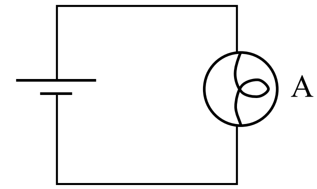
Resistor circuits

1. A bulb A is connected with ideal wires to an ideal battery as shown below.

a. Compare the potential difference across the bulb to the potential difference across the battery.



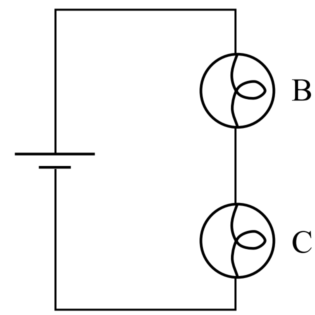
$$V_A = V_{battery}$$

b. Now two bulbs B and C, identical to the first one, are connected in series to the same battery . Compare:

• the current through bulbs B and C and through the battery.

$$I_B = I_C = I_{battery}$$

• the current through bulbs A (from section a), B and C.



$$I_B = I_C = \frac{I_A}{2}$$

• the potential difference across bulbs B and C and across the battery.

$$V_B = V_C = \frac{V_{battery}}{2}$$

• the potential difference across bulbs A, B and C.

$$V_B = V_C = \frac{V_A}{2}$$

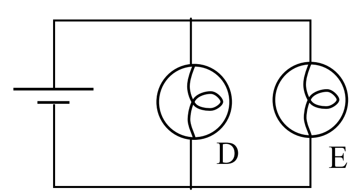
• the brightness of bulbs A, B and C.

Brightness means power:

$$P_B = P_C = \frac{P_A}{4} \qquad \left(P = I^2 R\right)$$

c. Finally, two bulbs D and E, identical to the first one, are connected in parallel to the same battery . Compare:

• the current through bulbs D and E and through the battery.



$$I_D = I_E = \frac{I_{battery}}{2}$$

• the current through bulbs A (from section a), D and E.

$$I_D = I_E = I_A$$

• the potential difference across bulbs D and E and across the battery.

$$V_D = V_E = V_{battery}$$

• the potential difference across bulbs A, D and E.

$$V_D = V_E = V_A$$

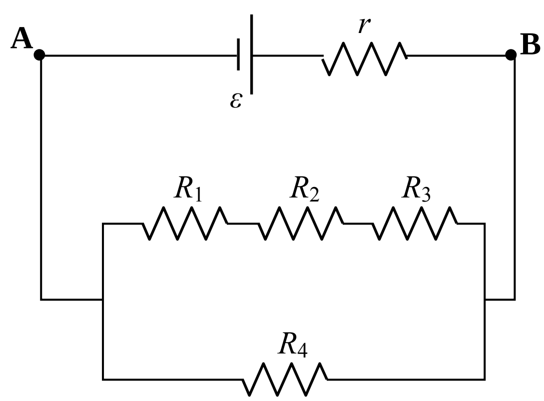
• the brightness of bulbs A, D and E.

$$P_D = P_E = P_A$$

d. Does the current through an ideal battery depend on the circuit to which it is connected? *Yes.*

e. Does the potential difference across an ideal battery depend on the circuit to which it is connected? *No.*

2. An ideal battery of emf ε = 12 V is connected to five resistors r, R_1, R_2, R_3 and R_4 as shown in the figure below. The current through r is 0.45 A.



R_1 = 10 Ω
R_2 = 20 Ω
R_3 = 30 Ω
R_4 = 40 Ω

Determine:

a. The magnitude of r.

$$R_{1-2-3} = R_1 + R_2 + R_3 = 60\ \Omega$$

$$R_{1-2-3-4} = \frac{1}{\dfrac{1}{R_{1-2-3}} + \dfrac{1}{R_4}} = 24\ \Omega$$

$$R_{all} = R_{1-2-3-4} + r$$

$$i = \frac{\varepsilon}{R_{1-2-3-4} + r} \qquad \Rightarrow \qquad r = \frac{\varepsilon}{i} - R_{1-2-3-4} = \frac{12\ \text{V}}{0.45\ \text{A}} - 24\ \Omega = 2.7\ \Omega$$

b. The potential difference between points A and B.

$$V_A - V_B = iR_{1-2-3-4} = (0.45\ \text{A})(24\ \Omega) = 10.8\ \text{V}$$

$$\left(\text{or} \quad V_A - V_B = \varepsilon - ir\right)$$

c. The power produced by the battery.

$$P_{battery} = \varepsilon i = (12\ \text{V})(0.45\ \text{A}) = 5.4\ \text{W}$$

d. The power dissipated in resistor 2.

$$P = R_2 i_2^2$$

I_2 is the current through the top part of the parallel connection (ie, the current through R_1, R_2 and R_3):

$$i_2 = \frac{V_A - V_B}{R_{1-2-3}} = \frac{10.8\ \text{V}}{60\ \Omega} = 0.18\ \text{A}$$

Thus,

$$P = R_2 i_2^2 = (20\ \Omega)(0.18\ \text{A})^2 = 0.65\ \text{W}$$