Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

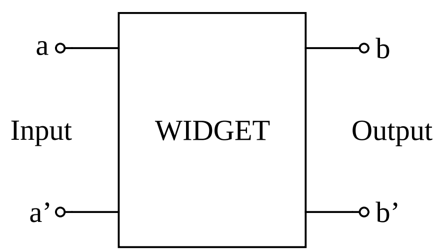
6.002 – Circuits and Electronics
Spring 2003

Handout S03-013 - Homework #2

Issued: Wed. Feb 12
Due: Fri. Feb 21

Note: Do your work on problems 2.2 through 2.4 directly on these sheets and turn them in with your solutions to the remaining problems.

Problem 2.1: Imagine a device called a "widget" which has the electrical characteristics shown below:



There is no electrical connection between the input terminals and the output terminals.

When a signal of 0 Volts is applied to aa', the resistance between b and b' is negligibly small, and may be approximated by a short circuit.

When a ± 5 V signal is applied to aa', the resistance between b and b' is very large, and may be approximated by an open circuit.

In the following problems, you are free to use constant voltage sources and resistors.

(A) Can widgets be combined to create a NAND gate? Demonstrate.

(B) Can widgets be combined to create a AND gate? Demonstrate.

(C) Can widgets be combined to create a NOR gate? Demonstrate.

(D) Can widgets be combined to create a OR gate? Demonstrate.

Name:____

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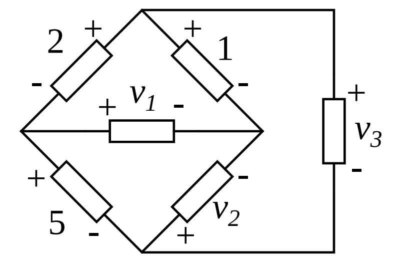
Problem 2.2: In each of the following circuits, determine the values of the indicated voltages and/or currents.. (Voltages are in volts and currents are in amperes.)

(a)

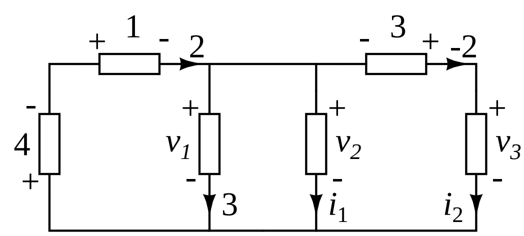


$v_1 =$ __________

$v_2 =$ __________

$v_3 =$ __________

(b)



$v_1 =$ __________

$v_2 =$ __________

$v_3 =$ __________

$i_1 =$ __________

$i_2 =$ __________

Name:______________________________________

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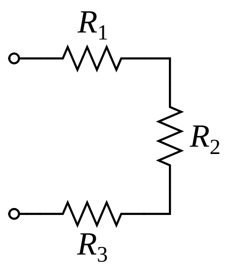
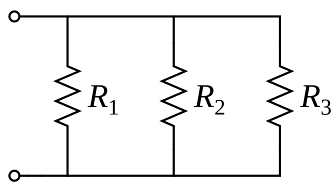
Problem 2.3: For each of the circuits below express the resistance R, or the equivalent conductance $G = \frac{1}{R}$, at the terminals in terms of the element resistances R_n (or conductances $G_n = \frac{1}{R_n}$). Write your answers next to the circuits.

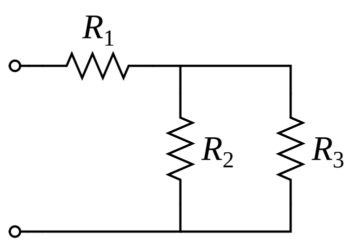
(a)



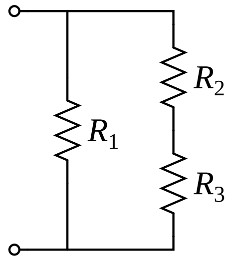
(b)



(c)



(d)



Name:____

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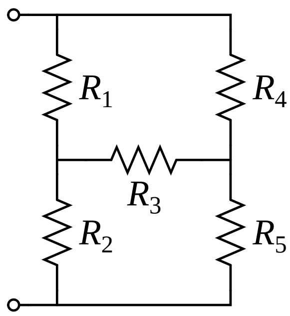
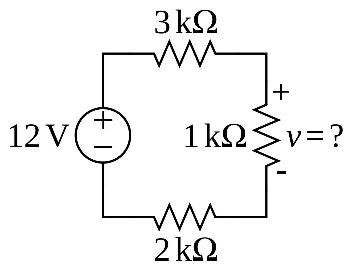
(e) Can the same methods used in Parts (a) through (d) be used to find the resistance at the terminals of the circuit below? If so, express it; if not, explain why not.

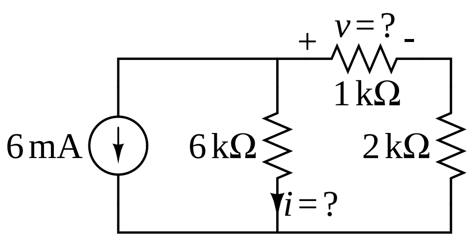


Problem 2.4: In each of the following circuits determine the voltages and/or currents indicated. The units are volts (V), milliamperes (mA), and kilo-ohms (kΩ).

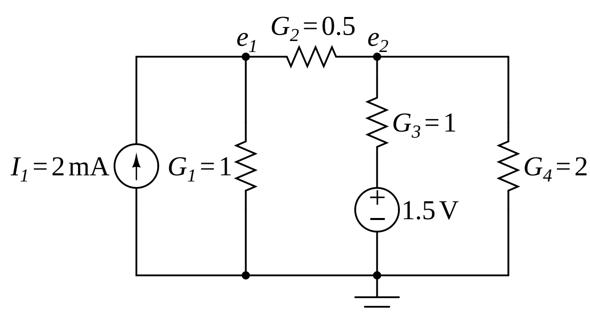
(a)



(b)



Problem 2.5: The circuit show below has two independent sources. All elements are assigned numerical values.



The units are volts (V), milliamperes (mA), and millimhos (mmho) (1 milliampere $= 10^{-3}$ amperes, 1 millimho $= 10^{-3}$mhos. The conductance of a resistor of R ohms is $\frac{1}{R}$ mhos).

The questions which follow illustrate the utility of the superposition principle in linear circuits.

1) Assume that the 2mA current source I_1 is active and the voltage source is inactive or dead. Redraw the circuit on your solution pages under these conditions.

2) Analyze this reduced circuit to obtain symbolic expressions for the voltages e_1 and e_2 in terms of the conductances. You should be able to do this without solving simultaneous equations by using parallel and series reductions to find e_1, and then working to the right to find e_2.

3) Substitute numbers for the symbolic element values in your results for part 2 and determine the values of e_1 and e_2 for I_1 acting alone. Specify units!

4) Repeat parts 1, 2, and 3 for the 1.5 V voltage source active and the other source dead. Use

series and parallel reductions.

5) Verify that the node equations for the complete circuit are:

$$\begin{aligned}(G_1+G_2)e_1 \quad - \qquad\qquad G_2e_2 &= I_1\\ -G_2e_1 \quad + \quad (G_2+G_3+G_4)e_2 &= G_3V\end{aligned}$$

After turning the algebraic crank, the symbolic forms of the two node equations for the original two-source circuit shown above yield the following solutions:

$$\begin{aligned}e_1 &= \frac{I_1(G_2+G_3+G_4)+VG_2G_3}{G_1(G_2+G_3+G_4)+G_2(G_3+G_4)}\\ e_2 &= \frac{I_1G_2+V(G_1+G_2)G_3}{G_1(G_2+G_3+G_4)+G_2(G_3+G_4)}\end{aligned}$$

When the component values are inserted in these equations, the results are:

$$\begin{aligned}e_1 &= 1.55\text{V}\\ e_2 &= 0.65\text{V}\end{aligned}$$

Add together the two component parts of e_1 and e_2 calculated in parts 3) and 4). That is:

$$e_1 = e_1\Big|_{I_1\ \substack{\text{Acting}\\ \text{Alone}}} + e_1\Big|_{V\ \substack{\text{Acting}\\ \text{Alone}}}$$

and similiarly for e_2. If your analysis is correct, the values of the voltages obtained in this manner – that is, by employing the superposition principle – will be the same as those obtained by solving the node equations simultaneously.

The amount of grind required is less when superposition is employed. This will be true whenever the circuit topology is such that series/parallel reductions can be employed