Tutorial 1

1. The capacity of a car battery is usually specified in ampere-hours. A battery rated at say, 100 A-h should be able to supply 100A for 1 h, or 50A for 2h, 25A for 4 h or any other combination yielding product of 100A-h. How many coulombs of charge should we be able to draw from a fully charged 100A-h battery?

Solution:

Known quantities:
Battery nominal rate of 100A-h.

To find:
The charge derived from the battery.

Assumptions:
Battery is fully charged.

Analysis:

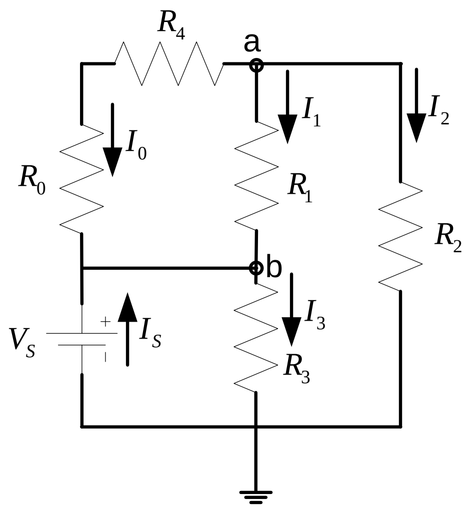
Current (Amp) = Charge (Coulomb) / time (second)

Charge (coulomb) = Current (Amp) x time (second)

Ans:

Charge potentially derived from the fully charged battery would be:
100 A-h = 100 (Amp) x 3600 (sec)=3600000=$3.6\text{x}10^5$ C .

2. Use Kirchoff's current law to determine the unknown currents in the circuit of the figure. Assume that I_0=-2A, I_1=-4A, I_s=8A and V_s=12V.



Solution:

Known quantities:
Currents in all but one branch attached to a node.

To find:
Unknown current in one of the branches attached to the node.

Analysis:
KCL can be used to find one unknown current if all the other currents into and out of a node are known.

For node (a), given currents are I_1 and I_0 are given and unknown current is I_2.

For super node around (b) , given currents are I_s, I_1 and I_0 and unknown current is I_3.

Ans:

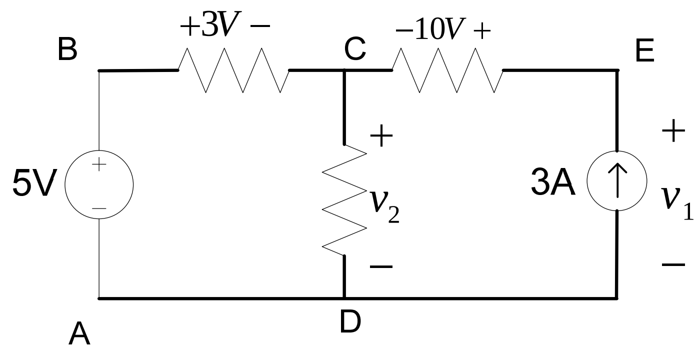
Applying KCL at node (a), sum of currents leaving node (a)=0

$$I_0 + I_1 + I_2 = 0 \Rightarrow I_2 = -(I_0 + I_1) = -(-2-4) = 6A$$

Applying KCL at super node (b), sum of currents leaving = 0

$$-I_0 - I_s - I_1 + I_3 = 0 \Rightarrow I_3 = I_0 + I_s + I_1 = -2-4+8 = 2A$$

3. Apply KVL to find the voltages v1 and v2 in the figure.



Solution:

Known quantities:

Voltage drops around all but one branch in the loop.

To find:

The unknown voltage across one of the branches in the loop.

Analysis:

According to KVL, the sum of voltage rises (or sum of voltage drops) around a closed loop is zero.

Ans:

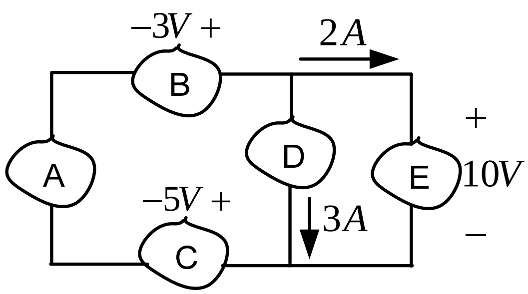
Applying sum of voltage rises around the loop ABCDA, we get

$5-3-v_2=0 \Rightarrow v_2=2V$

Applying sum of voltage falls (just to show as an alternate way) around the loop ABCEDA:

$-5+3-10+v_1=0 \Rightarrow v_1=12V$

4. For the circuit given here,
   a. Determine which components are absorbing power and which are delivering power.
   b. Is conservation of power satisfied? Explain your answer.



Solution:

Known quantities:
A circuit with a few voltages and currents.

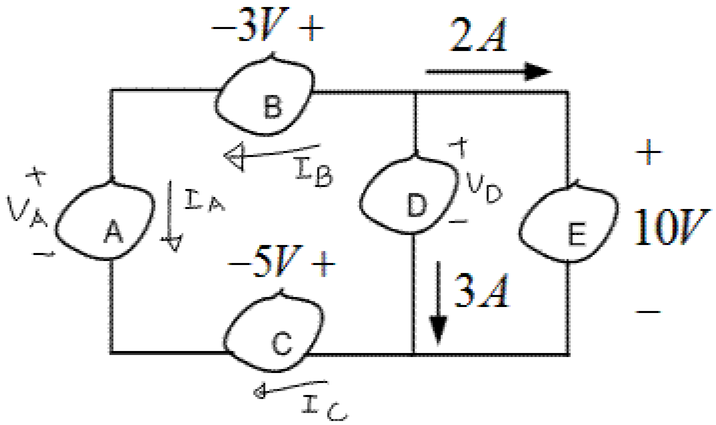
To find:
The power delivered by each elements.

Analysis:
We can do circuit analysis to find the voltage and current associated with all the elements in the circuit. Then we can find the power delivered each element.

We can label the unknown voltages and currents for the circuit following passive sign convention (current entering into the positive reference terminal for voltage).

Ans:

If we consider the loop containing ABEC, and apply KVL (sum of voltage rises):



$$V_A + 3 - 10 - 5 = 0 \Rightarrow V_A = 12V$$
$$V_D = V_E = 10V$$

Applying KCL at the junction (node) of B, D and E; sum of outgoing currents =0:

$$I_B + 2 + 3 = 0 \Rightarrow I_B = -5A$$

As elements A, B and C are in series, we

$$I_A = I_B = -5A$$
$$I_C = -I_A = 5A$$

With voltages and currents known for all the elements, following the passive sign convention.

We can calculate the power as product of voltage and current:

$P_A = V_A I_A = 12*(-5) = -60W$ i.e. element A is a generator.

$P_B = V_B I_B = 3*(-5) = -15W$ i.e. element B is a generator.

$P_C = V_C I_C = 5*5 = 25W$ i.e. element C is a passive element.

$P_D = V_D I_D = 10*3 = 30W$ i.e. element D is a passive element.

$P_E = V_E I_E = 10*2 = 20W$ i.e. element E is a passive element.

Total power supplied = 60+15=75W

Total power absorbed = 25+30+20=75W

Conservation of power is proved.

5. An incandescent light bulb rated at 100W will dissipate 100W as heat and light when connected across a 110-V ideal voltage source. If six of these are connected in series across the same source, determine the power each bulb will dissipate.

Solution:

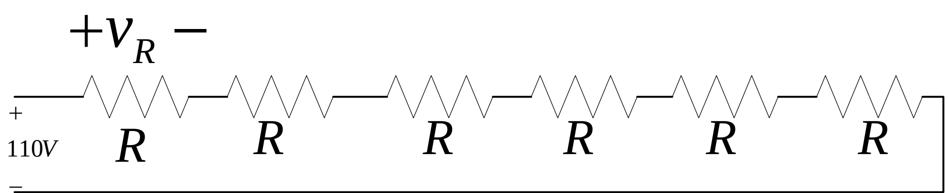
Known quantities:
Power and voltage rating of the bulbs.

To find:
The power dissipated by each bulb when six bulbs are connected in series.

Analysis:
We can find the resistance from the voltage and power rating. Use voltage divider principle, find the voltage across each bulb. From the voltage and resistance, we can find the power dissipated in each bulb.

Ans:
Rating of bulbs: P=100W, V=110V

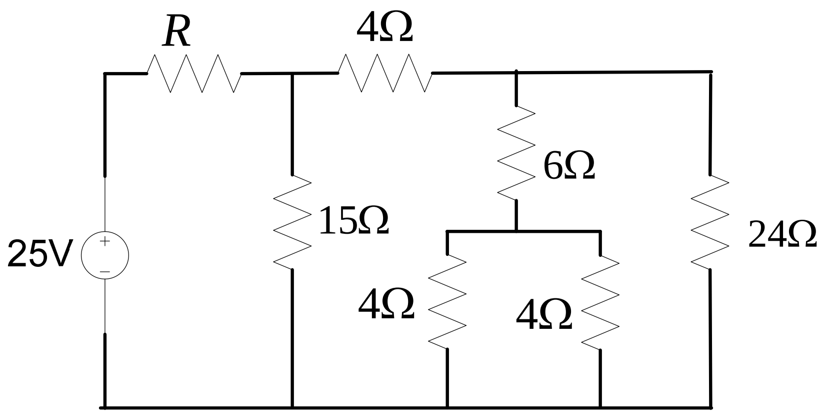
$$P = VI = V\frac{V}{R} = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{110 \times 110}{100} = 121\Omega$$



Applying voltage divider principle, voltage across each bulb is $v_R = 110 * \frac{R}{6R} = 18.33V$

Power dissipated in each bulb then, $P = \frac{V^2}{R} = \frac{18.33 \times 18.33}{121} = 2.78W$

6. In the circuit given here, the power absorbed by the 15-Ohm resistor is 15W. Find R.



Solution:

Known quantities:
Resistive network with the resistance and power in one branch (this gives the voltage and current in that branch)

To find:
To find the unknown resistance of a branch.

Analysis:
We can apply series/parallel equivalent for resistors to find the equivalent resistance parallel to the We can then apply current divider principle to find the current in the branch parallel to the 15Ohm branch. We can also find the total current through the unknown resistor.

As the voltage drop across the 15 Ohm resistor is known, from KVL, we can find the voltage drop across the unknown resistor R.

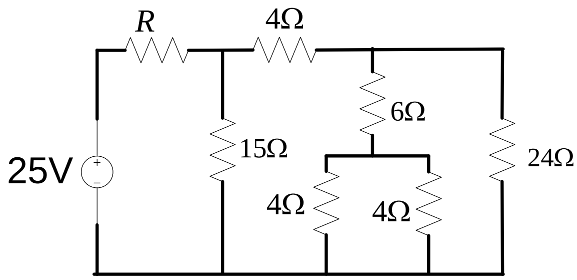
Then we can determine the unknown resistor R.

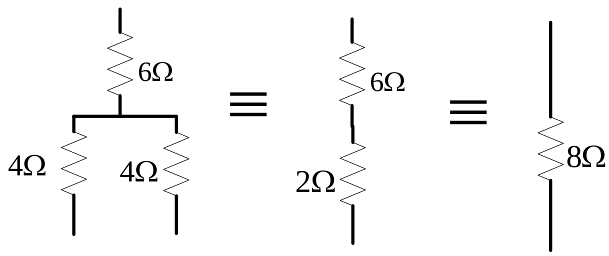
Ans:

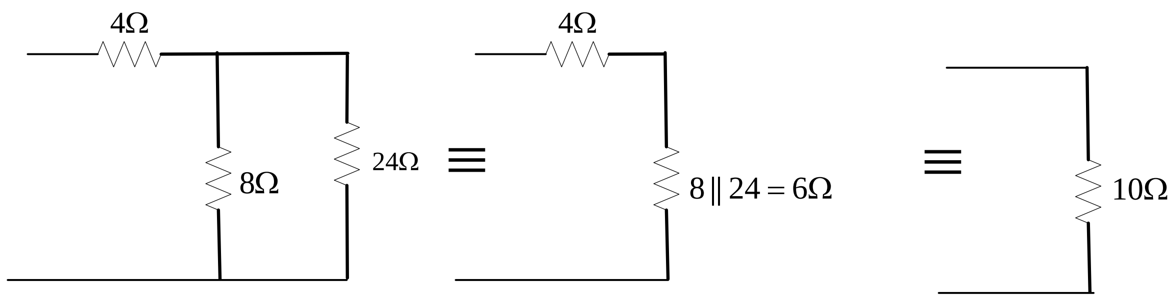
$$R = 15\Omega, P = 15W$$

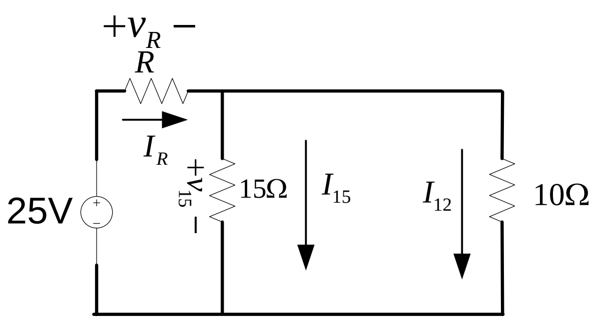
$$P = I^2 R \Rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{15}{15}} = 1A$$

We can use series/parallel rules for resistors to find the new equivalent circuit:









Applying current division principle:

$$I_{15} = I_R \frac{10}{10+15} = I_R \frac{10}{25}$$

$$I_{10} = I_R \frac{15}{10+15} = I_R \frac{15}{25}$$

$$\frac{I_{10}}{I_{15}} = \frac{15}{10} \Rightarrow I_{10} = I_{15} \frac{15}{10} = 1.5A$$

$$I_R = I_{15}\frac{25}{10} = 2.5A$$

Applying KVL around the loop containing the power supply, R and 15 Ohm resistor:

$$v_{15} = 15V$$
$$25 - v_R - v_{15} = 0 \Rightarrow v_R = 25 - 15 = 10V$$

We can now calculate the resistance R:

$$R = \frac{v_R}{I_R} = \frac{10}{2.5} = 4\Omega$$