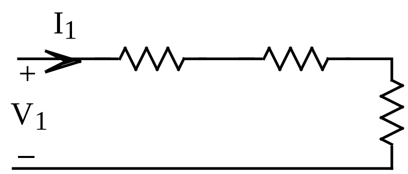
ECE 109 - EQUIVALENT CIRCUITS - INVESTIGATION 17
EQUIVALENT RESISTANCE

FALL 2006 **A.P. FELZER**

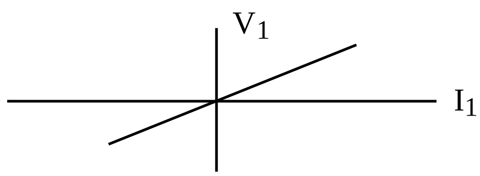
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs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

From our previous Investigations we know that series and parallel circuits have equivalent resistances R_{EQ}. The objective of this Investigation is to make use of our results on node equations to demonstrate that general resistor circuits also have equivalent resistances. Be sure to take a look at the **Computer Demos** on Equivalent Resistances of General Resistor Circuits.

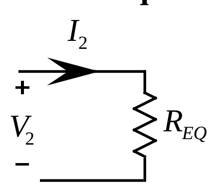
1. As we said in the introduction we know from our Investigations on series and parallel resistor circuits that the voltage V_1 across a series resistor circuit like the following



is proportional to the current I_1 flowing through it as follows



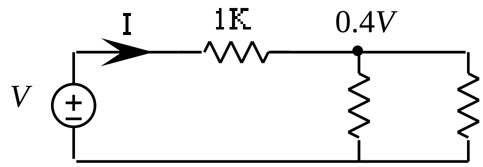
with $V_1 = R_{EQ}I_1$. And so we say this circuit is **equivalent** to a single resistor R_{EQ} as follows



because **whenever** $V_1 = V_2$ **then** $I_1 = I_2$. We say they're equivalent because both circuits respond to the outside world the same - they both have the same currents flowing into them whenever the voltages across them are the same. What this all boils down to, of course, is that the equation for V_1 as a function of I_1 is the same as that for V_2 as a function of I_2. By the same analysis we can also show that parallel resistor circuits are equivalent to single resistors. Now make use of these results to

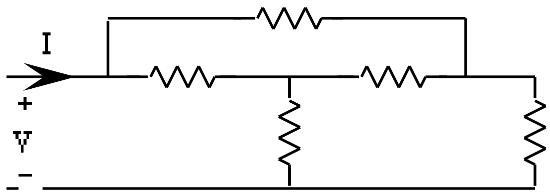
   a. Find and draw the equivalent resistance R_{EQ} of three 1K resistors connected in series
   b. Find and draw the equivalent resistance R_{EQ} of two 2K resistors in parallel

2. Find I as a function of V in the following circuit



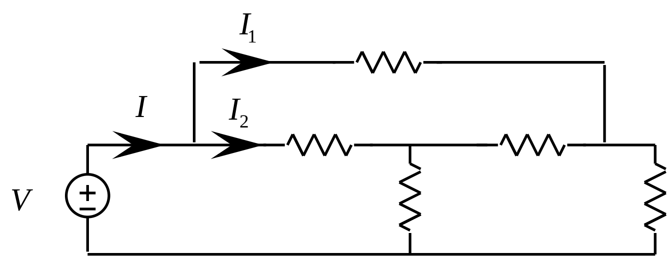
and then make use of the result to find the circuit's equivalent resistance $R_{EQ} = V/I$. Note that $V_1 = 0.4V$ is 0.4 times the value of the input voltage source - V does not stand for volts.

3. The objective of this and the rest of the problems in this investigation is to illustrate the fact that general resistor ciricuits are equivalent to single resistors just like simple series and parallel circuits are. The procedure for finding $R_{EQ} = V/I$ of general resistor circuits like the following



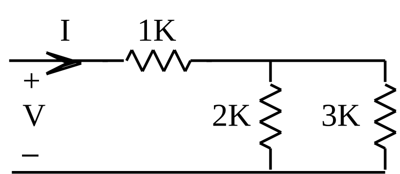
is the same as for series and parallel circuits except that now we must use more general analysis methods like node equations as follows:

(1) We first connect a voltage source (just like we did for series and parallel circuits) as follows

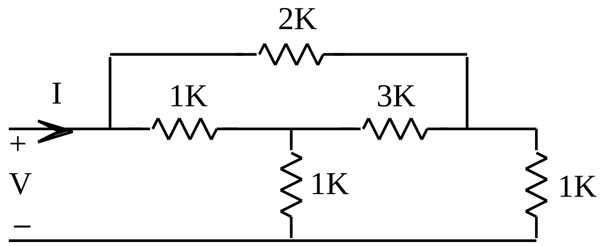


(2) Then solve the node equations for the node voltages in terms of V
(3) Then make use of Ohm's Law and the node voltages from Step (2) to express $I = I_1 + I_2$ in terms of V
(4) And finally solve for $R_{EQ} = V/I$

Memorize this general procedure for finding R_{EQ} of resistor circuits. And then make use of it to find and draw R_{EQ} of the following circuit.

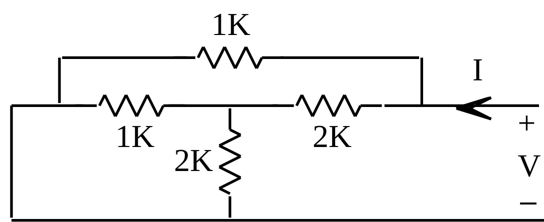


4. Given the following circuit

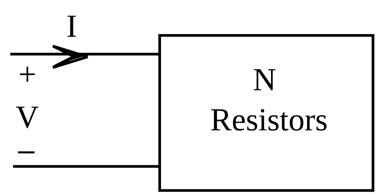


a. Use the algorithm of Problem (3) to find R_{EQ} and then make use of your result to sketch V as a function of I
b. What is the total power being delivered to the resistors in the circuit of part (b) if V = 5 volts. How much energy will be delivered in 10 minutes

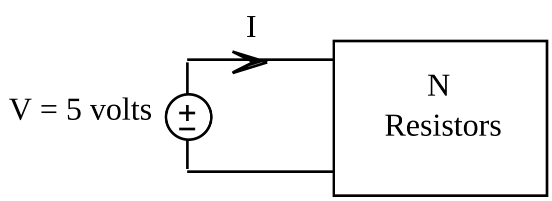
5. Use the algorithm of Problem (3) to find the equivalent resistance $R_{EQ} = V/I$ of the following circuit



6. Suppose we take a circuit N of resistors as follows

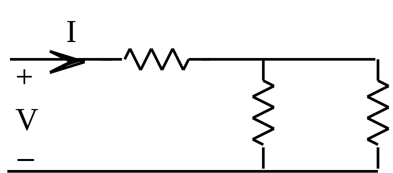


and connect a V = 5 volt source across it as follows



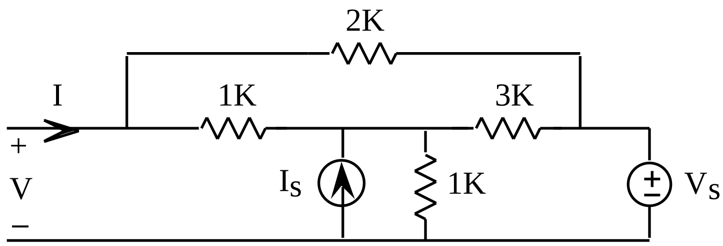
a. What is the equivalent resistance R_{EQ} of N if I = 2 ma.
b. What is I if $R_{EQ} = 2K$. *Be sure to redraw the circuit with N replaced by its equivalent resistance* R_{EQ} *before doing any calculations.*

7. Given the following circuit



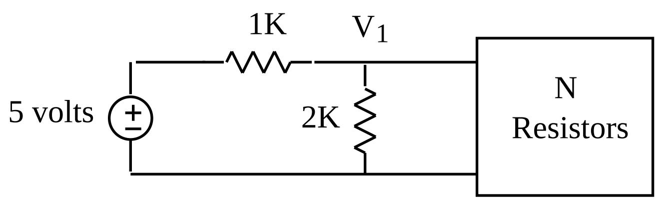
Find I when V = 5 volts if I = 2 ma when V = 3 volts. Explain how you got your result. As usual, be sure to draw all equivalent circuits.

8. Find the equivalent resistance R_{EQ} of the following circuit



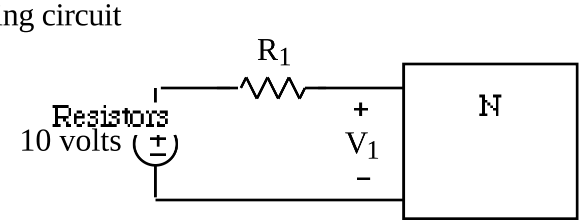
when both $I_S = 0$ and $V_S = 0$. Note that a current source with no current flowing through it is equivalent to an open circuit and a voltage source with no voltage across it is equivalent to a short circuit. *Be sure to redraw the circuit before you write any equations.*

9. Find V_1 in the following circuit



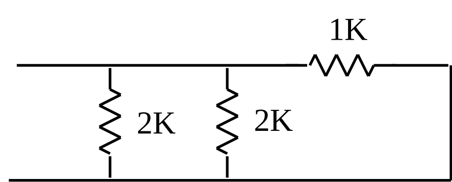
if the equivalent resistance of N is $R_{EQ} = 2K$. *Be sure to redraw the circuit with N replaced by its equivalent resistance before you write any equations.*

10. Find R_1 in the following circuit



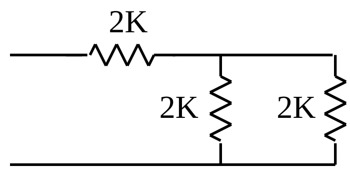
if $V_1 = 4$ volts and N has an equivalent resistance $R_{EQ} = 5K$. *Be sure to redraw the circuit with N replaced by its equivalent resistance before you write any equations.*

11. Find the equivalent resistance of the following circuit by **inspection** - without writing any equations

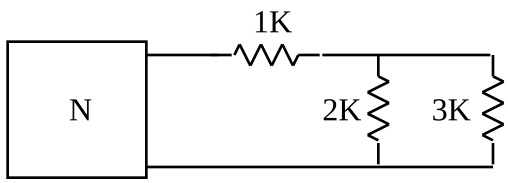


Be careful - many students get this one wrong the first time they do it.

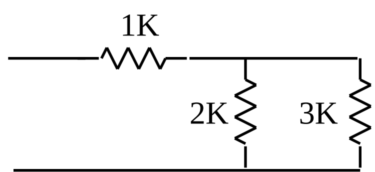
12. Find R_{EQ} of the following circuit by inspection



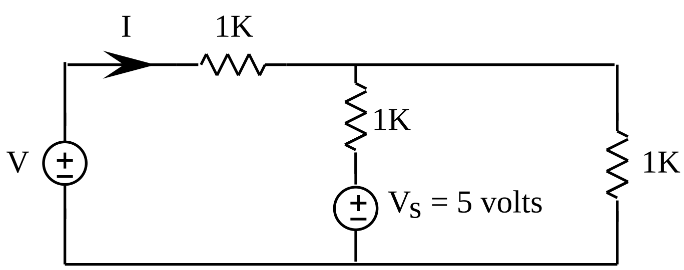
13. Find R_{EQ} of the resistors connected to N in the following circuit



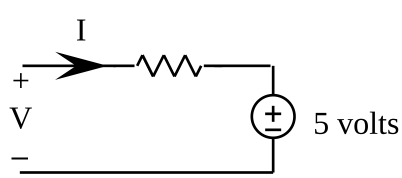
That is, find R_{EQ} of the resistor circuit



14. For review, find the value of V in the following circuit when $I = 0$

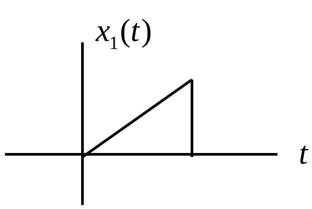


15. Find I and V in the following circuit



16. Math Review: Sketch the integrals of the following signals

a.



b.