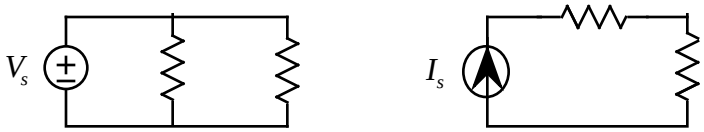
ECE 109 - SERIES AND PARALLEL - INVESTIGATION 11
EQUIVALENT RESISTANCE

SUMMER 2007 **A.P. FELZER**

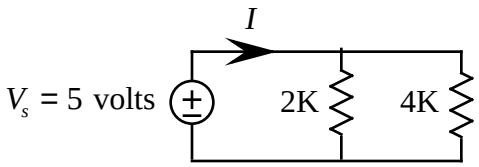
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs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

In the last two Investigations we saw how to calculate all the voltages and currents in parallel circuits with voltage sources and series circuits with current sources as follows

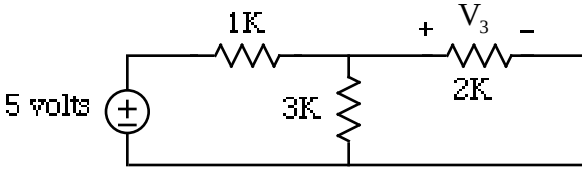


The objective of this Investigation is introduce equivalent resistances and show how they can be used to simplify the analysis of series circuits with voltage sources and parallel circuits with current sources. Be sure to take a look at the **Computer Demos** on Series and Parallel Resistor Circuits.

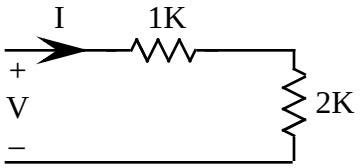
1. We begin with some review problems. Find the current I in the following circuit



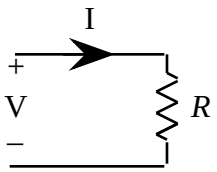
2. Find V_3 in the following circuit



3. Now suppose we have two resistors connected in series as follows

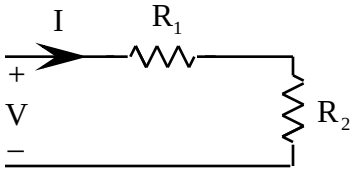


   a. Find V as a function of I. Hint - connect a current source of value I at the input and then analyze the circuit
   b. Make use of your result in part (a) to sketch V as a function of I
   c. Describe your graph in part (b)
   d. What single resistor R as follows

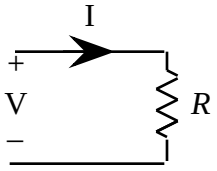


has the same equation and graph for V as a function of I

4. Generalizing on the circuit of Problem (3) as follows

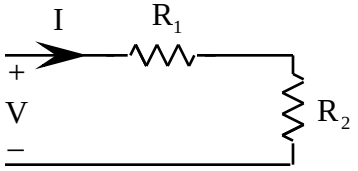


a. Find V as a function of I
b. Sketch V as a function of I
c. Describe your graph in part (b)
d. What single resistor R as follows



has the same equation and graph of V as a function of I

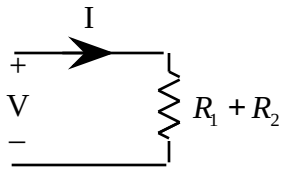
5. From Problem (4) we know that if R_1 and R_2 are in series as follows



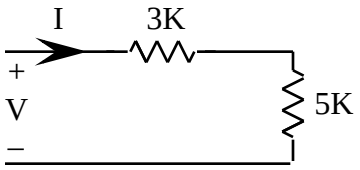
then V and I are related by the equation

$$V = (R_1 + R_2)I$$

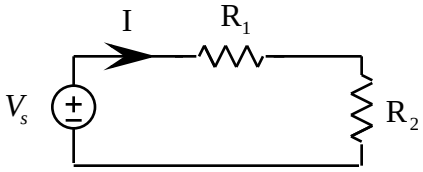
just like they are for a single resistor of value $R_1 + R_2$ as follows



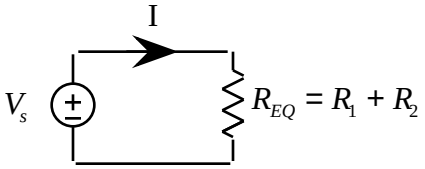
We call $R_{EQ} = R_1 + R_2$ the **equivalent resistance** of the series R_1 and R_2. Find and draw the equivalent resistance R_{EQ} of the following circuit



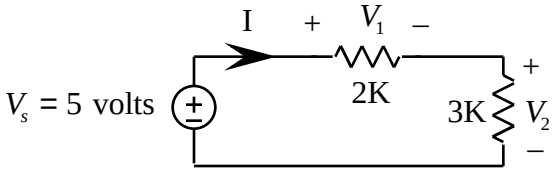
6. Equivalent resistance R_{EQ} is very useful because it enables us to find the current I in a series circuit like the following



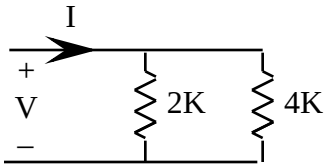
by analyzing the simpler equivalent circuit as follows



Make use of equivalent resistance to find I and the resistor voltages in the following circuit

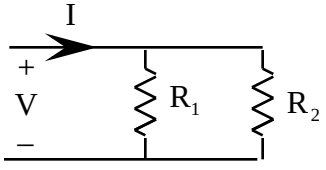


7. We now find the equivalent resistances of resistors connected in parallel like the following



   a. Find and sketch V as a function of I. Hint - connect a voltage source of value V across the input and then analyze the circuit
   b. Make use of your result in part (a) to find and draw the equivalent resistance R_{EQ} of this circuit

8. Generalizing on the circuit of Problem (7) as follows

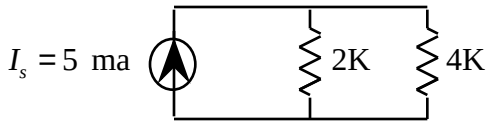


   a. Find and sketch V as a function of I
   b. Make use of your result in part (a) to verify that the equivalent resistance of this parallel

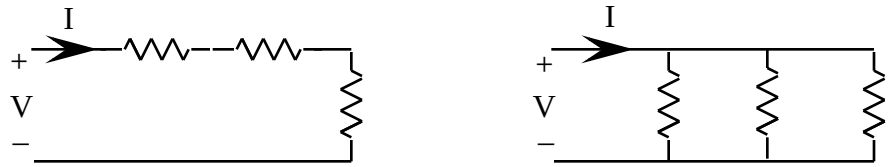
circuit is

$$R_{EQ} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

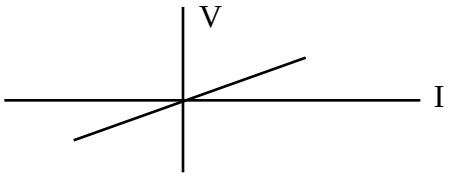
9. Make use of equivalent resistance to find all the voltages and currents in the following parallel circuit



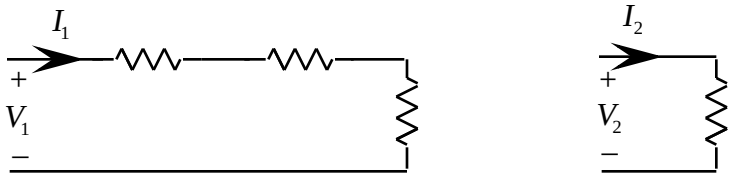
10. Generalizing on our series and parallel results we see that if connect sources across series and parallel circuits like the following



then V will be proportional to I with graphs as follows

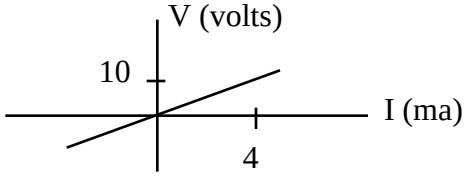


just like for single resistors and so are *equivalent* to single resistors - have the *same* currents $I_1 = I_2$ currents when they have the *same* voltages $V_1 = V_2$. **Memorize** this result. Now suppose we have two resistor circuits as follows



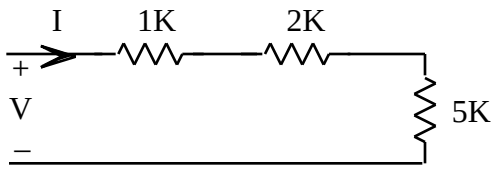
a. Find I_2 if $V_1 = V_2 = 5$ volts and $I_1 = 3$ ma and the circuits are equivalent
b. Find possible values of I_1 and I_2 if $V_1 = V_2 = 5$ volts and the circuits are not equivalent
c. Can the two circuits be equivalent if $V_1 = 1000 I_1$ and $V_2 = 900 I_2$. How can you tell

11. Find and draw the **equivalent resistance** R_{EQ} of a circuit with the following graph for V as a function of I

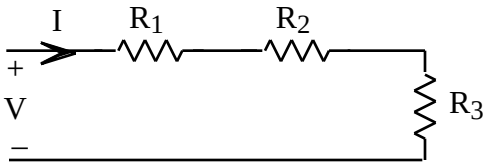


12. Find the equivalent resistances R_{EQ} of each of the following series resistor circuits by connecting a current source and then finding V as a function of I

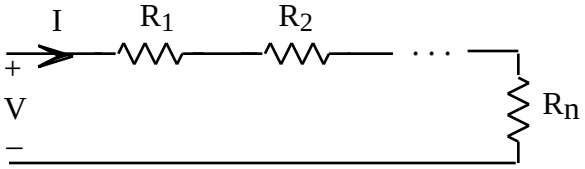
a.



b.



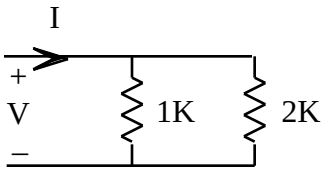
c.



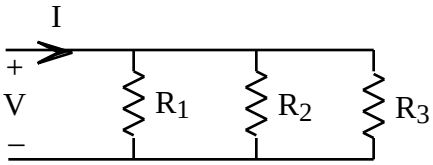
13. How will adding another resistor in a series circuit affect its equivalent resistance R_{EQ}. How do you know. **Memorize** this result.

14. Find and then draw the equivalent resistance R_{EQ} of each of the following parallel resistor circuits by connecting a voltage source and then finding V as a function of I

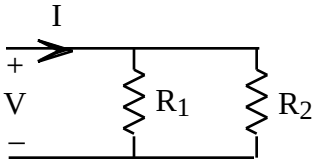
a.



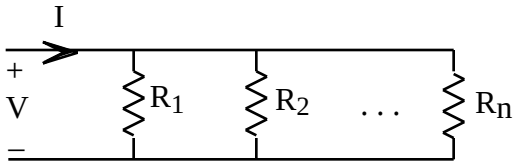
c.



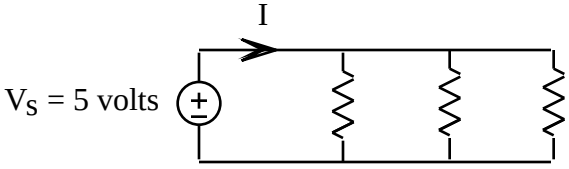
b.



d.



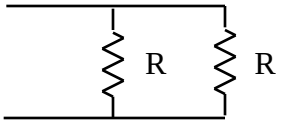
15. How will adding another resistor to a parallel circuit as follows

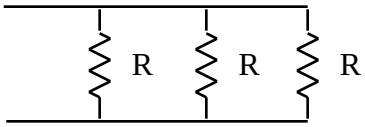


affect the value of its equivalent resistance R_{EQ}. How do you know. **Memorize** this result.

16. Find and draw the equivalent resistances of each of the following parallel circuits with equal

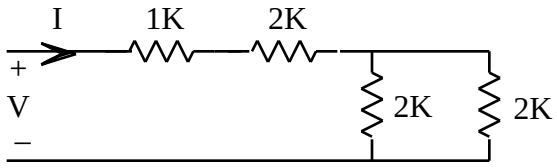
resistors

a. 

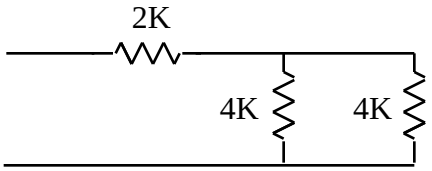
b. 

Memorize these results for the equivalent resistances of equal resistors in parallel

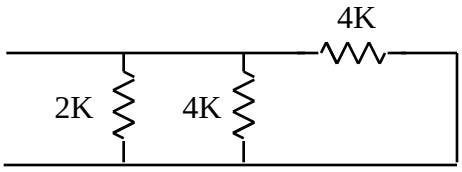
17. Find and draw the equivalent resistance R_{EQ} of the following circuit



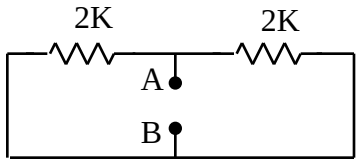
18. Find the equivalent resistance of the following circuit



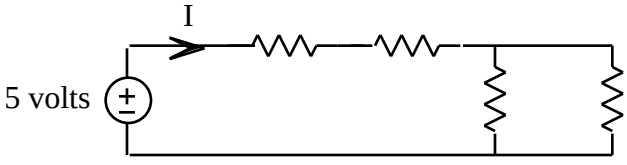
19. Find the equivalent resistance of the following circuit



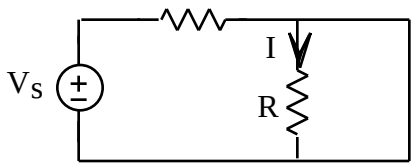
20. What will an ohmmeter read for R_{EQ} when connected to terminals A-B in the following circuit



21. Find and draw the equivalent resistance R_{EQ} of the following circuit with I = 2ma.

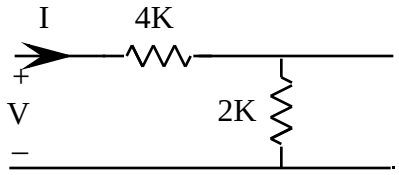


22. What is the current I in the following circuit. Explain why it has the value it does

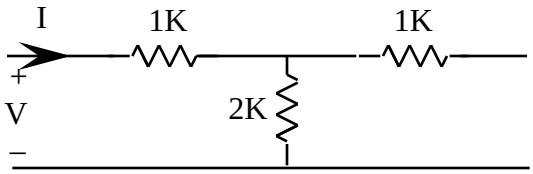


Note that we refer to the wire across R as a **short** and say R is **shorted out**

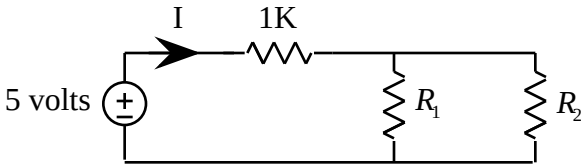
23. Find the equivalent resistance of the following circuit



24. Find the equivalent resistance $R_{EQ} = V/I$ of the following circuit

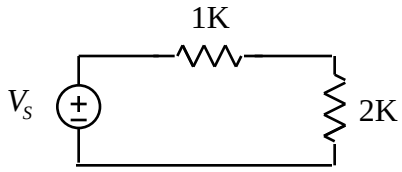


25. The importance of equivalent circuits like the ones we've been calculating is that they can simplify the analysis of complicated circuits. Find I in the following circuit



if the equivalent resistance of R_1 and R_2 is $R_{EQ} = 1K$

26. What is V_S in the following circuit



if the total power being delivered to the resistors is $P = 10$ mw

27. Math Review: Sketch the product $y_1(t) = x_1(t)\ x_2(t)$ of $x_1(t)$ and $x_2(t)$ as follows