1. (24 pts) Use nodal analysis to find the voltage $V_{R3}$ and the current $I_{R2}$. You MUST show all the steps of nodal analysis work to get credit, including drawing appropriate symbols and labels on the circuit shown.

2. (34 pts) $V_a$ is the nodal voltage at node a and $V_b$ is the nodal voltage at node b.
   a) Find $Z_2$ in polar form
   b) $I_1 := (20 - 25 \cdot j) \cdot mA$ Find $V_{in}$
   c) Find $Z_1$ in any form
3. (24 pts) The same input signal (at right) is connected to two 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. The op-amp is connected to +14V & -14V power supplies.

b) $C := 0.5 \cdot \mu F$
4. (34 pts) A couple of transistors are used to control the current flow through an inductive load. The switch has been closed, as shown, for a long time.

a) Assume both transistors are in saturation. Find the minimum $\beta$ for transistor $Q_2$. $\beta_2 = ?$

Hint: You will need to find the voltage at the base of $Q_2$. You may assume that $I_E \approx I_C$ for both transistors.

b) Find the minimum $\beta$ for transistor $Q_1$ to be in saturation. $\beta_{1\text{min}} = ?$
c) Something is wrong. Transistor Q₂ is getting too hot. You measure the voltage across the load and find that \( V_L := 3.1 \). How much power is being dissipated in transistor Q₂?

d) Next you measure the voltage at the collector of Q₁ and find that \( V_{C1} := 8.2 \) with respect to ground. Find the actual \( \beta \)'s of both transistors and tell me what's wrong.

You replace the faulty component and everything is back to the way it was in part a)

e) The diode in this circuit conducts a significant current: (circle one)
   A) never.  D) always.
   B) when the switch closes.  E) when the switch opens.
   C) whenever the switch is closed.  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.)
5. (42 pts) the C's, L, & R together are the load in the circuit shown. Find the following: Be sure to show the correct units for each value.

a) The magnitudes of these 3 currents. 
\[ |I_{R1}| = ? \quad |I_L| = ? \quad |I_C| = ? \]

b) The real power. \( P = ? \)

c) The reactive power. \( Q = ? \)

d) The complex power. \( S = ? \)

e) The apparent power. \( |S| = ? \)
5. continued  

f) The power factor. \( \text{pf} = ? \)

g) The power factor is:  
   i) leading  
   ii) lagging  
   (circle one)

h) The magnitude of the source current.  \( |I_S| = ? \)

i) Remove the inductor and replace it with a new component which makes the power factor the entire load perfect (make \( \text{pf} = 1 \)). Determine the type and value of this component.

j) Find the new magnitude of the source current.  \( |I_S| = ? \)
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.

$$v_o(t)$$

Answers

1. 5.2 V 213 mA  
2. a) 125 Ω / -56.2°  
b) 7.77V / 11.9°  
c) 168 Ω / 29.5°

4. a) 30 or 29 is more correct  
b) 115.6  
c) 6 W  
d) 15.96 or 14.96 is more correct  
e) E  
g) 4.8 A

5. a) 12 Ω 4 A 12 Ω  
b) 2304 W  
c) 672 VAR  
d) (2304 – 672·j) VA  
e) 2400 VA  
f) 0.96  
g) i)  
h) 20 A  
i) Add a 33.2mH inductor in parallel with load.  
j) 19.2 A