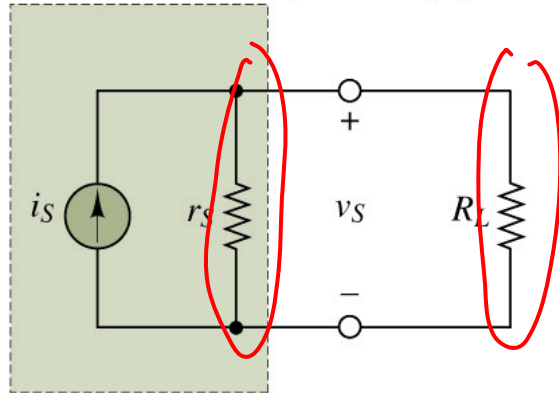
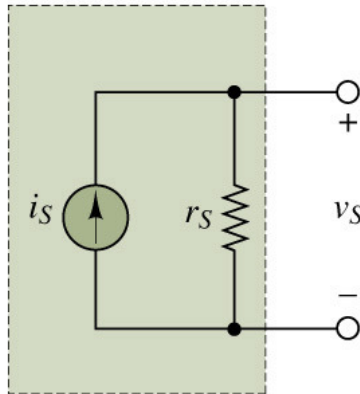


Practical current sources

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A model for practical current sources consists of an ideal source in *parallel* with an internal resistance.



Maximum output voltage for practical current source with open-circuit load:

$$v_{S \max} = i_s r_s$$

Ideal current source: $r_s = \infty$ (use r_s for internal resistance)

$$i_L = \frac{R_{EQ}}{R_L} i_s$$

$$\frac{1}{R_{EQ}} = \frac{1}{r_s} + \frac{1}{R_L} = \frac{r_s R_L}{r_s + R_L}$$

$$R_{EQ} = \frac{r_s R_L}{r_s + R_L} = \frac{r_s}{1 + \frac{R_L}{r_s}} i_s$$

The output current is now depend on the R_L

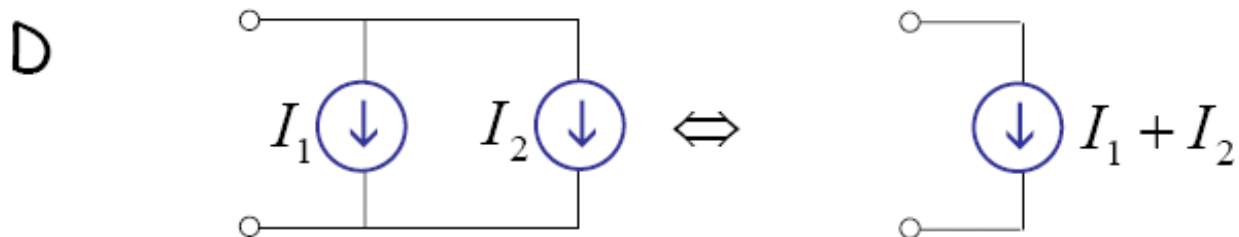
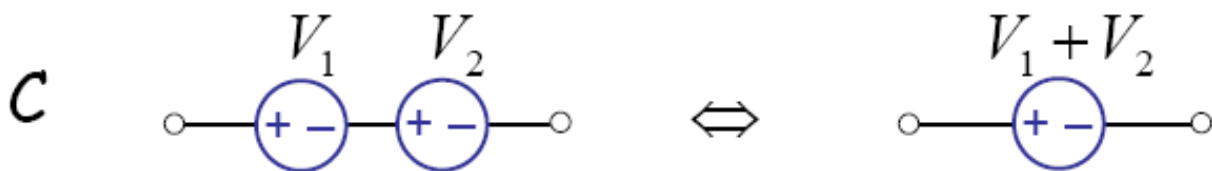
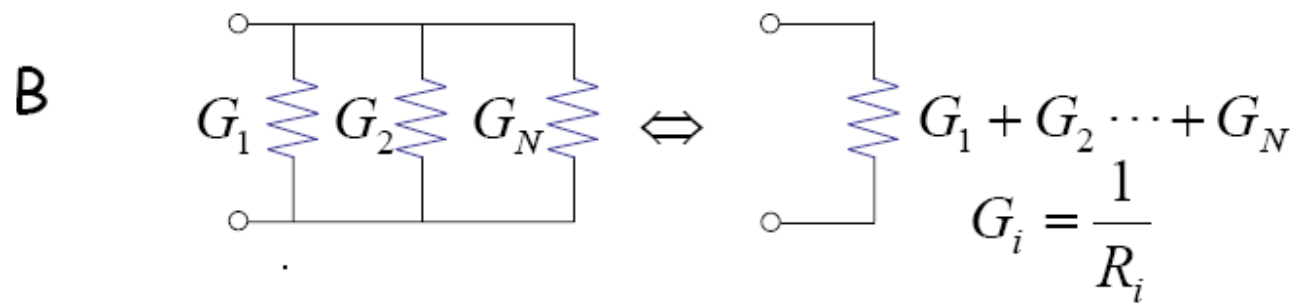
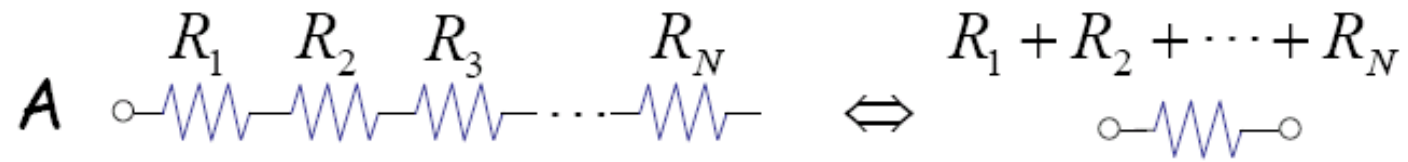
Make $r_s \gg R_L$, so $i_L \approx i_s$, independent on R_L

Concept Check

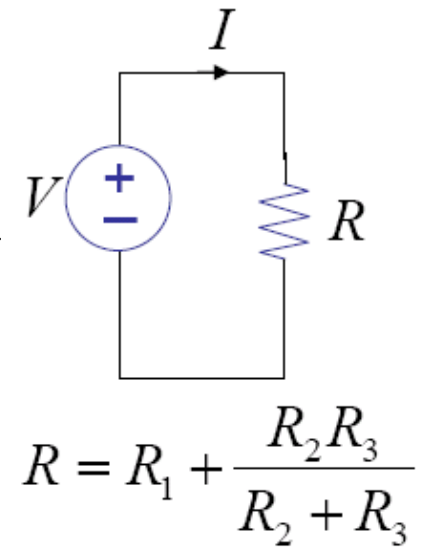
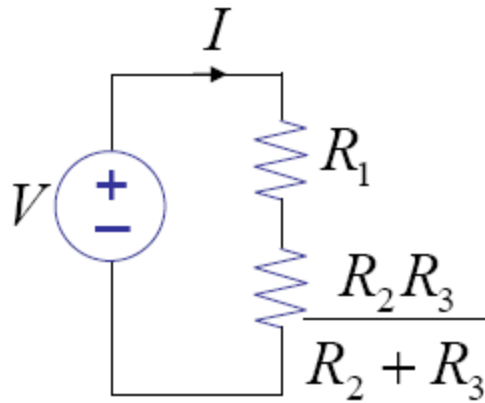
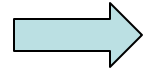
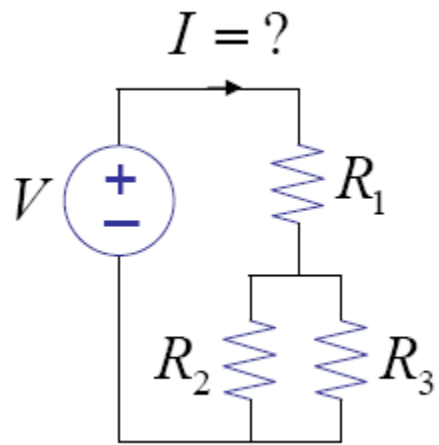
There are three identical batteries rated 1.5V and max. output current is 200 mA.

- If they are connected in series,
 - what is total output voltage?
 - What is max. output current?
- If they are connected in parallel,
 - what is total output voltage?
 - What is max. output current?

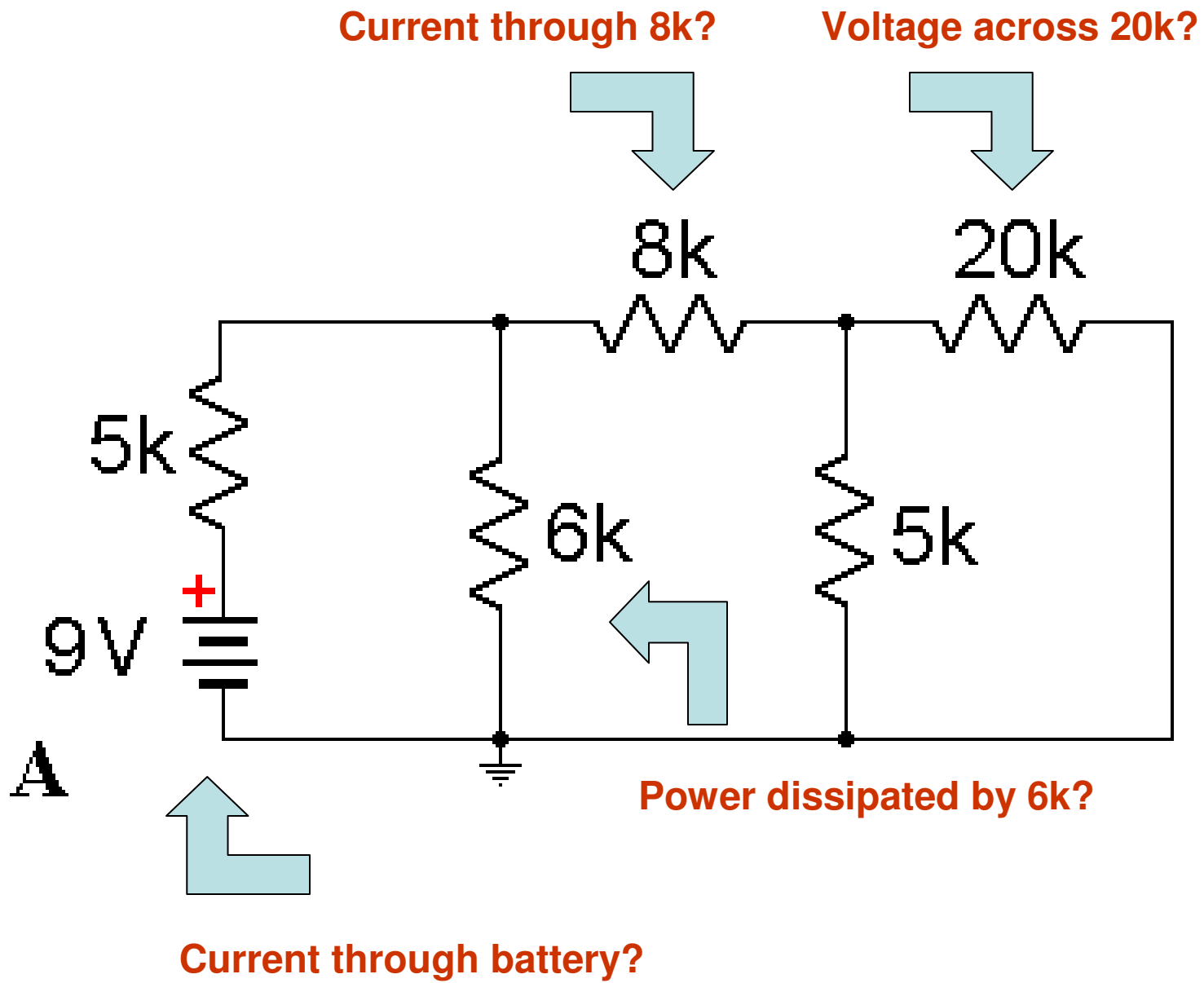
Method 1: Simple circuit analysis: Apply element combination rules



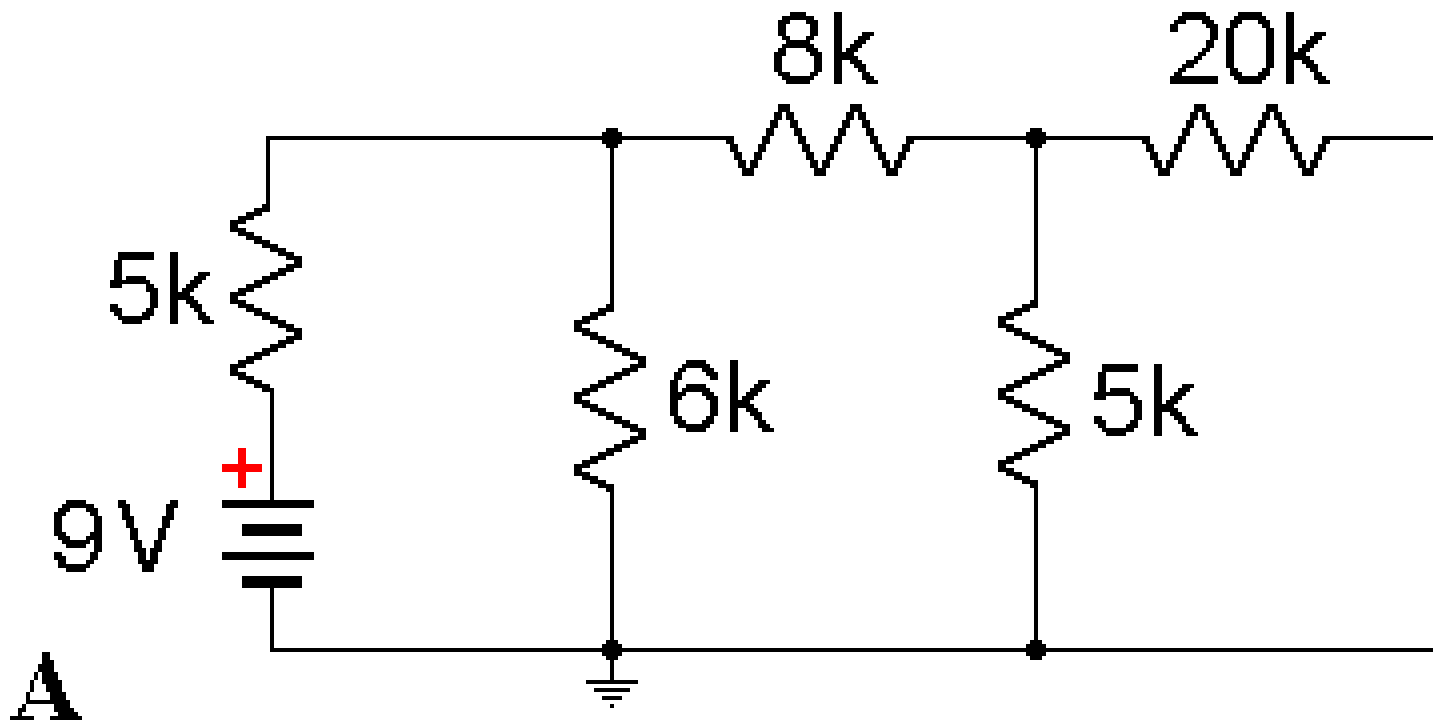
Example

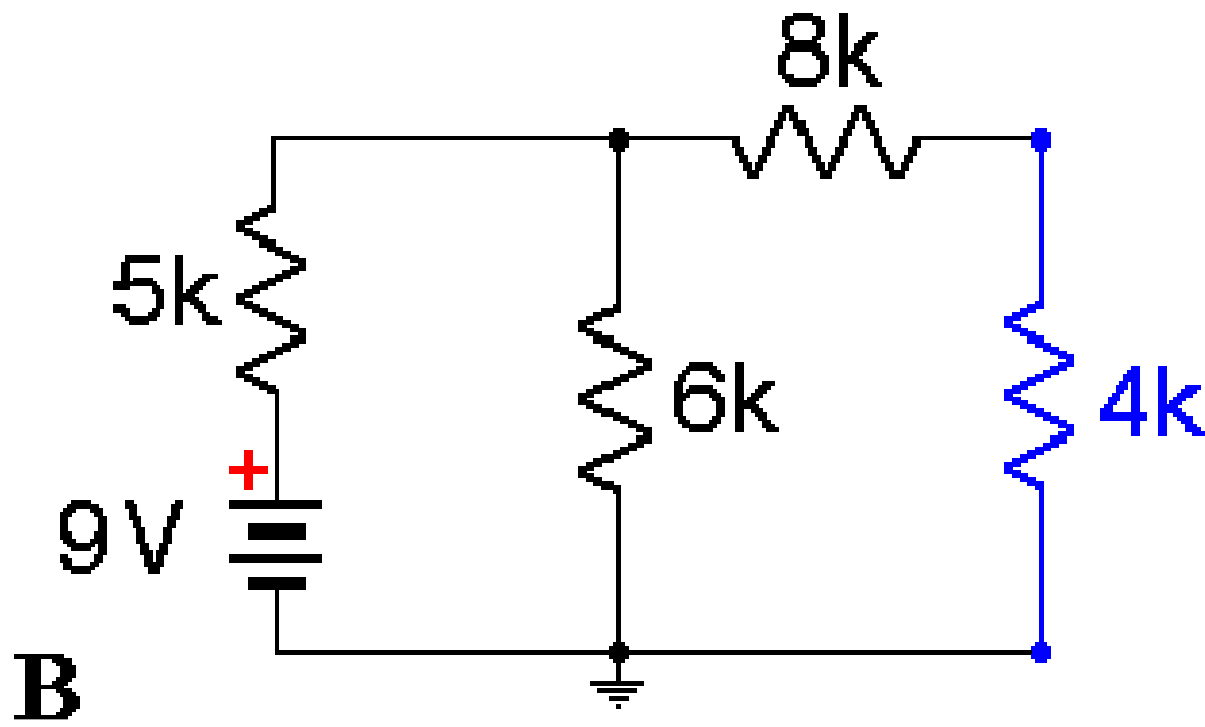


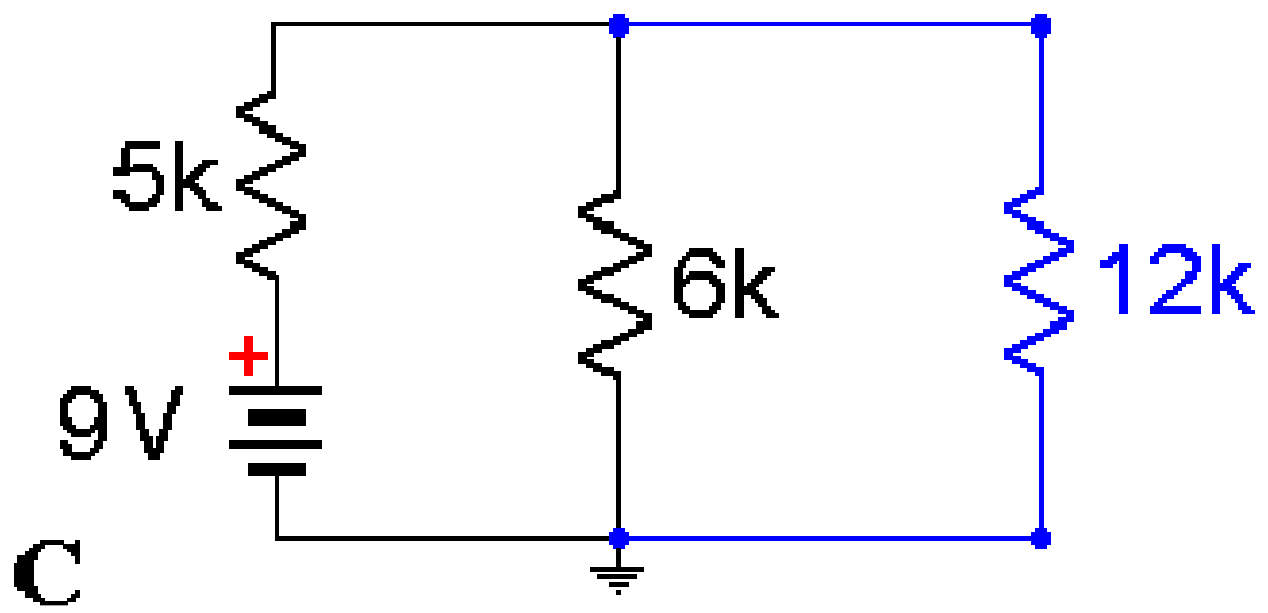
$$I = \frac{V}{R}$$

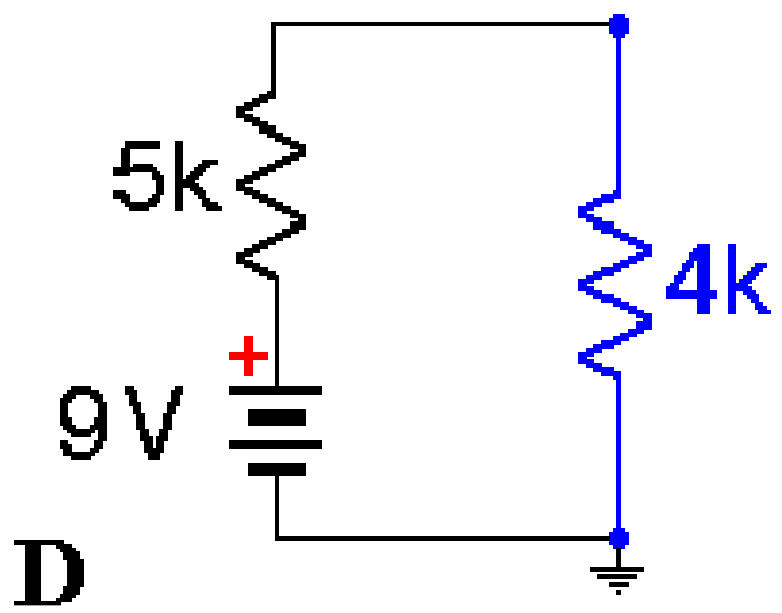


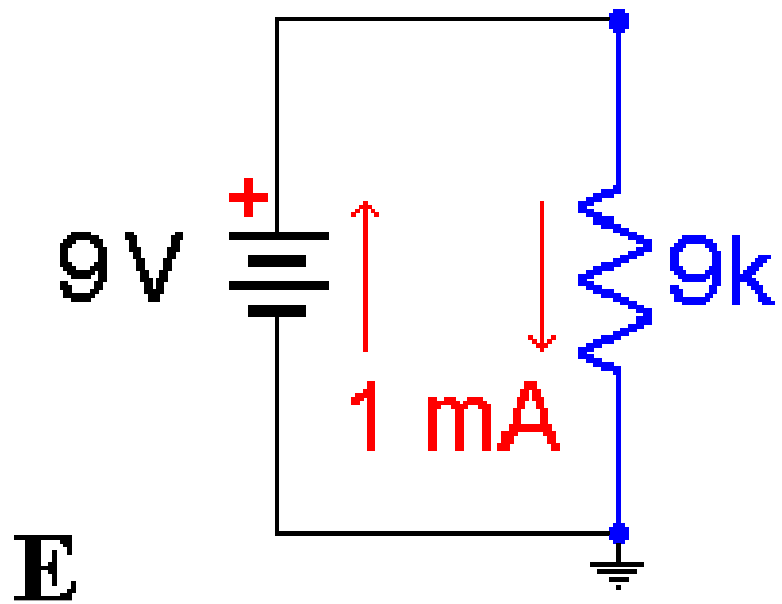
$$\frac{5 \times 20}{20 + 5} = 4k$$



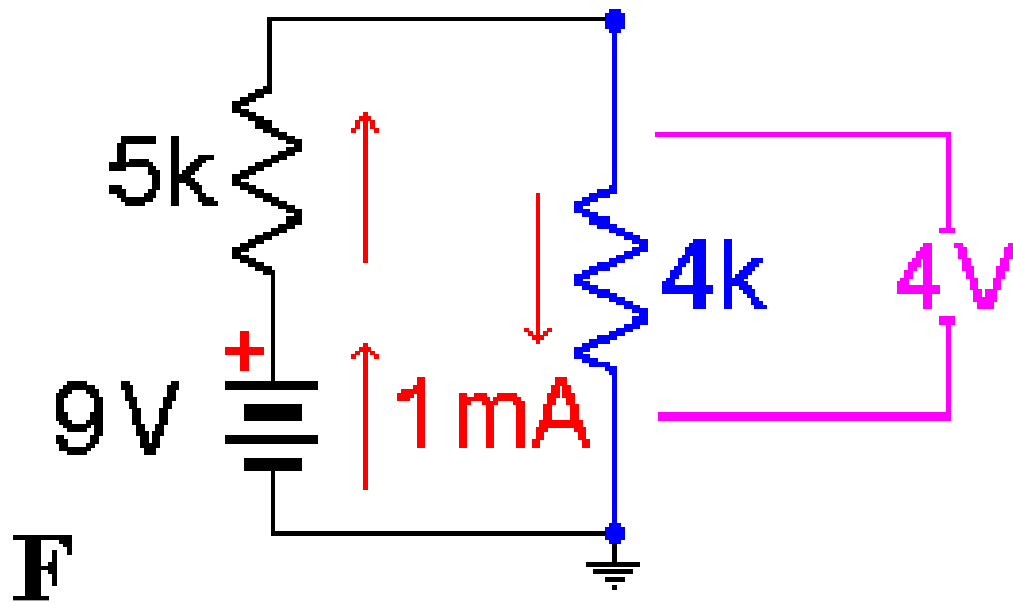






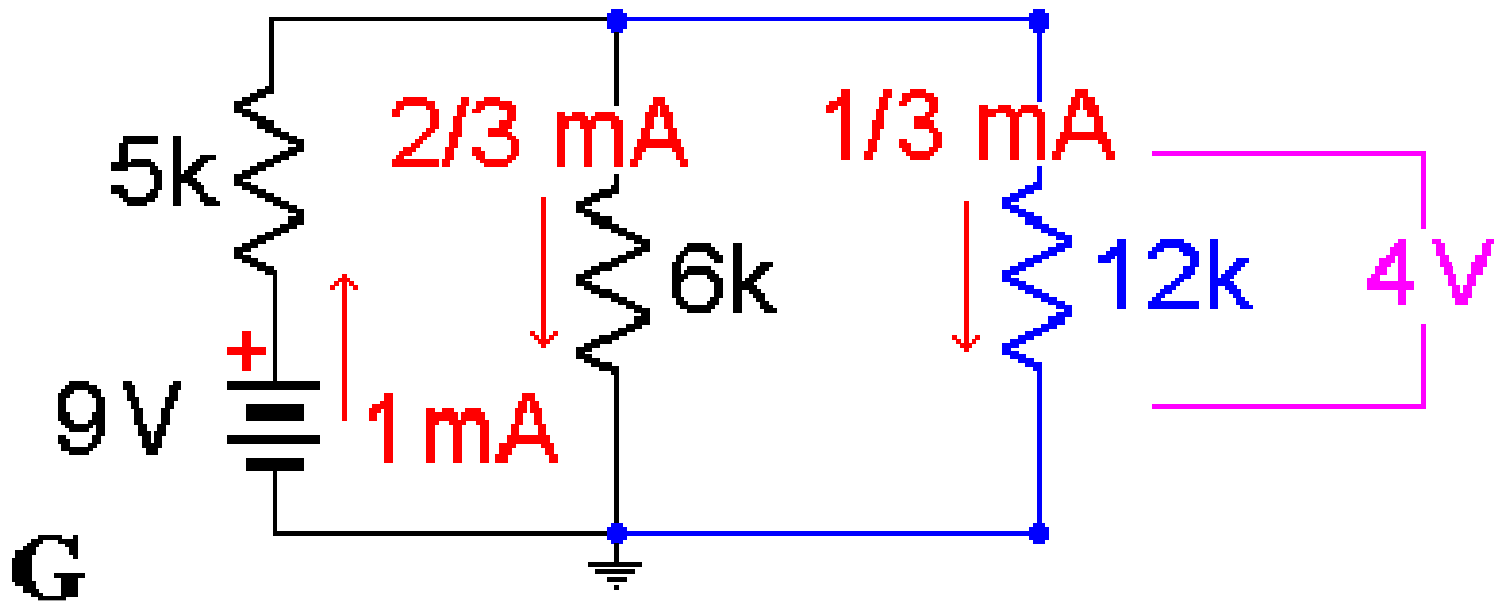


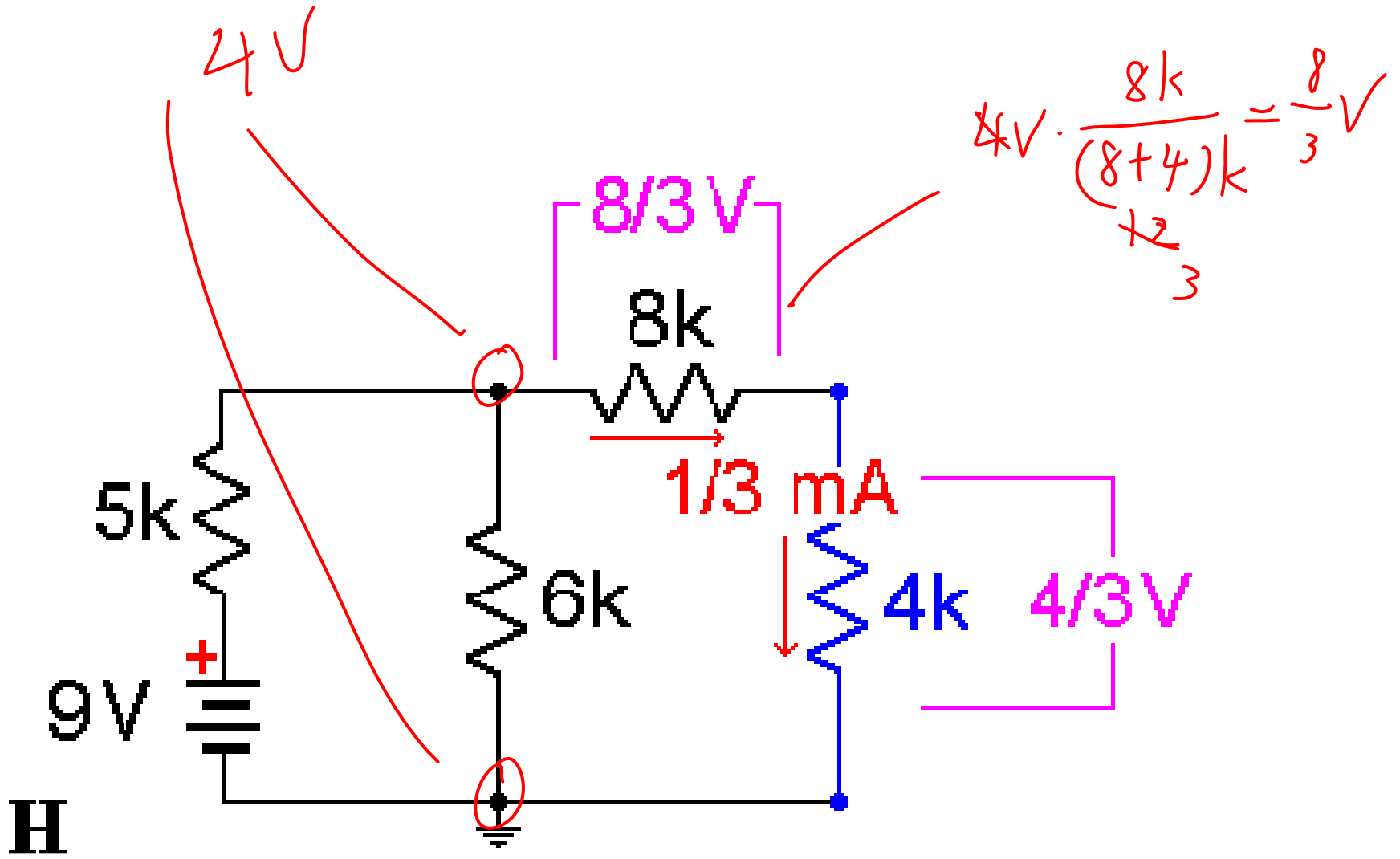
$$V_{4k} = 9V \frac{4k}{5k + 4k} = 4V$$

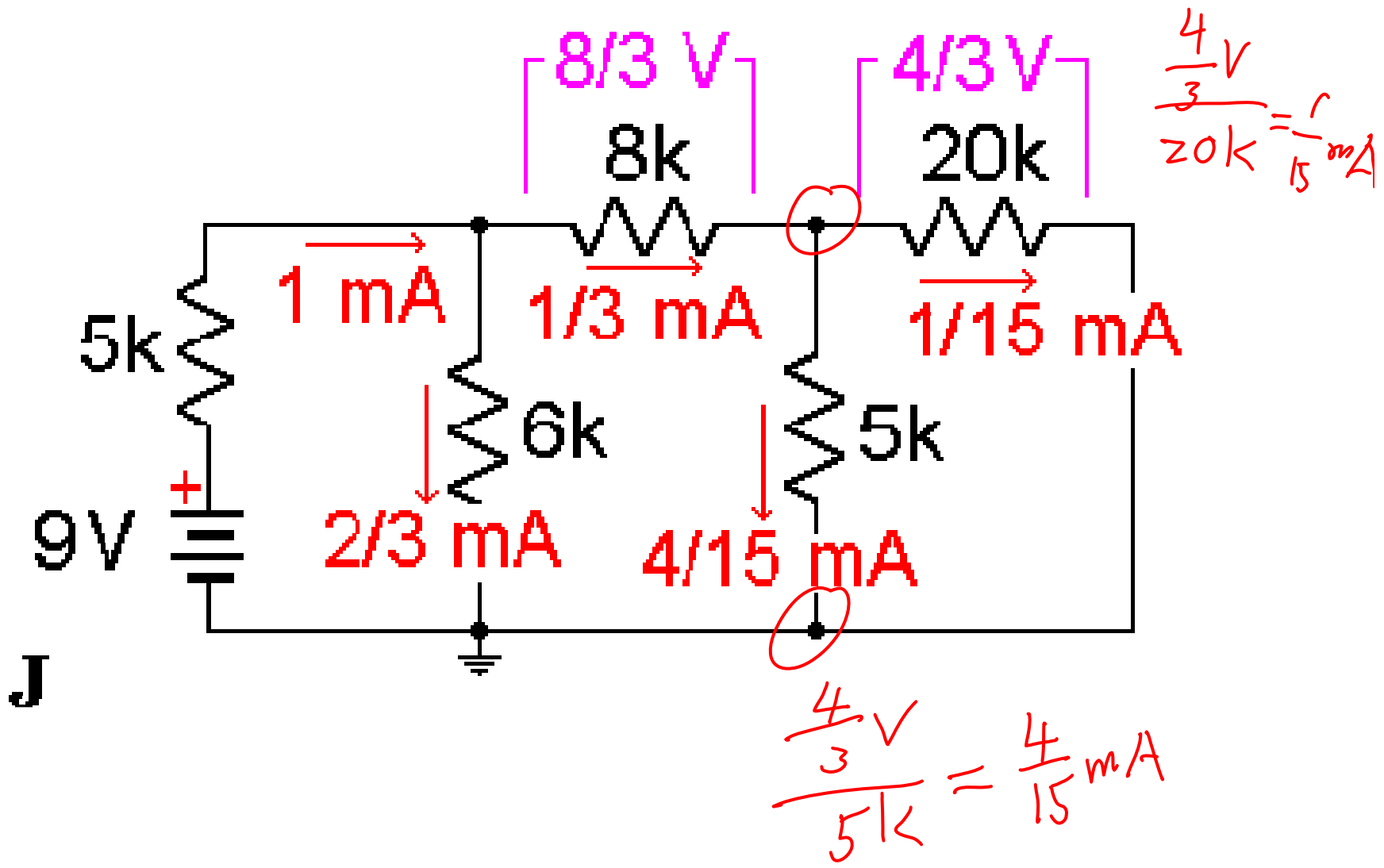


$$1 \text{ mA} \cdot \frac{4 \text{ k}\Omega}{6 \text{ k}\Omega} = \frac{2}{3} \text{ mA}$$

$$1 \text{ mA} \cdot \frac{4 \text{ k}\Omega}{12 \text{ k}\Omega} = \frac{1}{3} \text{ mA}$$





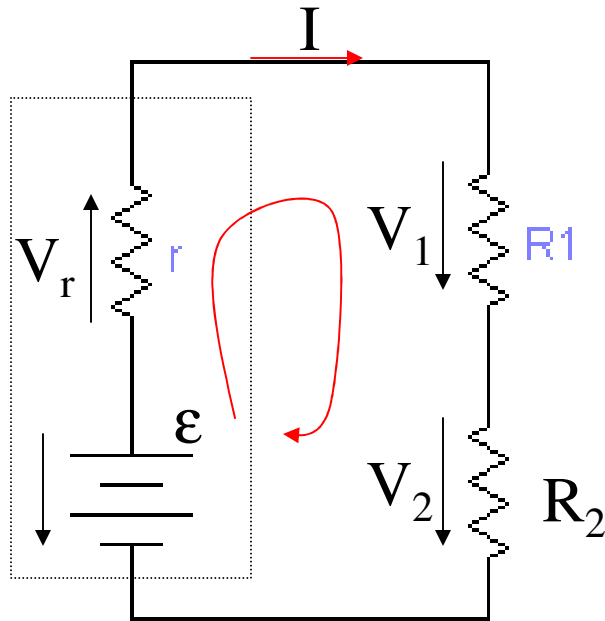


J

Method 2a: KVL & KCL

Kirchhoff's Voltage Law (KVL)

The algebraic sum of voltages around a closed **loop** must be zero



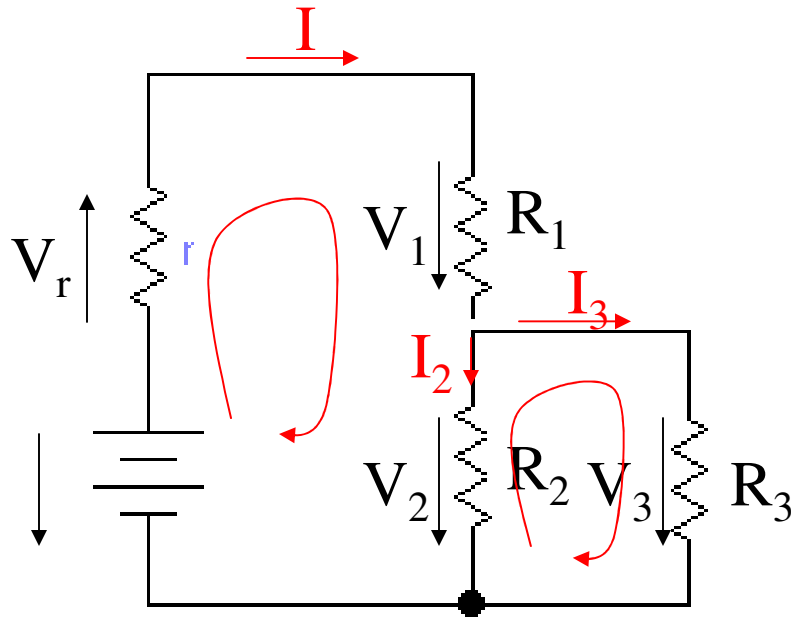
$$-\epsilon + V_r + V_1 + V_2 = 0$$

$$\begin{aligned}\epsilon &= V_r + V_1 + V_2 \\ &= I(r + R_1 + R_2)\end{aligned}$$

$$I = \epsilon / (r + R_1 + R_2)$$

1. For each branch, draw current direction (**arbitrary**) and label the voltage direction (**determined by the current direction**). Voltage on a voltage source is always from positive to negative end.
2. Define either **clockwise** or counterclockwise direction as positive loop direction. **Once the direction is defined, you have to use the same convention in every loop.** The sign for the voltage across each component is positive if voltage direction is the same as the defined loop direction, negative otherwise. (can use current direction to determine the sign)
3. Apply KVL: $+V$ if V is in the same direction defined above.

Kirchhoff's Voltage Law: multiloop



$$-\epsilon + V_r + V_1 + V_2 = 0$$
$$-V_2 + V_3 = 0$$

$$\epsilon = Ir + IR_1 + I_2 R_2$$
$$-V_2 + V_3 = 0$$