About Homework 1

Reopen the prairielearn system again for those who have not done or submitted it.

The time window starts from today to the end of Saturday (10/14)

For the following homework

You must submit it by the deadline !!!

Don't ask me to offer you second chance if you miss it.

Lecture 6: Kirchhoff's Laws in Circuits

- Kirchhoff’s Current Law (KCL) – Conservation of Charge
- Kirchhoff’s Voltage Law (KVL) – Conservation of Energy
- Solving Circuits with KCL, KVL, and Ohm’s Law
- Power Conservation in Circuits

Kirchhoff's Current Law

Current in = Current out

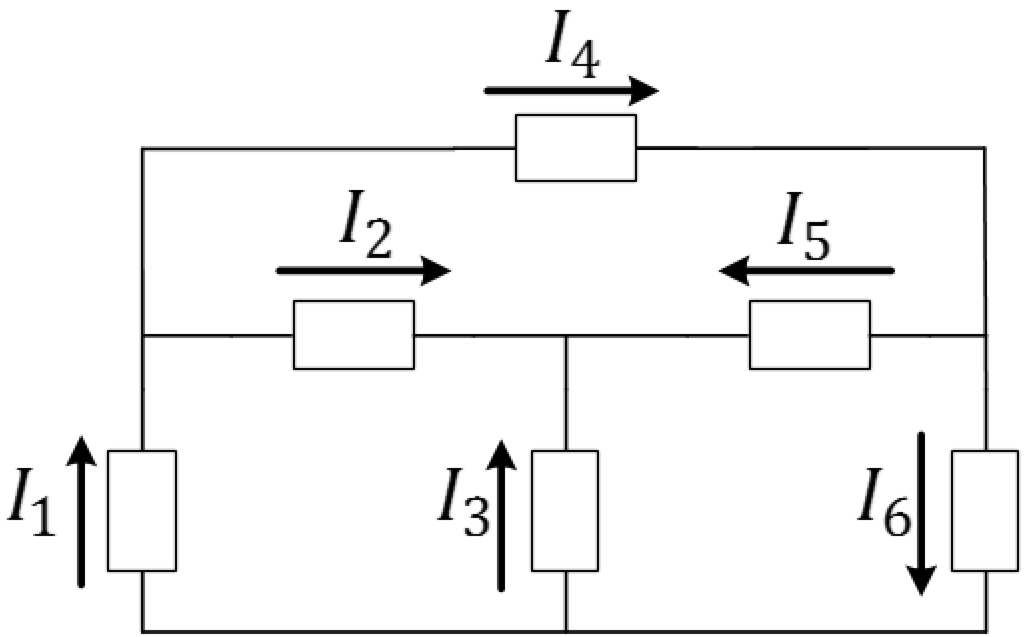
Conservation of charge!

(What goes in must come out, or…
…the total coming in is zero)

Image source: MONGABAY.COM

$$Through\ a\ closed\ surface\ (balloon), \sum_{k=1}^{N} I_k = 0\ where\ I_k\ are\ the\ currents\ flowing\ in\ (alt.out)\ of\ the\ balloon.$$

KCL equations are often used at *nodes*, but can also be used for a *sub-circuit*



Q: Which of the equations is NOT a correct application of KCL?

A. $I_1 = I_2 + I_4$
B. $I_4 = I_5 + I_6$
C. $I_1 + I_3 = I_6$
D. $I_3 + I_5 = I_2$
E. $I_6 - I_4 = I_3 + I_2$

Kirchhoff's Voltage Law

The sum of all voltages around any closed path (loop) in a circuit equals zero

Conservation of Energy!

With voltage, what goes up, must come down

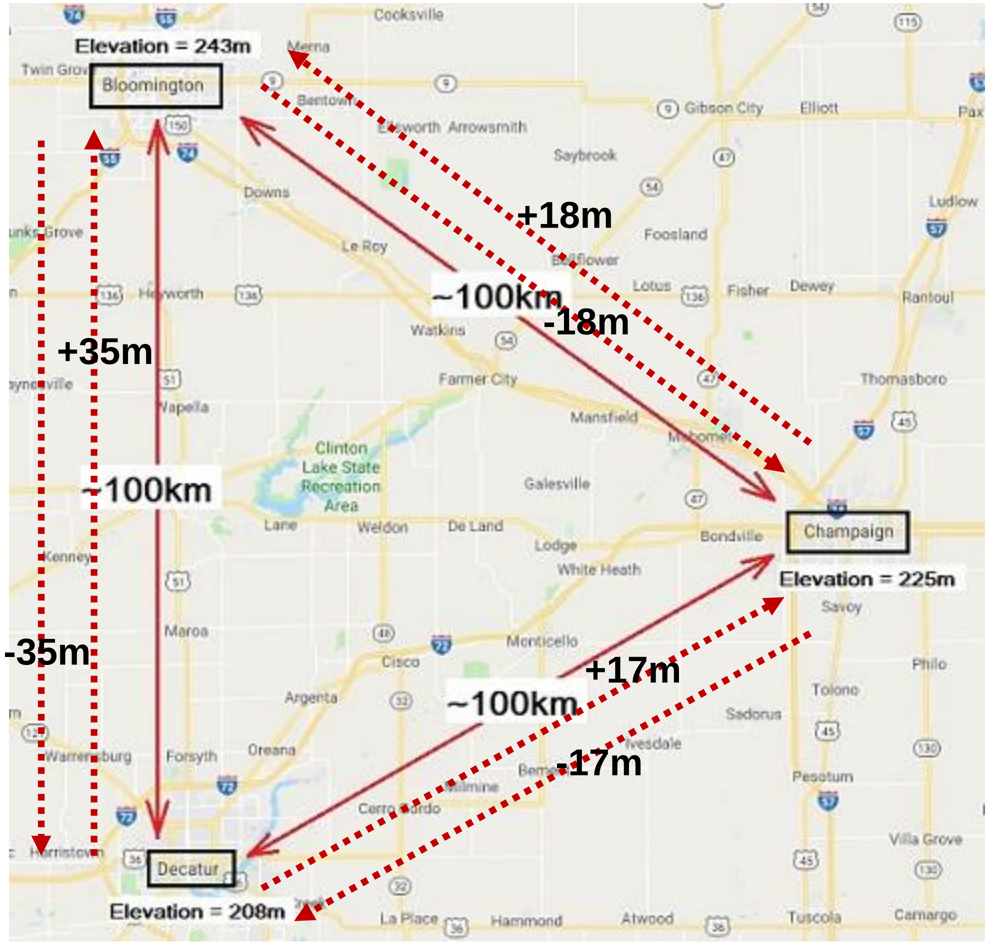
$$Around\ a\ closed\ loop\ (path) \sum_{k=1}^{M} V_k = 0 \ \ where\ V_k\ are\ the\ voltages\ measured\ CW (alt.\ CCW)\ in\ the\ loop.$$

KVL and Elevation Analogy

$$\text{Around a closed loop (path)} \sum_{k=1}^{M} V_k^{clockwise} = 0$$

Winter mountaineering in the German/Austrian Alps. Photo: Bernd Eberle.

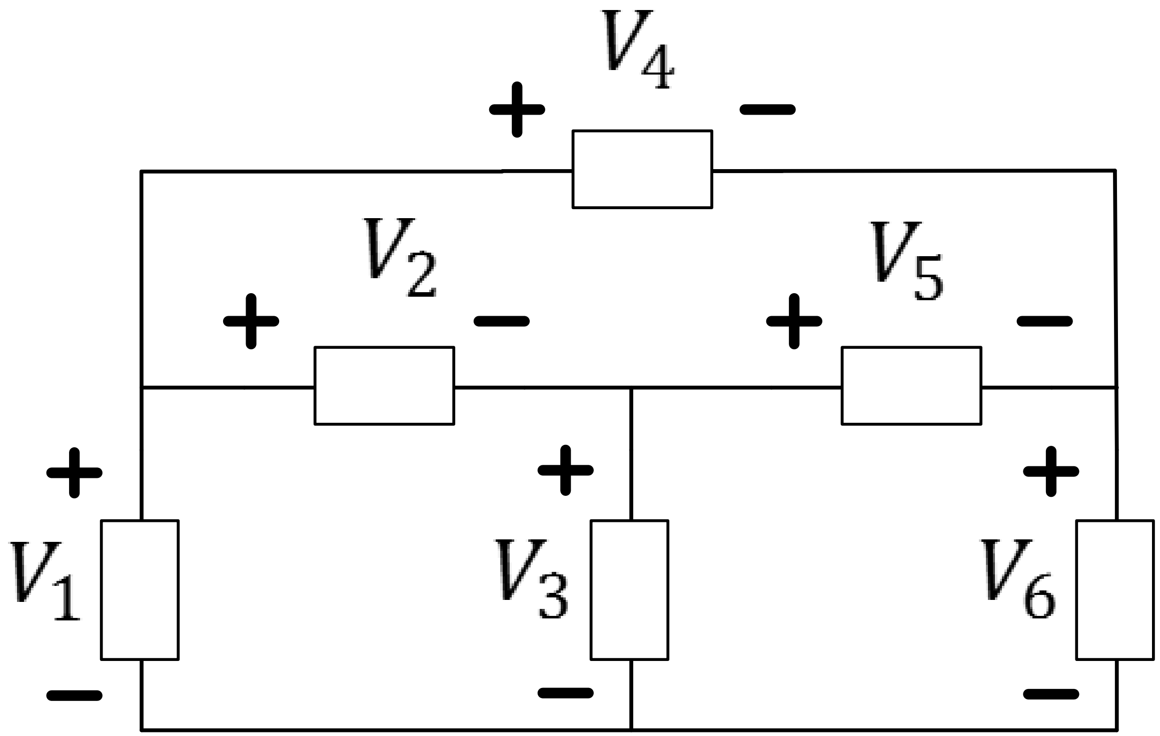
Picture: https://www.explore-share.com/blog/what-is-mountaineering/



One can add up elevation changes as we go in a complete loop from city to city.

The result should be zero, independent of the path taken.

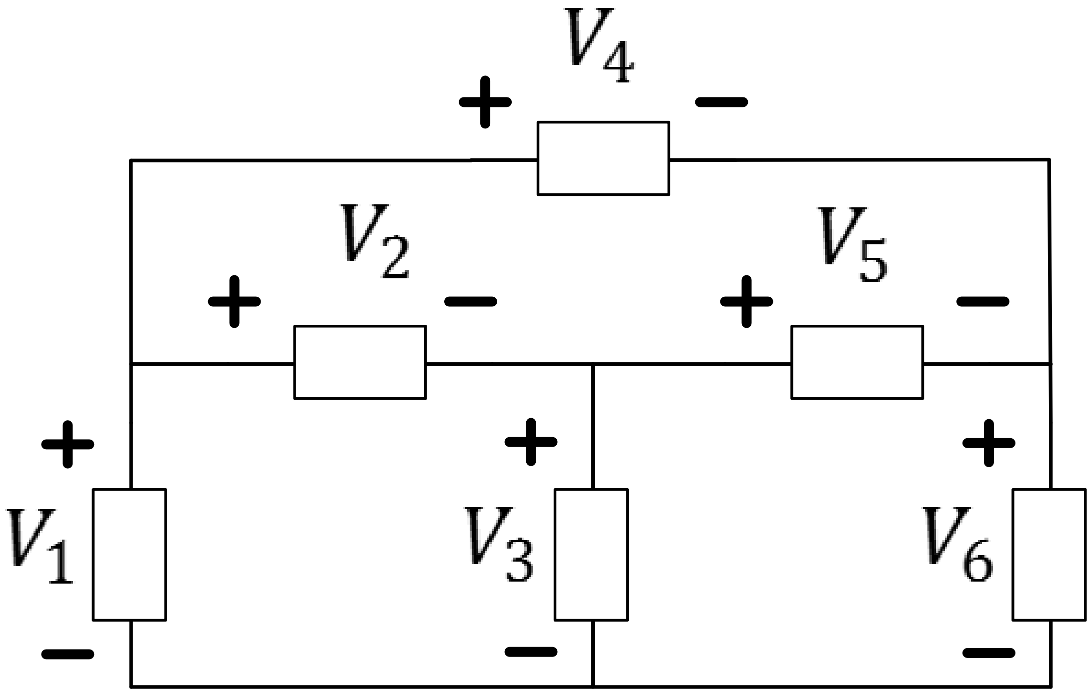
Keeping track of voltage drop *polarity* is important in writing correct KVL equations.



Q: Which of the equations is NOT a correct application of KVL?

A. $V_1 - V_2 - V_3 = 0$
B. $V_1 = V_2 + V_5 + V_6$
C. $V_1 - V_4 = V_6$
D. $V_3 + V_2 = V_1$
E. $V_3 + V_5 = V_6$

Missing voltages can be obtained using KVL.



In History…

The conceptual theories of electricity held by **Georg Ohm** were generalized in **Gustav Kirchhoff**'s laws (1845). Later, **James Clerk Maxwell**'s equations (1861) generalized the work done by Kirchhoff, Ampere, Faraday, and others.

ECE 329 Fields and Waves I

Explore More!

$$\oiint_{\partial\Omega} \mathbf{E}\cdot \mathrm{d}\mathbf{S} = \frac{1}{\varepsilon_0}\iiint_{\Omega} \rho \, \mathrm{d}V$$

$$\oiint_{\partial\Omega} \mathbf{B}\cdot \mathrm{d}\mathbf{S} = 0$$

$$\oint_{\partial\Sigma} \mathbf{E}\cdot \mathrm{d}\boldsymbol{\ell} = -\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Sigma} \mathbf{B}\cdot \mathrm{d}\mathbf{S}$$

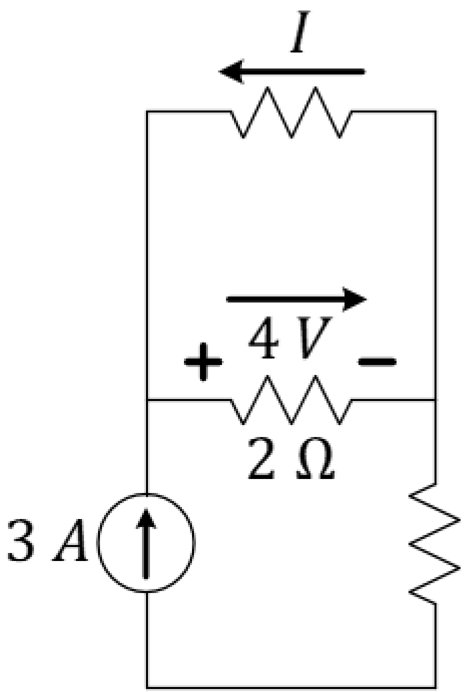
$$\oint_{\partial\Sigma} \mathbf{B}\cdot \mathrm{d}\boldsymbol{\ell} = \mu_0 \iint_{\Sigma} \mathbf{J}\cdot \mathrm{d}\mathbf{S} + \mu_0\varepsilon_0 \frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Sigma} \mathbf{E}\cdot \mathrm{d}\mathbf{S}$$

Maxwell's equations in Integral Form
Image Credit: Wikipedia.org

Q: What are the values of the voltages V_1, V_2 and V_6 if $V_3 = 2\,V, V_4 = 6\,V, V_5 = 1\,V$?

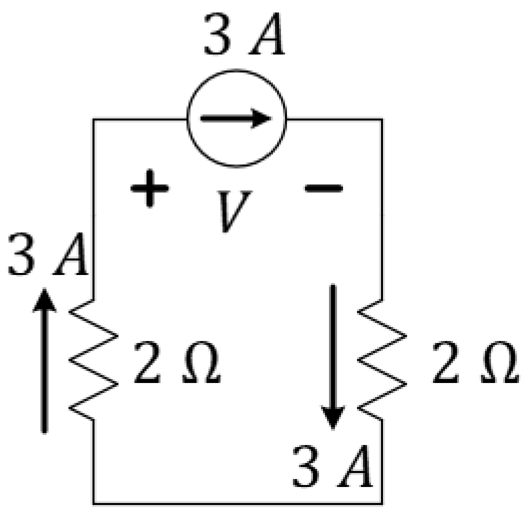
Examples

Q: Find the value of I.



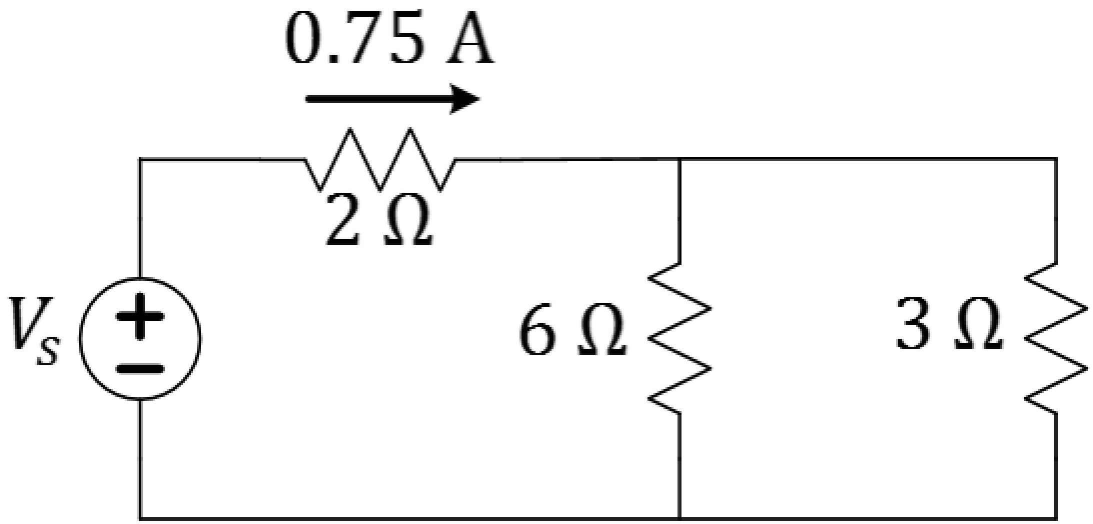
A. $-3\ A$
B. $-2\ A$
C. $\boxed{-1\ A}$
D. $1\ A$
E. $2\ A$

Q: Find the value of V.



A. $\boxed{-12\ V}$
B. $-6\ V$
C. $-3\ V$
D. $6\ V$
E. $12\ V$

Circuits solved with Ohm's + KCL + KVL



Q: What is the value of the source voltage?

Q: How much power is the source supplying?

Q: How much power is each resistance consuming?

L6 Learning Objectives

a. Identify and label circuit nodes; identify circuit loops
b. Write node equation for currents based on KCL
c. Write loop equations for voltages based on KVL
d. Solve simple circuits with KCL, KVL, and Ohm’s Law
e. Calculate power in circuit elements, verify conservation