ECE 215 Spring 2025

Objective 1.1:
DC Circuit Analysis

UNITED STATES
AIR FORCE
ACADEMY

Admin

- Any Gradescope or Teams issues?
- Questions about syllabus? *Only if you've read it*.
- Quiz 0: due T2 by 2359
- Retakes for Quizzes due 1 week after grades are published
  - See instructions on how to submit a retake
- Quiz 1 (Objs 1-2): due M6/T6 (21/22 Jan) by 2359
  - Work practice problems posted on course website to prep!

- **Objective 1.1**: I can calculate the voltages, currents, and power associated with devices in a simple DC-powered circuit using tools such as KVL, KCL, voltage and current dividers, Ohm's Law, and the power equation.

Good Lab Practices

We will be doing hands-on lab work throughout this course - get excited!

Some things to remember:

- Keep power supply off when making changes
- Check all connections before engaging power
- Analyze first, so you know what to expect
- Keep food and drinks away from equipment

EQUIPMENT - DMM

Function Switch

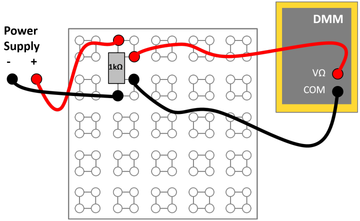
Voltage/ Resistance Input

Current Inputs

Common Ground

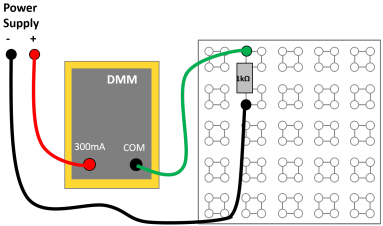
MEASURING R, V, & I

Voltage/Resistance



- Should the DMM's internal R be large or small?

Current



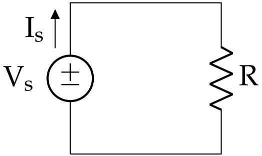
- Should the DMM's internal R be large or small?

Ohm's Law

- For a linear resistor/device: Voltage, Resistance, and Current are related

Ohm's Law

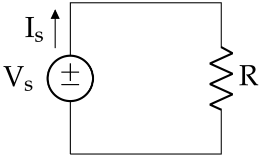
$$V = I \cdot R$$



- Ex: A 12V source is connected to a 1000Ω resistor - how much current flows through the resistor?
- Measure to verify!

Electrical Power

- Power is work done over time
- Power $= \dfrac{\Delta E}{\Delta t} = \dfrac{dE}{dt} \rightarrow \dfrac{\mathrm{J}}{\mathrm{s}} = \mathrm{Watt}$
- $\mathrm{V} = \dfrac{dE}{dq}, \mathrm{I} = \dfrac{dq}{dt}$
- Find power consumption of R in previous slide



Power Equation

$$P = I \cdot V$$

Engineering Notation

- Engineering notation is similar to Scientific notation...
- Exponent is ALWAYS a multiple of 3
- Coefficient somewhere between 1 and 999.999 . . .
- Wait...but why?
- Convert to engineering notation...
    - 0.00003056 W =
    - 0.707 A =
    - 3.014×10^7 V =
- Don't forget about significant figures...

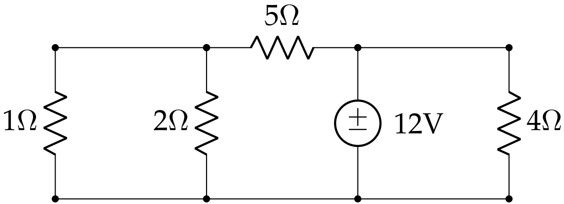
10^{12}	T (tera)
10^{9}	G (giga)
10^{6}	M (mega)
10^{3}	k (kilo)
10^{-3}	m (milli)
10^{-6}	μ (micro)
10^{-9}	n (nano)
10^{-12}	p (pico)
10^{-15}	f (femto)
10^{-18}	a (atto)

Standard Units

Quantity	Unit	Notes
Charge	Coulomb (C)	6.241×10^{18} electrons = 1C
Energy	Joules (J)	
Time	Seconds (s)	
Current	Ampere (A)	1A = 1/s
Voltage	Volts (V)	1V = 1 J/C
Power	Watts (W)	1W = 1 J/s
Resistance	Ohms (Ω)	

Key Terms

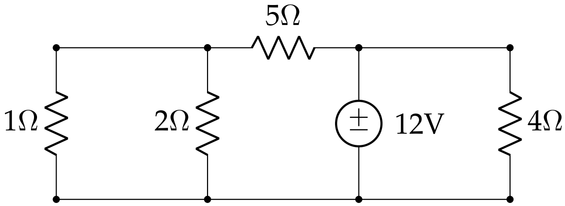
- Branch
- Node
- Loop
- Mesh



A 2 terminal element.

Key Terms

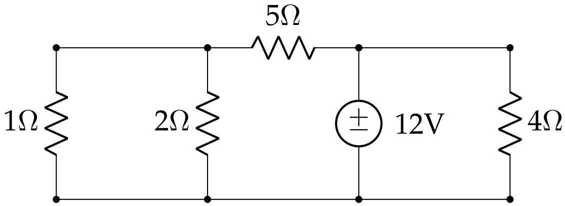
- Branch
- Node
- Loop
- Mesh



A connection of 2 or more components.

Key Terms

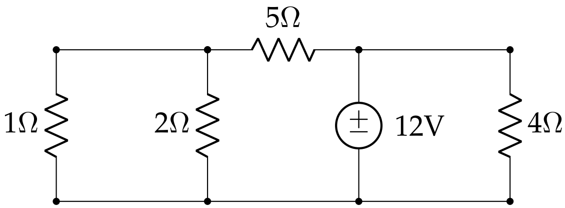
- Branch
- Node
- Loop
- Mesh



Any closed path through a circuit.

Key Terms

- Branch
- Node
- Loop
- Mesh



A loop that does not contain another loop.

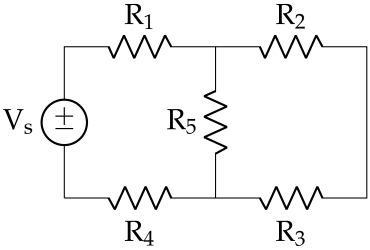
Kirchhoff's Voltage Law (KVL)

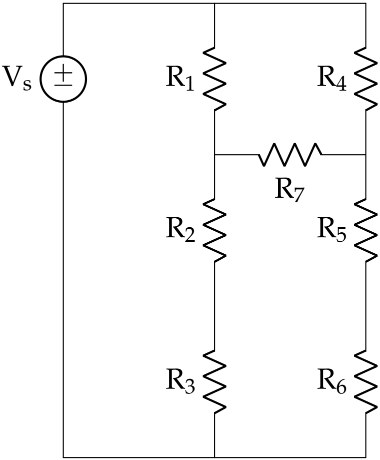
KVL

The algebraic sum of voltages around ***any closed loop*** in a circuit is zero.

- Method:
  1. Label voltage polarities (how?)
  2. Move around the loop and write each voltage; you may use the **first or second** sign as polarity - just stay consistent!
  3. Set the sum of the voltages equal to zero
  4. Solve for the desired voltage

KVL - Label & Write Voltage Equations

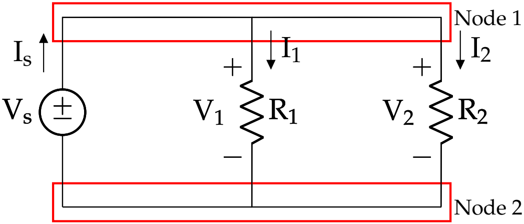




Kirchhoff's Current Law (KCL)

KCL

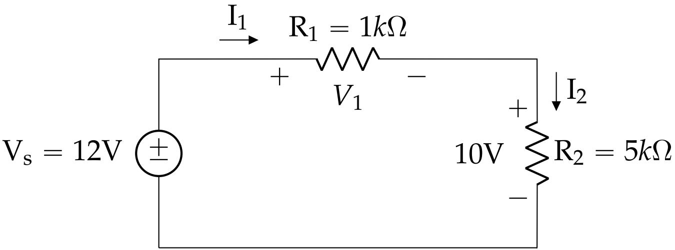
The algebraic sum of all currents at a node equals zero.



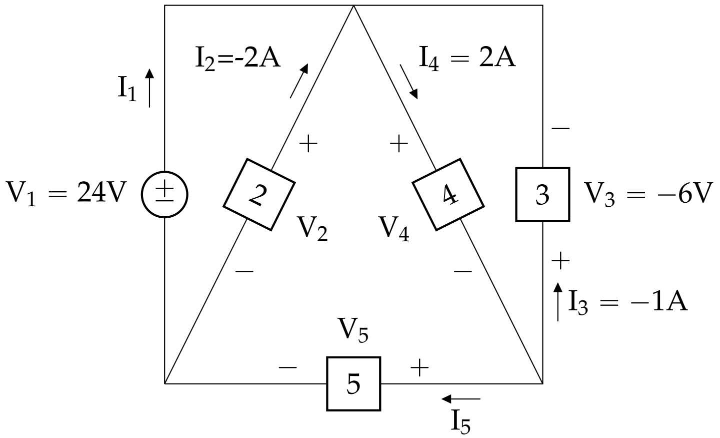
Method:

1. Label all voltages, using same convention as with KVL
2. Identify all nodes
3. Label all currents in circuit, including directions
4. Write each current, in an equation for each node (current into node = positive)
5. Set the sum of the currents equal to zero
6. Solve for the desired current(s)

EXAMPLE - FIND V_1, I_1, I_2



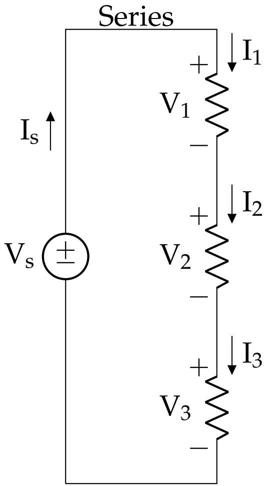
Example - find I_1,I_5, V_2,V_4,V_5

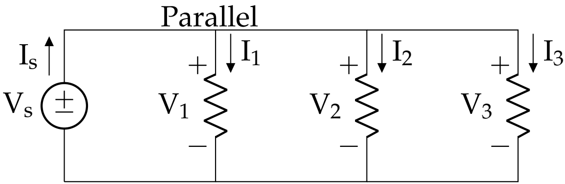


EXAMPLE - FIND I_1,I_5, V_2,V_4,V_5

- How many nodes are there?
- Write valid KCL equations for each node.
- Find I_1 and I_5
- How many meshes are there?
- Write valid KVL equations for each mesh.
- Find V_2, V_4, and V_5.

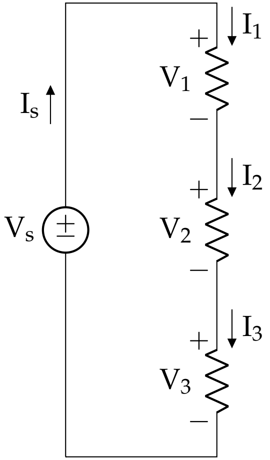
Key Terms





- Series: Two or more elements cascaded or connected sequentially. Series components only share one node.
- Parallel: Two or more elements connected to the same two nodes.

Resistors in Series



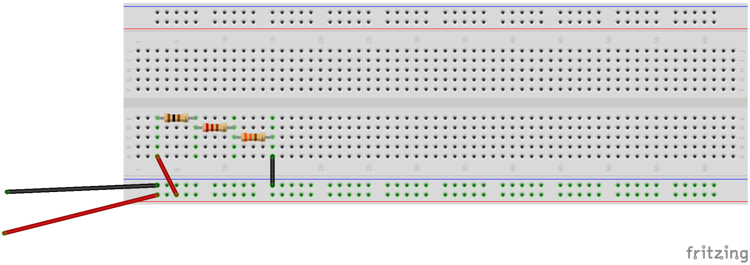
What does this circuit tell us about resistors in series?
(Hint: Let's use KCL, KVL, and Ohm's law)

Equivalent Series Resistance

$R_{eq} = R_1 + R_2 + \ldots + R_N$

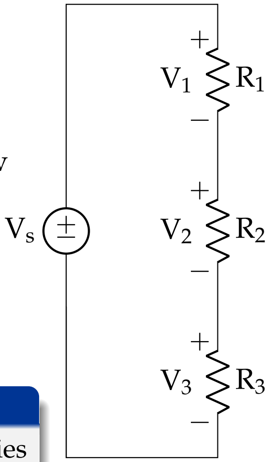
R_{eq} is ALWAYS larger than the largest resistor!

Series Circuit in Practice



Voltage Division

- If the current through series resistors is the same, what about the voltage?
- Each resistor ”eats up”' some of our potential
- Voltage division helps us determine how much each resistor “drops”



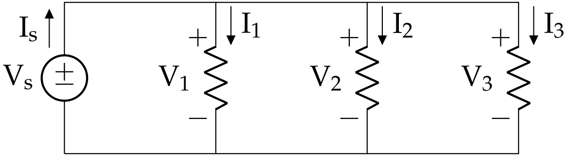
Voltage Division

$$V_x = V_s \frac{R_x}{R_{eq}}$$

Current

Current through series resistors is the same

Resistors in Parallel



What does this circuit tell us about resistors in parallel?

Equivalent Parallel Resistance

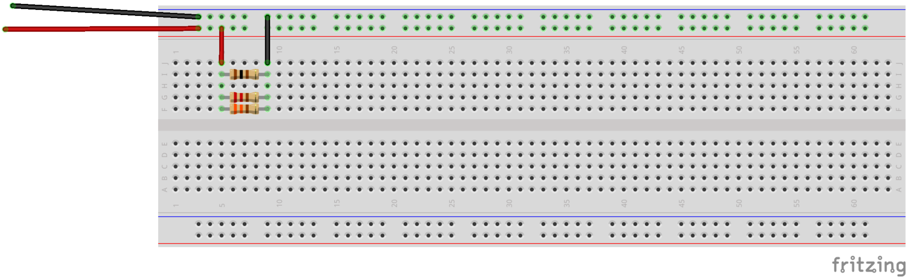
$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_N}}$$

ALWAYS smaller than the smallest Resistor!

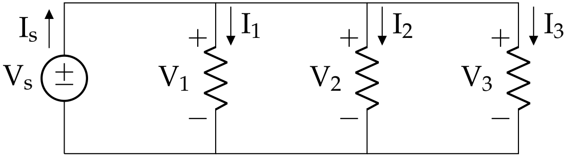
Voltage

Voltage is the same across resistors in parallel

Parallel Circuits in Practice



Current Division



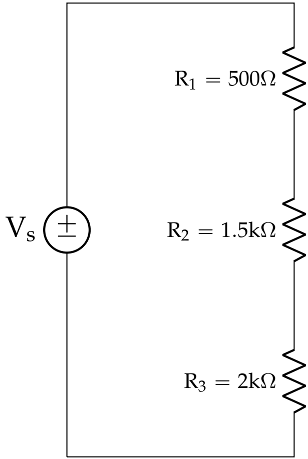
- If the voltage is the same across parallel resistors, what about current?
- Current division helps determine how current flows through parallel components
- What tools do we have available (again)??

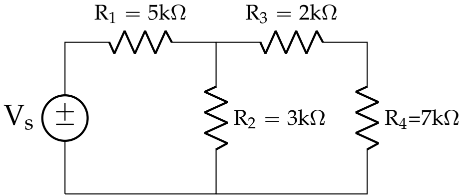
Current Division

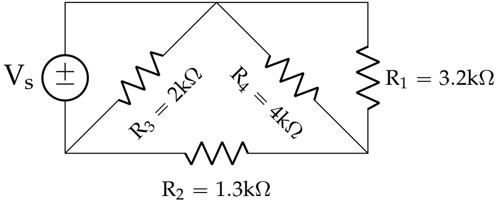
$$I_x = I_{\text{total}} \frac{R_{eq}}{R_x} \qquad \text{For 2 resistors} \longrightarrow I_x = I_{\text{total}} \frac{R_y}{R_{\text{sum}}}$$

Equivalent Resistance Examples

Find R_{eq}



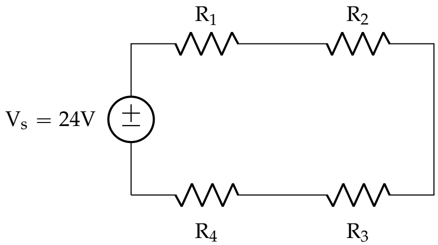


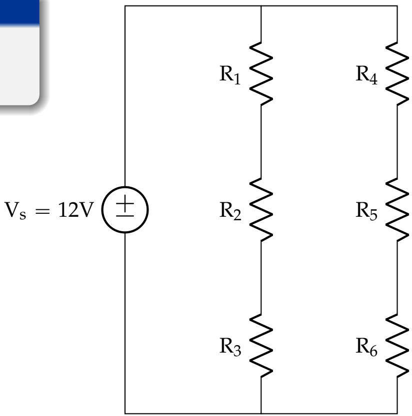


Voltage and Current Division Examples

Objective

Find Voltages/Currents across each Resistor and power consumed.





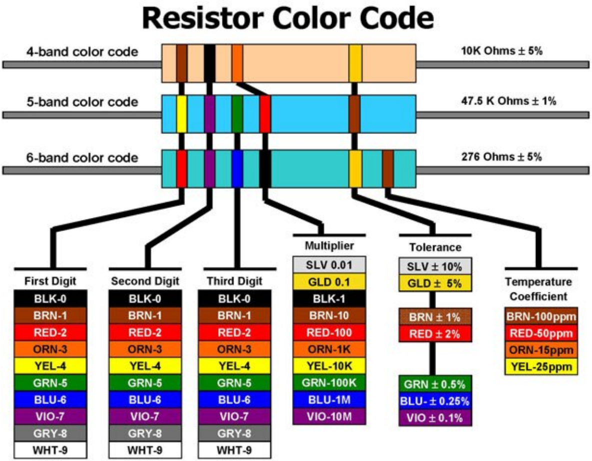
$R_1 = 100\Omega$ $R_2 = 60\Omega$

$R_3 = 120\Omega$ $R_4 = 80\Omega$

$R_1 = 1k\Omega$ $R_2 = 500\Omega$ $R_3 = 1.5k\Omega$

$R_4 = 750\Omega$ $R_5 = 900\Omega$ $R_6 = 1.2k\Omega$

RESISTOR COLOR CODE



- Q: What dictates wattage?
  - $\frac{1}{8}$ W $\rightarrow$ 3.3mm
  - $\frac{1}{4}$ W $\rightarrow$ 6.0mm
  - $\frac{1}{2}$ W $\rightarrow$ 8.5mm
  - 1 W $\rightarrow$ 11mm
  - 2 W $\rightarrow$ 15mm
- Q: What values are available?

Resistor Values

- Q: How much voltage can you put across a $1k\Omega$ $\frac{1}{4}$W resistor?

- How much current can you put through a 470Ω $\frac{1}{2}$W resistor?

Heuristic

Operate at half of operating power