I can’t easily make out what your peak values are, I’ll assume you don’t know. Don’t forget to show inversions. All op-amps are powered by ±10 V power supplies.

a) \[ \begin{array}{c}
R_1 := 5\,\text{k}\Omega \\
R_2 := 20\,\text{k}\Omega \\
R_3 := 80\,\text{k}\Omega
\end{array} \]

b) \[ \begin{array}{c}
C := 0.2\,\mu\text{F} \\
R := 10\,\text{k}\Omega
\end{array} \]
9. Do you want your grade and scores posted on the Internet? If your answer is yes, then provide some sort of alias. Otherwise, leave blank.

The grades will be posted online in PDF form in alphabetical order under the alias that you provide here. I will not post grades under your real name. It will show the homework, lab, and exam scores of everyone who answers here.

**Answers**

1. 822 Hz

2. a) \(6 \cdot V + 9 \cdot V \cdot e^{-\frac{1}{168 \mu s}}\)  
b) 9.31 \(V\)  
c) 15 \(V\) – \(5.69 \cdot V \cdot e^{-\frac{1}{60 \mu s}}\)

3. 28 mH Inductor

4. a) 463 W  
b) 463 W  
c) 3.86 \(A\) / \(0^\circ\)  
d) \(R := 18.5 \Omega\)  
\(C := 174 \mu F\)  
e) i)

5. a) \(\frac{1}{L \cdot C}\)  
b) 0  
c) \(2 - \frac{R_1 + R_3}{L} \pm \sqrt{\left(\frac{R_1 + R_3}{L}\right)^2 - \frac{4}{L \cdot C}}\)

6. (volts)

7. a) 23.1 \(\Omega\) or 23.8 \(\Omega\) (2nd ans is more accurate)  
b) 0.39 W  
c) 129 or 125  
d) 3.58 W  
e) The smoke would get out.  
f) B  
g) 1.95 \(A\)  
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).

8. a) 1.5 \(V\) - 10 mA 20 mA 1.2 \(V\)  
b) no \(V_{D1} := 1.5 \cdot V > 0.7 \cdot V\)  
c) no \(I_{D2} := -10 \cdot mA < 0\)  
d) yes \(I_{D3} := 20 \cdot mA > 0\)  
e) i) \(V_{R1}\) is actually 0.7 \(V\) which is less than 1.5 \(V\) so less current will flow through \(R_1\)

9. \(v_{o1}(t)\)

\(10.5 \cdot V\)  
9 \(V\)  
2.5 \(V\)

\(-10.5 \cdot V\)

\(-5.5 \cdot V\)

\(v_{o2}(t)\)

4 \(V\)

\(-4 \cdot V\)

\(\text{time (ms)}\)

\(\text{time (ms)}\)