1. (18 pts)
a) Find and draw the Thévenin equivalent of the circuit shown. $V_S$ represents a +DC power source (just like those you're used to seeing in transistor and op-amp circuits). If it helps you, draw a 12 V battery connected from ground to the $V_S$. The load resistor is not shown, but would be hooked between $V_O$ and ground.

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

c) A load of some sort is connected to the circuit above, it could be a simple resistor, or it could be a transistor circuit, or whatever. It draws a current of 0.1mA, what is the value of $V_O$ now?

2. (11 pts) The switch has been open for a long time and is closed at time $t = 0$. Find the complete time expression of $V_C(t)$. $V_S$ represents a +DC power source (just like problem 1).

3. (11 pts) The transformer shown in the circuit below is ideal. Find the following:
a) $I_1 = ?$
b) $V_2 = ?$

4. (20 pts) To get partial credit, show each step and each answer along the way.
a) Find $I_n$ in polar form.
b) Find $V_T$.
c) $Z_1 + Z_2$ together are the load. What is the power factor of this load? $pf = ?$

Hint: use the phase angles of $I_n$ and $V_T$ to find this.
d) Circle 1:
   i) The power factor is leading (source current leads the source voltage)
   ii) The power factor is lagging (source current lags the source voltage)
5. (18 pts) a) Find the characteristic equation of the circuit shown (after the switch moves to the lower position at t = 0). You MUST show work to get credit.

b) Find the solutions of the characteristic equation given these component values.
\[ R_1 = 25\, \Omega \quad R_2 = 125\, \Omega \quad L = 5\, \text{mH} \quad C = 0.08\, \text{mF} \]

c) This circuit is: (circle one) i) underdamped  ii) critically damped  iii) overdamped  iv) can't tell

6. (22 pts) Assume the diodes are silicon with a 0.7V forward voltage drop:
Assume the LEDs have a 2V forward voltage drop:

a) Assume that diode D1 and diode D2 both conduct.
Find \( I_{R1}, I_{R2}, I_{R3}, I_{D1}, \) and \( I_{D2} \) based on these assumptions.
\[ I_{R1} = \quad I_{R2} = \quad I_{R3} = \quad I_{D1} = \quad I_{D2} = \]

b) Was the assumption about \( D_1 \) correct? yes no (circle one)
How do you know?

c) Was the assumption about \( D_2 \) correct? yes no (circle one)
How do you know?

7. (16 pts) The input voltage to the circuit at right is shown below (dotted line). Accurately draw the output voltage you expect to see across \( R_2 \) and the diode. Label the important voltages and times.
8. (36 pts) Fill in the blanks in the circuit.
You may neglect \( I_B \) (assume that it's 0).

\[ I_{R1} = \ldots \]

b) Is the transistor operating in the active region?
(circle one) Yes No

Show your evidence.

c) If \( R_C \) is too big the transistor will no longer be in its active region and will saturate. What value of \( R_C \) just begins to cause saturation? Hint: Assume \( V_{CE} = 0.2 \) V and find the \( R_C \) that would cause that.

d) \( \beta = 150 \) Use the value of \( I_C \) that you calculated above to approximate the value of \( I_B \) (previously neglected).

e) Compare this value to \( I_{R1} \). Was it reasonable to neglect \( I_B \)? (is \( I_B < 10\% \) of \( I_{R1} \)) Yes No (circle one)

f) If the \( I_B \) from part d were correct, would \( V_B \) be lower, higher or the same as you found earlier?
(circle one) \( V_B \) would be: lower higher same

g) (4 pts extra credit) If the \( I_B \) from part d were correct, find \( V_B \). Hint: problem 1.

h) Considering only \( I_C \) and \( V_{CE} \), how much power does this transistor dissipate?

\[ \frac{V_o}{V_s} = ? \]

9. (8 pts) Design an amplifier with a gain of 10. The output voltage must be in phase with the input voltage (no inversion is allowed). Draw the circuit and show the values you would use.

10. (8 pts) Design an amplifier with a gain of 15. The output voltage should be 180 out of phase with the input voltage (inversion is required). Its input resistance must be greater than 10 kΩ. That is, from the input's point of view, the amplifier should look like more than a 10 kΩ resistor hooked to ground.
11. (10 pts) You want to make the amplifier of problem 10 in the lab, using a LM324 op-amp. (Yes, you must have an answer for problem 10, make a guess if you don’t know but include at least two components besides the op-amp in your guess.)

Show parts with values (may be shown as schematic symbols).
Show power supply connections. (You don’t need to show extra power supply filter capacitors.)
Show all ground connections.
Show signal input connection(s).
Show scope connection(s) to observe the output on CH2.
Crossing wires will not be assumed to connect unless you show a dot at the crossing. I have shown CH1 scope connections to the signal generator as an example.

12. Do you want your grade and scores posted on my door and on the internet?  Yes  No  (Circle one)
If your answer is yes, then provide some sort of alias or password: ____________________________

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 an excel spreadsheet which you can download. Both will show all your homework, lab, and exam scores.

Answers

1. a) $V_{Th} = 2.2V$  b) $R = 898\Omega$  c) 2.11V

2. $2.2V - 2.2V \cdot e^{-\frac{1}{1.8ms}}$

3. a) 0.1A  b) 13.2V

4. a) $I_{in} = 20mA / 36.9^\circ$  b) $V_T = 4.57V / 44.7^\circ$  c) 0.844  d) ii, leading, angle of $V_T$ is greater than $I_{in}$

5. a) $0 = s^2 + \frac{1}{R^2C}s + \frac{1}{LC}$  b) -50,000 1/sec  c) ii, critically damped

6. a) 28mA  50mA  80mA  22mA  -30mA  b) yes, $I_{D1} = 22mA > 0$  c) no, $I_{D2} = -30mA < 0$

7. $V_0 vs t$

8. a) $V_B = 2.2V$  $I_{R1} = 2mA$  $V_E = 1.5V$  $I_C = I_E = 15mA$
    b) $V_C = 7.5V$  $V_{CE} = 6V$  c) 687Ω  d) 0.1mA  e) $I_B = 5%I_{R1}$, yes  f) lower
    g) 2.11V  h) 90mW  i) 3

9. $R_1$ = any value from 100Ω to 110kΩ
   $R_1$ is 9 times bigger ($R_1 = 9R_1$).

10. $R_1$ = any value from 11kΩ to 66kΩ
    $R_1$ is 15 times bigger ($R_1 = 15R_1$).