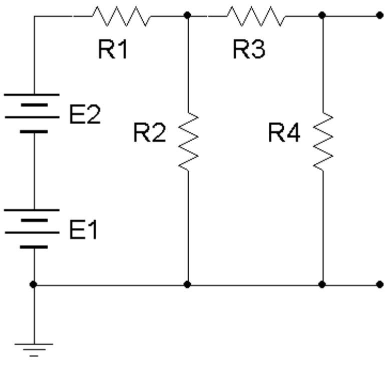
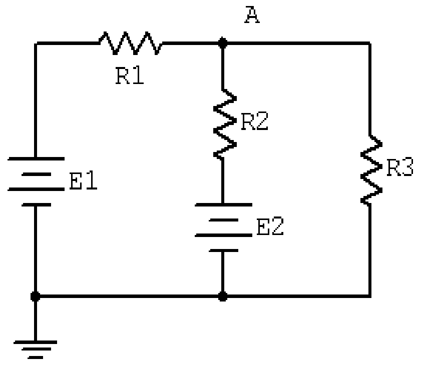
DC Circuits Self Test: Series-Parallel and More

1. For the circuit below, find the voltages across R3 and R4. Also find the current through R1. E1=6V, E2=20V, R1=1k, R2=2k, R3=3k, R4=5k



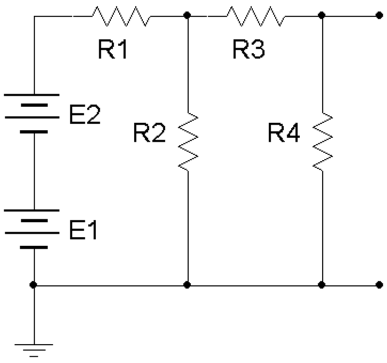
2. Solve the circuit below for the voltage across R3 (i.e., V_A). Do this three ways: A) Convert the sources, combine and solve; B) Use Superposition; C) Create a Thevenin equivalent that drives R3 and solve. E1=10V, E2=20V, R1=1k, R2=2k, R3=3k.



3. Bonus question: What value of R3 in problem 2 produces maximum power in R3 and what is that power?

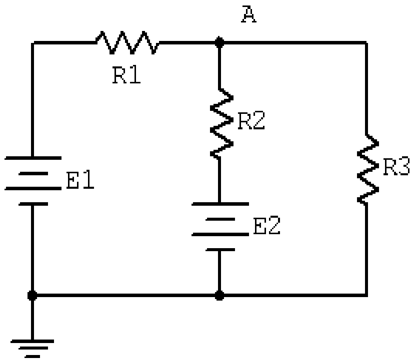
Answers

1. For the circuit below, find the voltages across R3 and R4. Also find the current through R1. E1=6V, E2=20V, R1=1k, R2=2k, R3=3k, R4=5k



E1 and E2 are in series for a total of 26V. One way to find the voltages across R3 and R4 is to first find the voltage across R2 and then perform a voltage divider. The voltage across R2 can also be found via a voltage divider. The 26V source is split between R1 (1k) and the combination of R2 in parallel with the series sum of R3 and R4, or 2k||(3k+5k)=1.6k. By VDR, VR2 is 26V*1.6k/(1k+1.6k)=16V. This voltage is then split between R3 and R4. Using VDR again, VR4=16*5k/(5k+3k)=10V, and by KVL, VR3=16V-10V or 6V. Finally, VR1=26V-16V (from KVL) or 10V. Therefore, IR1=10V/1k=10mA.

2. Solve the circuit below for the voltage across R3 (i.e., V_A). Do this three ways: A) Convert the sources, combine and solve; B) Use Superposition; C) Create a Thevenin equivalent that drives R3 and solve. E1=10V, E2=20V, R1=1k, R2=2k, R3=3k.



A: The first source converts to 10V/1k=10mA in parallel with 1k. The second converts to 20V/2k=10mA in parallel with 2k. This leaves a complete parallel-only circuit consisting of 20mA feeding 1k||2k||3k=545.5. The parallel voltage is 20mA*545.5=10.91V

B: For superposition, consider each source by itself and replace all other sources with their ideal internal resistance (a short for E sources, an open for I sources). For E1 we wind up with E1 feeding R1 which is in series with the parallel combo of R2||R3. R2||R3=1.2k. A voltage divider will yield VR3 thusly: VR3=10V*1.2k/(1k+1.2k)=5.455V. Considering source E2, we wind up with E2 feeding R2 which is in series with the combo of R1||R3. R1||R3=750. A voltage divider yields VR3 as follows: VR3=20V*750/(750+2k)=5.455V. Both of these potentials are positive with respect to ground so we add them to find the final value of VR3, or 5.455+5.455=10.91V.

C: For the Thevenin equivalent, unhook R3 and peer into the two remaining ports. Replace the sources with their ideal internal resistances (short the E sources) to find Rth. This yields R1||R2 or 666.7. Eth is the open circuit output voltage which is V_A (with R3 removed, of course). The resulting circuit is a simple series loop. Note that E2 and E1 oppose producing 20V-10V=10V with the polarity of E2 (a counterclockwise current). This potential splits between R1 and R2. VR2=10V*2k/(1k+2k)=6.667V. Note the polarity of VR2 is + to - ground to A. Therefore, V_A=E2-VR2 or 20V-6.667=13.333V. The Thevenin equivalent is 13.333V in series with 666.7 ohms. Apply this to the load (R3) and use VDR to solve for VR3. VR3=13.333*3k/(3k+666.7)=10.91V.

3. Use the Thevenin equivalent. R3 is set to Rth or 666.7. The load will see half the Thevenin voltage due to matched resistors. $P=V^2/R$ so Pload_max = $(13.333/2)^2/666.7$=66.67mW.