ECE 109 - TRANSFER FUNCTIONS - INVESTIGATION 24
MAXIMUM POWER IN RESISTOR CIRCUITS

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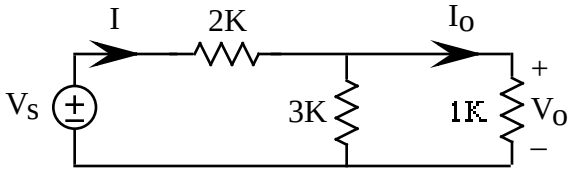
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

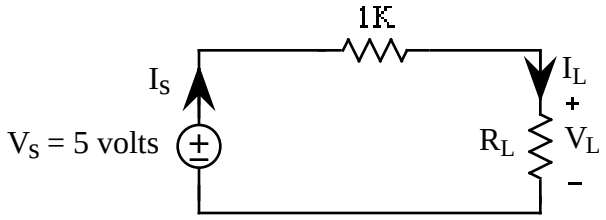
From the last four Investigations we know how to find and make use of Thevenin Equivalent circuits. The objective of this Investigation is to make use of Thevenin's Equivalents to determine how the value of a circuit's load resistor affects the power being delivered to it.

1. We begin with a review problem. Given the following circuit



   a. Find the equivalent resistance $R_{EQ} = V_S / I$
   b. Find $G_1 = V_O / V_S$
   c. Find $G_2 = I_O / V_S$

2. The objective of this problem is to find the value of the load resistor R_L in the following simple circuit



   for which the power P_L is maximum

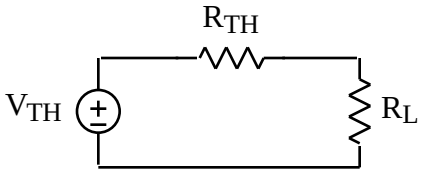
   a. **Before** you do any calculations, sketch V_S and I_S on separate graphs as functions of R_L. Then make use of these two graphs to graph the power $P_S = V_S I_S$ being delivered to the circuit as a function of R_L. Describe and explain your graph for V_S
   b. **Before** you do any calculations, sketch V_L and I_L on separate graphs as functions of R_L. Then make use of these two graphs to graph the power $P_L = V_L I_L$ as a function of R_L. Describe and explain your graph for P_L
   c. Now find an expression for P_L as a function of just R_L.
   d. Make use of your result in part (c) to calculate P_L for R_L = 0, 0.2K, 0.4K, 0.6K, 0.8K, 1K, 1.5K, 2K and 3K. Now plot the individual points and then connect them together to form a continuous curve. Describe your graph. Does it make sense. Explain
   e. Use Mathcad to obtain a graph of P_L as a function of R_L. Then make use of your graph to graphically find the value of R_L where P_L is maximum
   f. Analytically find the value of R_L that makes P_L maximum by finding where

$$\frac{dP_L}{dR_L} = 0$$

What is the corresponding maximum value of P_L

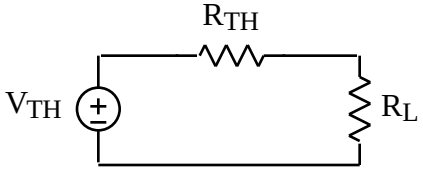
g. Compare your analytical and graphical results in parts (d) and (e) for the value of R_L for maximum power.

3. The objective of this problem is to generalize on the result in Problem (2) and find the value of R_L that maximizes the power P_L in the following Thevenin Equivalent

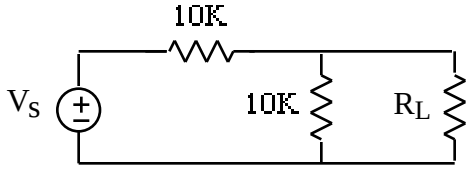


a. First find the power P_L as a function of R_L, R_{TH} and V_{TH}
b. Then go through the analysis to find the value of R_L that maximizes P_L

4. From Problem (3) we know that maximum power will be delivered to the load R_L in the following circuit when $R_L = R_{TH}$

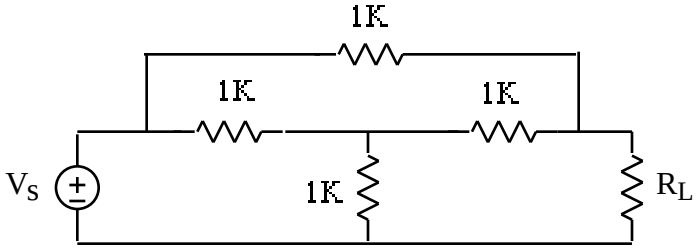


a. Make use of this result to find R_L for maximum power in the following circuit

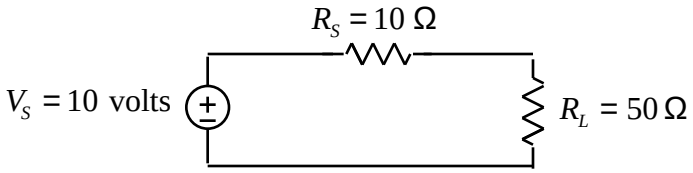


b. What is the maximum power delivered to R_L in part (a) if V_S = 5 volts

5. Find the value of R_L with maximum power in the following circuit



6. Suppose you get an advertisement to replace the voltage source in the following circuit



with a new source at only twice the price that has a source resistance $R_S = 50\Omega$ to "match your load and maximize your power transfer". Would you spend the extra money on this new source. Justify your answer.

7. Sketch graphs of each of the following sinusoids on separate graphs in preparation for the Investigations with time-varying inputs
   a. $x_1(t) = 2\cos(2\pi 1000t)$
   b. $x_2(t) = 5\cos(2\pi 1000t)$
   c. $x_3(t) = 5\cos(2\pi 1000t - \pi/3)$
   d. $x_3(t) = 5\cos(2\pi 1000t + \pi/3)$

8. Math Review - Sketch $x_1(t) = 2\cos(2\pi 100t)$ and $x_2(t) = 3\cos(2\pi 100t)$ on the same graph. Identify which is which