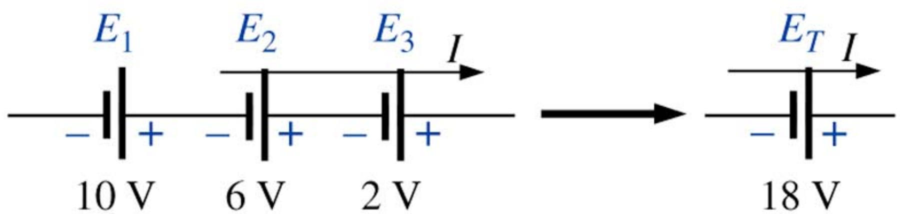
Today's Material

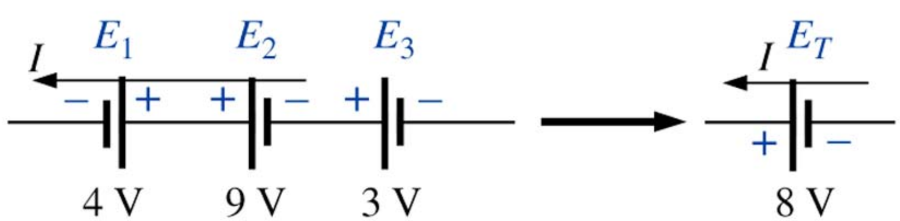
- Voltage Sources in Series (and series equivalent circuits)
  - Introduction
  - In the Lab (application)
  - Example
  - Breakout #1
- Kirchhoff's Voltage Law
  - Statement
  - Examples
  - Breakout #2

Voltage Sources in Series - Introduction

- To combine voltage sources in series, *algebraically* add the individual source values



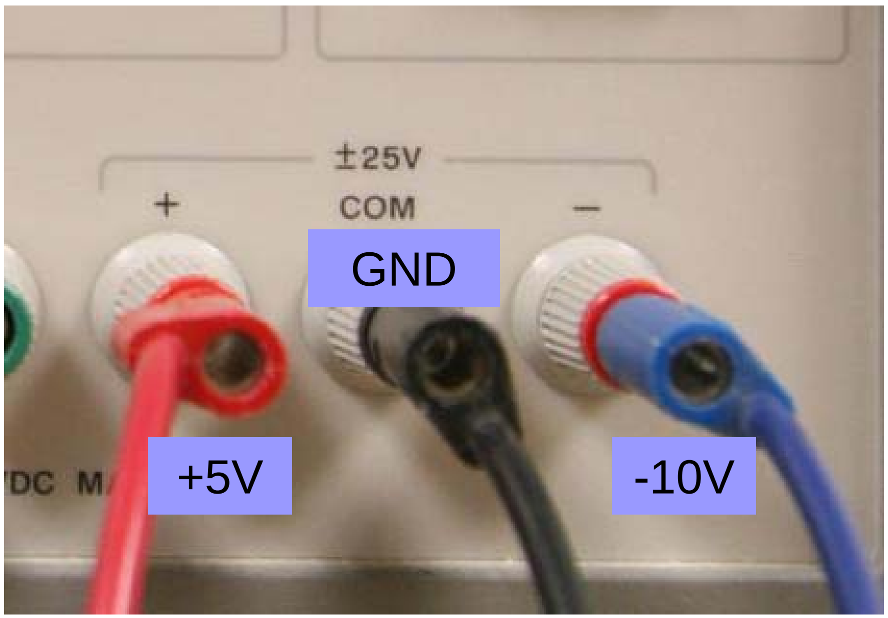
(a)

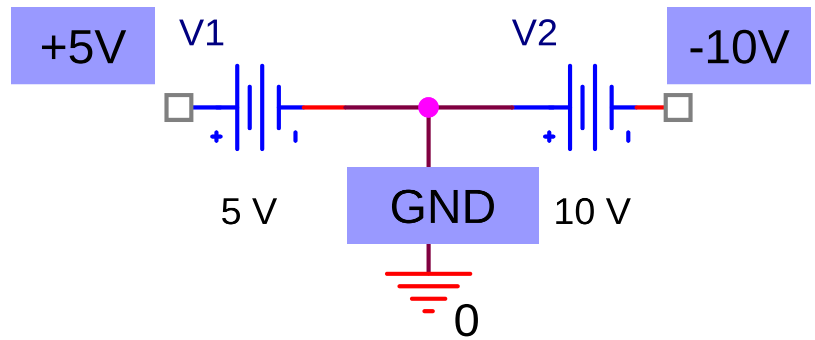


(b)

Voltage Sources in Series – In the Lab

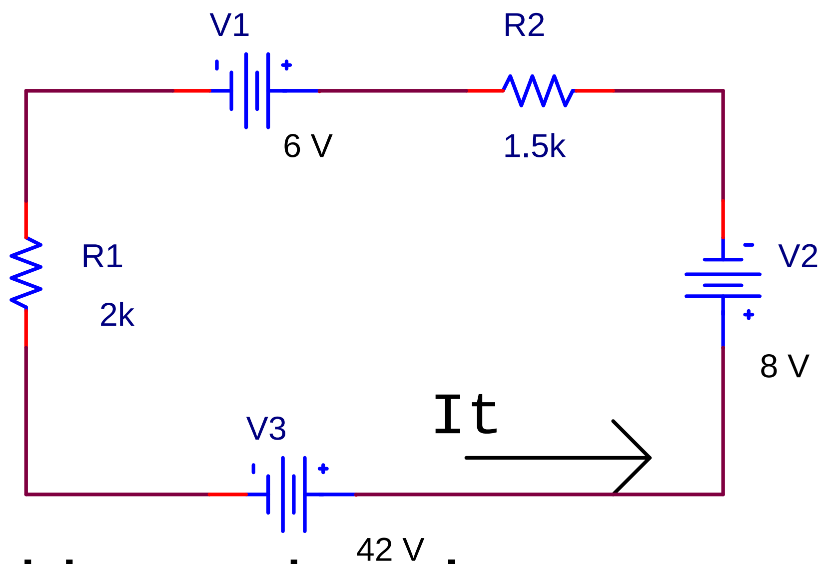
- Series voltage sources in lab





Example Series Circuit

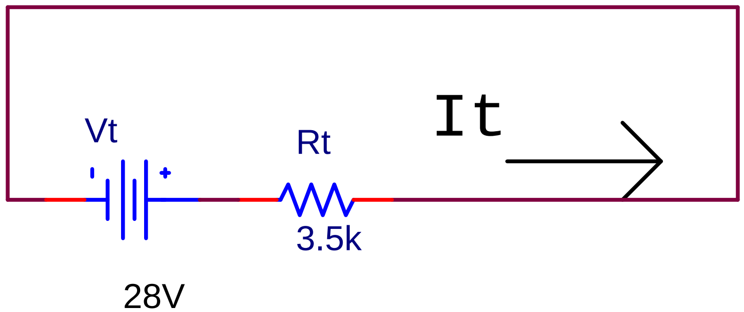
- Find I_T, The net source P_{DELIV}, P_{ABS}:



- Step 1: Combine series elements
  - Find R_T
    - R1+R2 = 3.5k-ohms
  - Find V_T - Polarity is *KEY*
    - $V_T = V_3 - V_2 - V_1 = 28$ V

Example Series Circuit

- Step 2: Draw the equivalent circuit



- Step 3: Analyze using standard circuit analysis techniques

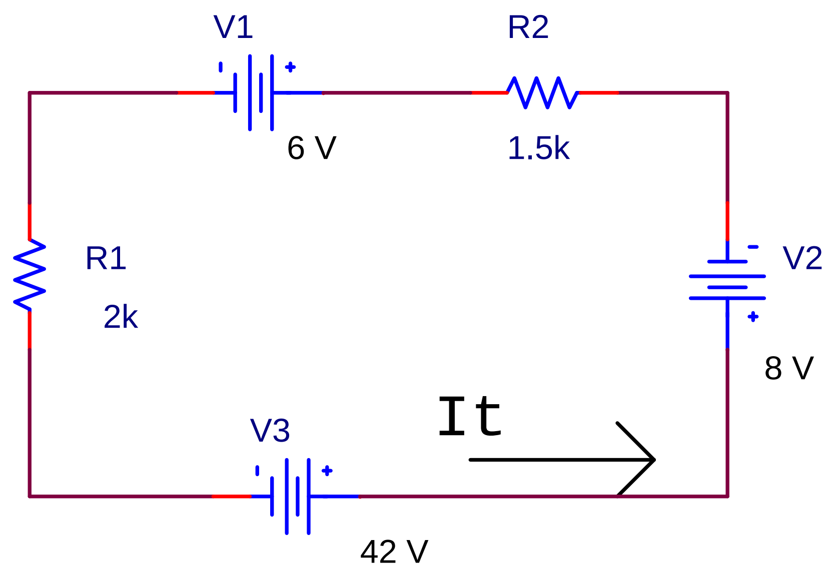
$$I_T = \frac{V_T}{R_T} = \frac{28\,\mathrm{V}}{3.5\mathrm{k}\,\Omega} = 8\,\mathrm{mA}$$

$$P_{DELIV} = V_T \cdot I_T = 28\,\mathrm{V} \cdot 8\,\mathrm{mA} = 224\,\mathrm{mW}$$

$$P_{ABS} = I_T^{\ 2} \cdot R_T = (8\,\mathrm{mA})^2 \cdot 3.5\,\mathrm{k}\Omega = 224\,\mathrm{mW}$$

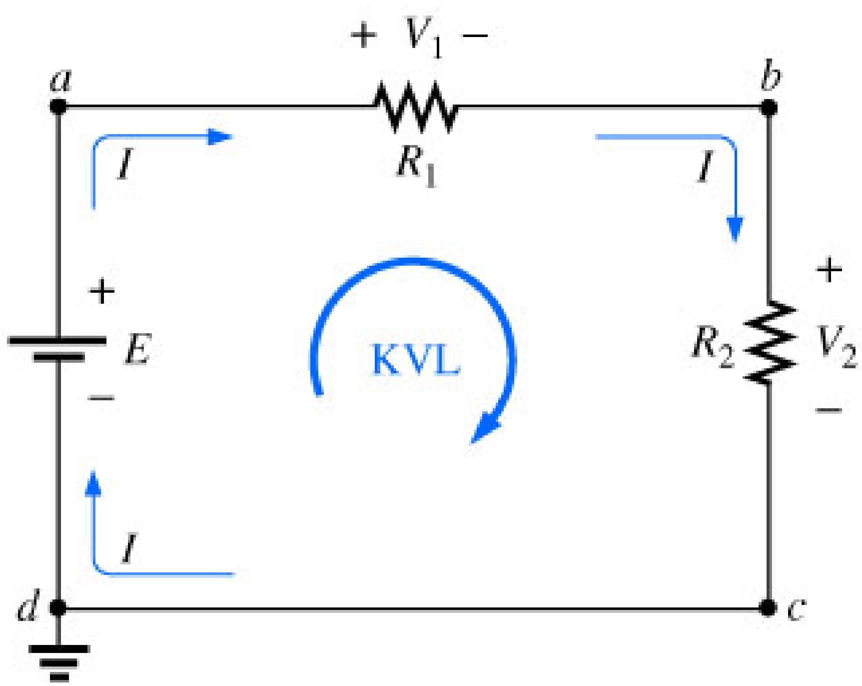
Breakout #1 – Using the same circuit

- Questions
  - Was source V_1 delivering or absorbing power? How much?
  - What about source V_2?
  - What about source V_3?



Kirchhoff's Voltage Law

- Kirchhoff's voltage law (KVL) states that the algebraic sum of the potential rises and drops around a closed loop (or path) is zero.



$$+E - V_1 - V_2 = 0$$

$$+V_{ad} - V_{ab} - V_{bc} = 0$$

Kirchhoff's Voltage Law

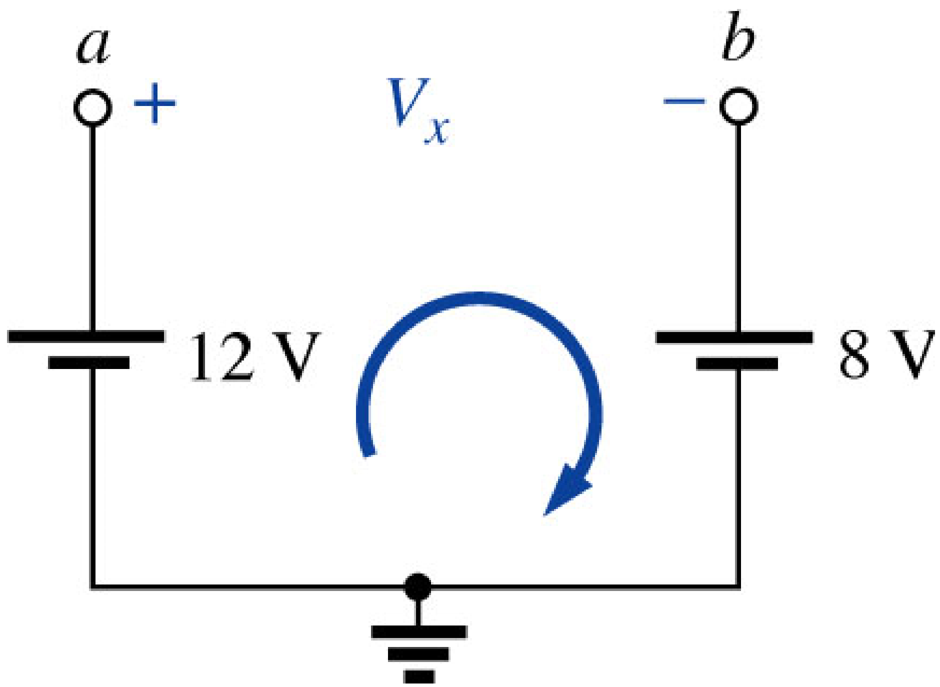
- The applied voltage of a series circuit equals the sum of the voltage drops across the series elements:

$$\sum V_{rises} = \sum V_{drops}$$

- The sum of the rises around a closed loop must equal the sum of the drops.
- The application of Kirchhoff's voltage law need not follow a path that includes current-carrying elements.
  - When applying Kirchhoff's voltage law, be sure to concentrate on the *polarities* of the voltage rise or drop rather than on the type of element.
  - Do not treat a voltage drop across a resistive element differently from a voltage drop across a source.

Kirchhoff's Voltage Law - Example

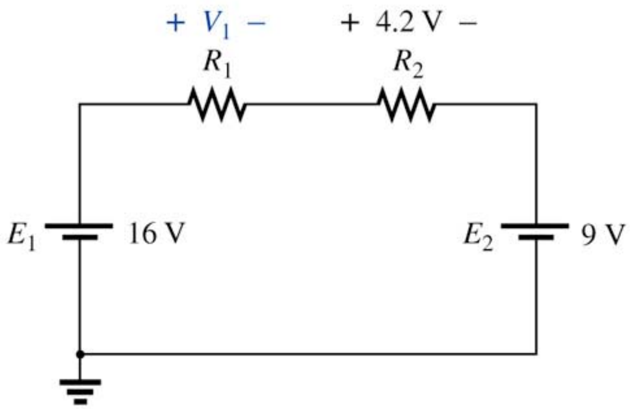
- Find Vab:



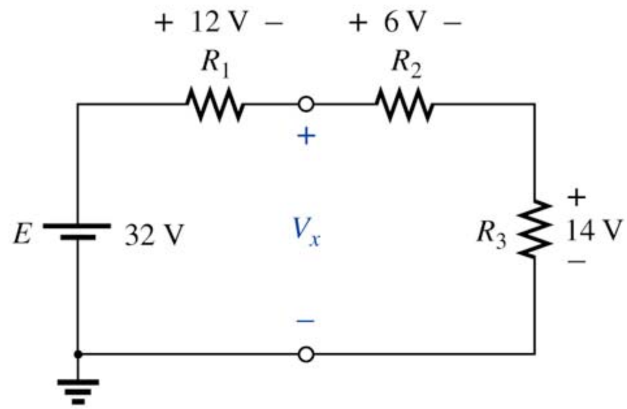
$$+12\,\text{V} - \text{Vab} - 8\,\text{V} = 0$$

$$\text{Vab} = 12\text{V} - 8\text{V} = 4\text{V}$$

Kirchhoff's Voltage Law – More Examples



Find V1



Find Vx

$$+16 - V_1 - 4.2V - 9V = 0$$

$$V_1 = 16V - 4.2V - 9V = 2.8V$$

$$+32V - 12V - Vx = 0$$

$$Vx = 32V - 12V = 20V$$

OR

$$+Vx - 6V - 14V = 0$$

$$Vx = 14V + 6V = 20V$$

Breakout #2

- Find V_{R1} and V_2