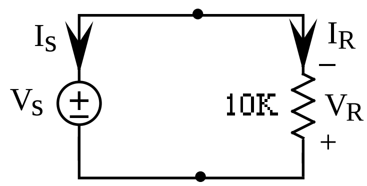
ECE 109 - THE VERY BASICS - INVESTIGATION 6
POWER AND ENERGY

SUMMER 2007 **A.P. FELZER**

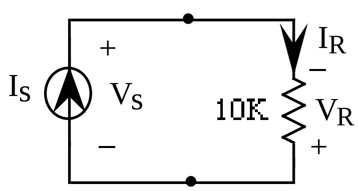
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs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

From the last Investigation we know how to analyze circuits with one resistor and one voltage source like the following



a. First find V_R from V_S
b. Then find I_R from V_R
c. And finally find I_S from I_R

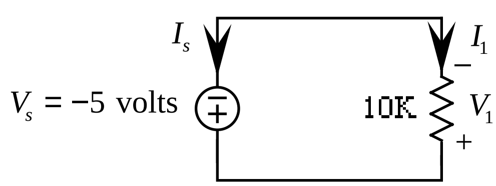
And we know how to analyze circuits with one current source and one resistor like the following



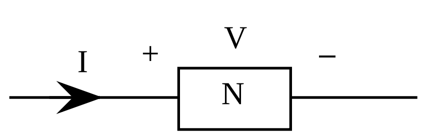
a. First find I_R from I_S
b. Then find V_R from I_R
c. And finally find V_S from V_R

The objective of this Investigation is to calculate the power and energy of such circuits. Power and energy calculations are particularly important because they tell us how long our batteries are going to last, how large our electric bills are going to be and how hot our circuits will get. Be sure to take a look at the **Computer Demos** on Energy and Power.

1. We begin with a review problem. Find V_1, I_1 and I_s in the following circuit



2. Let us begin by considering the energy being transferred between a circuit element N as follows



and the equivalent positive charges flowing through it.

a. Suppose that 3 joules of energy is transferred between N and every coulomb of equivalent positive charge that flows through it. Then the amount of energy transferred between N and 5 coulombs of equivalent positive charge is

$$\text{Energy Transferred } = \left(3\frac{joules}{coulomb}\right)(5\, coulombs) = 15\ joules$$

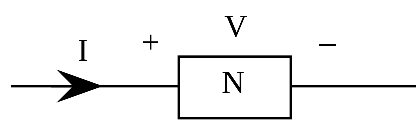
Now suppose that the equivalent positive charge flowing through N is flowing at the rate of 5 coulombs/sec. Then at what rate in joules/sec is energy being transferred between N and these equivalent positive charges. Do your calculation with all the units written out like in the equation above.

b. Find the rate energy is being transferred between N and the equivalent positive charges flowing through it if the voltage V across N and current I through N are as follows

$$\text{V} = 4\ volts = \left(4\ \frac{joules}{coulomb}\right) \quad \text{and} \quad \text{I} = 2\ amps = \left(2\ \frac{coulombs}{\text{sec}}\right)$$

c. Make use of your results in parts (a) and (b) to find an equation for the rate that energy is being transferred between N and the equivalent positive charge flowing through it in terms of V and I

3. From Problem (2) we have that if V is the voltage across and I the current through a circuit element N with associated reference directions as follows



then

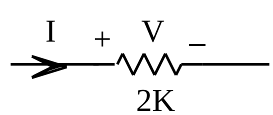
$$\text{Rate of Energy Transfer } = \left(V\ \frac{joules}{coulomb}\right)\left(I\ \frac{coulombs}{\text{sec}}\right) = VI\ \frac{joules}{\text{sec}}$$

But the rate energy is being transferred is by **definition** what we call the **power P**. So

$$P = VI$$

a. Explain in your own words why $P = VI$
b. Find the power for N in joules/sec if V = 6 volts and I = 3 amps

4. Now suppose we have a 2K resistor as follows



with a voltage

$$\text{V} = 5 \text{ volts} = 5\ \frac{\text{joules}}{\text{coulomb}}$$

across it and a current

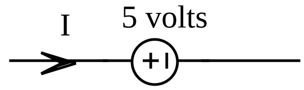
$$\text{I} = \frac{5 \text{ volts}}{2\text{x}10^{3} \text{ ohms}} = 2.5 \text{ ma} = 2.5\text{x}10^{-3}\ \frac{\text{couls}}{\text{sec}}$$

flowing through it

a. What's the power P - the rate in joules/sec - that energy is being transferred between the charges and the resistor. Explain how you got your result
b. How much energy E - in joules - would be transferred in 3 seconds

c. Which way is the energy being transferred - from the charged particles to the resistor or from the resistor to the charged particles. In particular, are the equivalent positive charges going from a higher to a lower potential and therefore transferring energy to the resistor or vice versa

5. Now suppose we have a voltage source



with a voltage

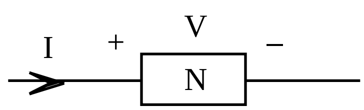
$$V_s = 5 \text{ volts} = 5 \frac{\text{joules}}{\text{coulomb}}$$

and a current

$$I = -2.5 \text{ ma} = -2.5\text{x}10^{-3} \frac{\text{couls}}{\text{sec}}$$

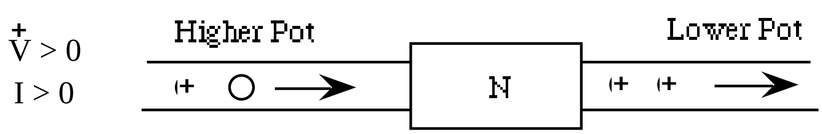
a. What's the power P - the rate in joules/sec is energy is being transferred between the charges and the source. Explain how you got your result
b. How much energy E - in joules - would be transferred in 3 seconds
c. Which way is the energy being transferred - from the charged particles to the voltage source or from the voltage source to the charged particles. Explain how you can tell

6. The objective of this problem is to determine the relationship between the signs of V and I of an arbitrary circuit element N as follows



and the direction energy is being transferred between N and the equivalent positive charges flowing through it.

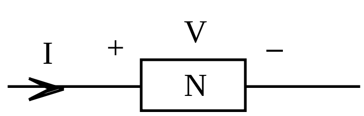
a. First draw pictures like this



for each of the following cases

(1) $V > 0$ and $I < 0$ (3) $V < 0$ and $I < 0$
(2) $V > 0$ and $I > 0$ (4) $V < 0$ and $I > 0$

Be sure to label which side is at the higher potential and which way the equivalent positive charge is flowing. Note that the reference directions for V and I as follows



stay the same as we change the values of V and I

b. Now make use of your data in part (a) to complete the following Table

V	I	VI	Direction of Energy Transfer
V>0	I>0	VI>0	$EPC \rightarrow N$

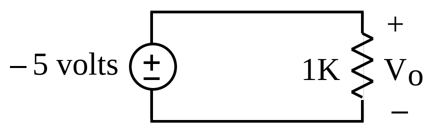
c. Make use of your results in parts (a) and (b) to determine what $P = VI > 0$ implies about the transfer of energy when the reference directions are associated: Are the epc transferring energy to N or is N transferring energy to them
d. Make use of your results in parts (a) and (b) to determine what $P = VI < 0$ implies about the transfer of energy when the reference directions are associated: Are the epc transferring energy to N or is N transferring energy to them
e. Why would you guess that engineers always use associated reference directions when calculating power.

7. We usually express powers P in units of **watts** where

$$1 \text{ watt} \equiv \frac{1 \text{ joule}}{\text{sec}}$$

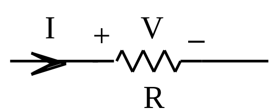
Go back and express the powers P in Problems (3) and (4) in terms of watts and milliwatts (mw)

8. Given the following circuit



a. Calculate the powers P of the voltage source and the resistor
b. What do the signs of the powers P in part (a) tell us about what's going on in the circuit
c. What is the sum of the two powers. Does this make sense. Explain

9. Given the following resistor



with associated reference directions - as usual

a. Find the power P in terms of just V and R. **Memorize** your result
b. Find an expression for the power P in terms of just I and R. **Memorize** your result
c. Make use of your results to show that $P \geq 0$ is always true for resistors
d. Find the energy transferred to the resistor in 10 seconds if V = 10 volts and I = 2 ma

10. Math Review: Make use of the equations $5 = 1000I + V$ and $V = RI$ to solve for V as a function of R