04-Basic Laws Part 1

Text: Chapter 2.1-2.2

ECEGR 210

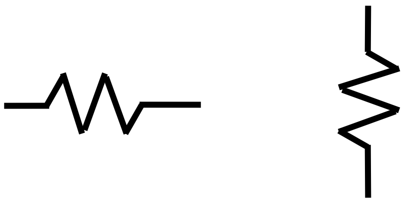
Electric Circuits I

Overview

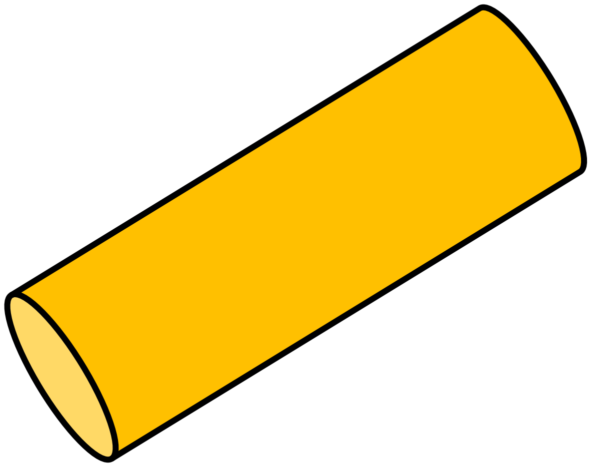
- Resistance
- Open/Short Circuits
- Ohm’s Law

Resistance

- Resistance: the ability to resist current
  - Expressed in Ohms (Ω)
  - Circuit symbol (Resistor)



- Dependent on:
  - Length (m)
  - Cross section (m^2)
  - Resisitivty (Ωm)



Resistance

- Resistance:

$$R = \rho \frac{\ell}{A}$$

- Where
  - R = resistance (Ω)
  - ℓ = Length (m)
  - A = Cross section (m^2)
  - ρ = Resisitivty (Ωm)

Resistance

- Resistivities
  - Silver: 1.64E-8
  - Copper: 1.72E-8
  - Aluminum: 2.8E-8
  - Gold:2.45E-8
  - Carbon:4E-5
  - Germanium:47E-2
  - Silicon:6.4E2
  - Paper:1E10
  - Glass: 1E12

Conductors (Silver, Copper, Aluminum, Gold)

Semiconductor (Carbon, Germanium, Silicon)

Insulators (Paper, Glass)

Example

- Compute the resistance of copper wire, with a diameter of 1.63 mm, that is 100m long.

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$$R = \rho \frac{\ell}{A} = (1.72x10^{-8}) \frac{100}{2.09x10^{-6}} = 0.823\Omega$$

Example

- If the length of a wire is doubled, what happens to the resistance?
  A. No change
  B. Increases by factor of 2
  C. Decreases by factor of 2
  D. Increases by factor of 8

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Example

- If the diameter of a wire is doubled, what happens to the resistance?
  A. No change
  B. Increases by factor of 2
  C. Decreases by factor of 4
  D. Increases by factor of 8

Example

- If the diameter of a wire is doubled, what happens to the resistance?
  A. No change
  B. Increases by factor of 2
  C. Decreases by factor of 4
  D. Increases by factor of 8

Conductance

- Sometimes it is useful to write Ohm's Law as I = V(1/R)
  - when voltage and resistance are known
- Conductance:
  - $G = 1/R$
- Where
  - G is expressed as Siemens (S), mhos (℧)

Wire Gauge

- When current flows through a resistance, heat is generated (it absorbs power)
- Can be dangerous if too much heat is generated
  - Insulation failure
  - Fire
- Voltage drop
  - Damages devices
  - Reduces performance

American Wire Gauge (AWG)

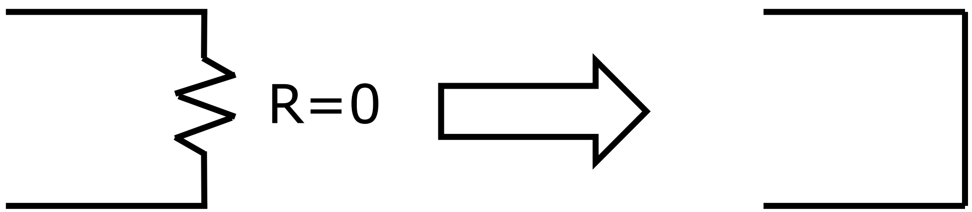
- Ensure wire has low enough resistance for application
- High current loads need low resistance wires
- Gauge: thickness (diameter) of wire
- AWG: standard thicknesses of conductors
  - Lower number the less resistance (larger cross section)

American Wire Gauge (AWG)

AWG	Diameter		Turns of wire		Area		Copper Resistance		
	(inch)	(mm)	(per in)	(per cm)	(kcmil)	(mm^2)	(Ω/km)	(Ω/kFT)	Copper wire Ampacity with 60/75/90 C insulation (A)
0000 (4/0)	0.46	11.684	2.17	0.856	212	107	0.1608	0.04901	195 / 230 / 260
000 (3/0)	0.4096	10.404	2.44	0.961	168	85	0.2028	0.0618	165 / 200 / 225
00 (2/0)	0.3648	9.266	2.74	1.08	133	67.4	0.2557	0.07793	145 / 175 / 195
0 (1/0)	0.3249	8.252	3.08	1.21	106	53.5	0.3224	0.09827	125 / 150 / 170
1	0.2893	7.348	3.46	1.36	83.7	42.4	0.4066	0.1239	110 / 130 / 150
2	0.2576	6.544	3.88	1.53	66.4	33.6	0.5127	0.1563	95 / 115 / 130
3	0.2294	5.827	4.36	1.72	52.6	26.7	0.6465	0.197	85 / 100 / 110
4	0.2043	5.189	4.89	1.93	41.7	21.2	0.8152	0.2485	70 / 85 / 95
5	0.1819	4.621	5.5	2.16	33.1	16.8	1.028	0.3133	
6	0.162	4.115	6.17	2.43	26.3	13.3	1.296	0.3951	55 / 65 / 75
7	0.1443	3.665	6.93	2.73	20.8	10.5	1.634	0.4982	
8	0.1285	3.264	7.78	3.06	16.5	8.37	2.061	0.6282	40 / 50 / 55
9	0.1144	2.906	8.74	3.44	13.1	6.63	2.599	0.7921	
10	0.1019	2.588	9.81	3.86	10.4	5.26	3.277	0.9989	30 / 35 / 40
11	0.0907	2.305	11	4.34	8.23	4.17	4.132	1.26	
12	0.0808	2.053	12.4	4.87	6.53	3.31	5.211	1.588	25 / 25 / 30
13	0.072	1.828	13.9	5.47	5.18	2.62	6.571	2.003	
14	0.0641	1.628	15.6	6.14	4.11	2.08	8.286	2.525	20 / 20 / 25
15	0.0571	1.45	17.5	6.9	3.26	1.65	10.45	3.184	
16	0.0508	1.291	19.7	7.75	2.58	1.31	13.17	4.016	— / — / 18

Open/Short Circuits

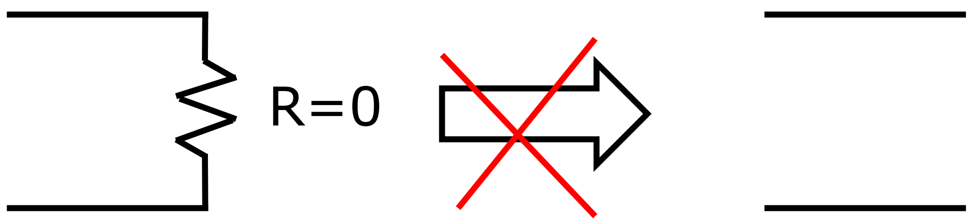
- How is a resistance of zero interpreted?



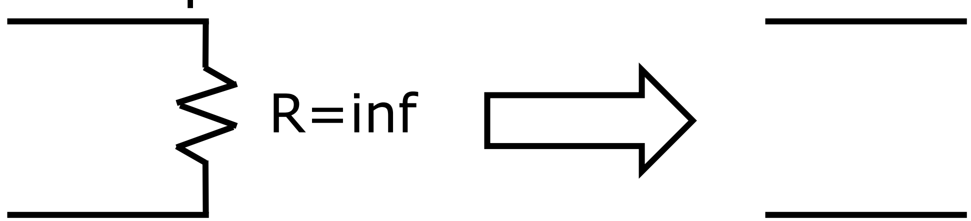
- Known as a “Short circuit”
  - High current flow
  - Like an closed switch
- Generally an unwanted condition
  - Overloading
  - Arcing

Open/Short Circuits

- Careful: zero resistance is does not mean a resistor is absent from the circuit



- No resistor is an "Open Circuit"
  - No current flow
  - Like an open switch



Resistance

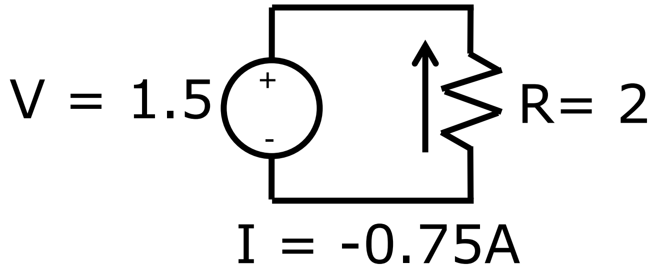
- Is zero resistance ever achieved?
- Can resistance ever be negative?

Ohm’s Law

- Ohm’s Law V=IR:
  - Describes the relationship between the voltage across a resistor
  - A fundamental law of circuit analysis
  - Voltage is <u>linearly</u> proportional to current
  - Careful attention must be paid to polarity

Ohm's Law

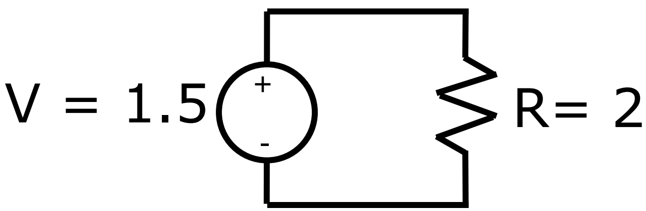
- Possible for the direction of current to initially be unknown or predefined
- Current may be negative wrt given polarity

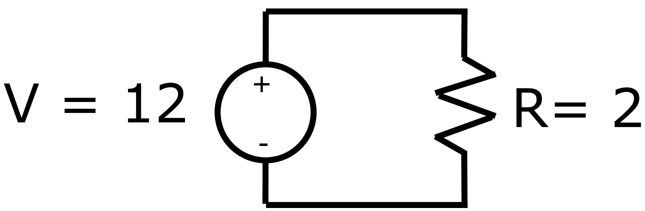


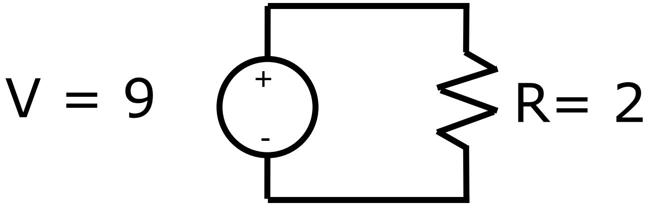
Assume polarity of current is defined

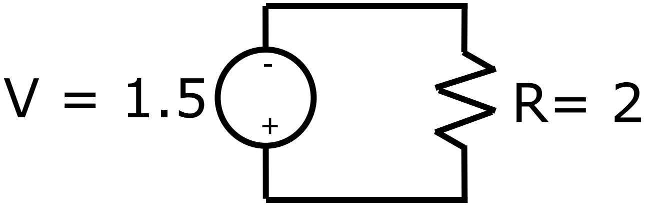
Example

- Find the current through R in each circuit and indicate its direction









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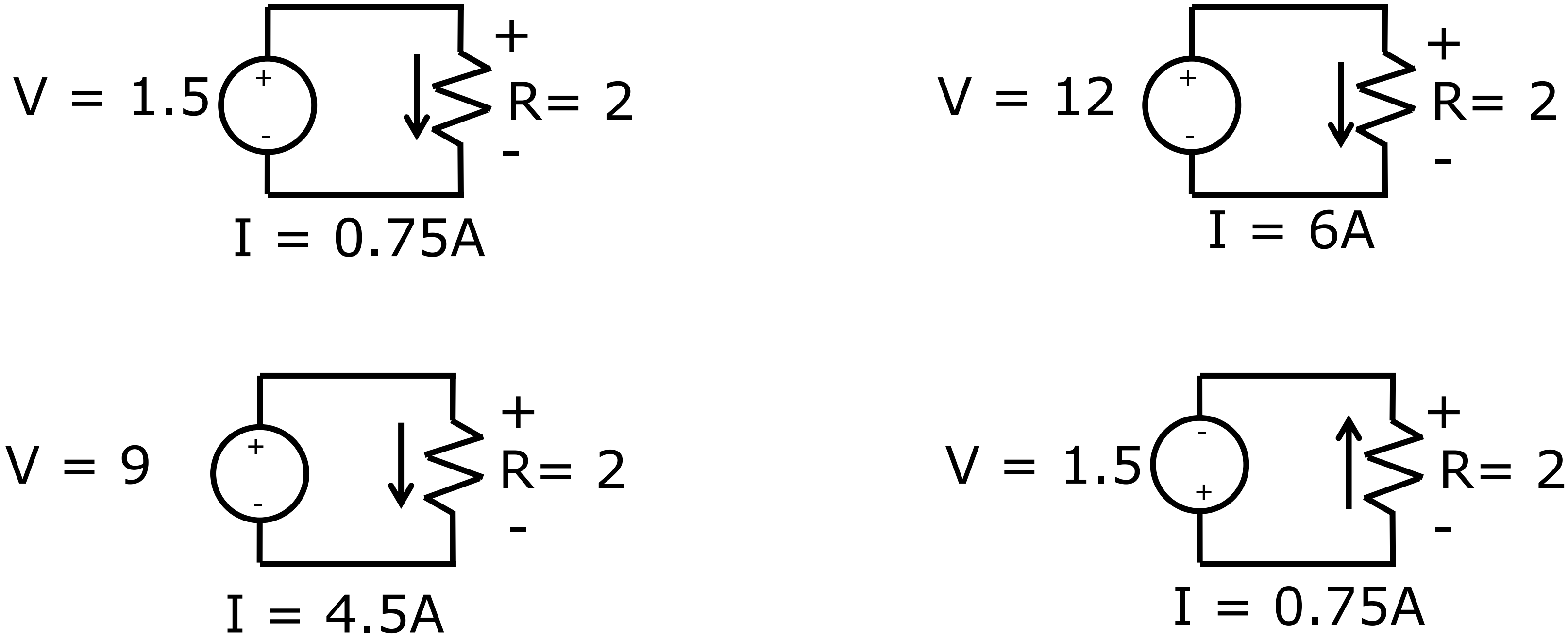

Power Computations

- Recall: $P = IV$

- Write P as a function of current and resistance

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  - $P = I^2R$
- This is an easy shortcut in circuit analysis!

Power Computations

- Recall: $P = IV$

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- Recall: $P = IV$
- Write P as a function of voltage and resistance
- Ohm's Law $V = IR$
- By substitution
  - $P = V^2/R$
- Another easy shortcut in circuit analysis!

Power Computations

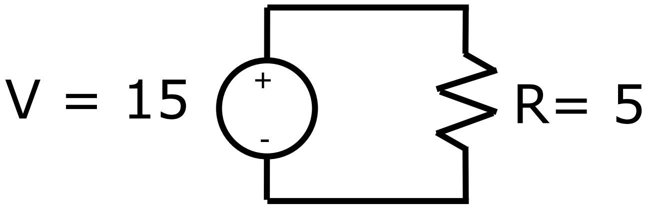
- Power absorbed by a resistor is proportional to the <u>square</u> of the <u>current through it</u>

- Power absorbed by a resistor is proportional to the <u>square</u> of the <u>voltage across it</u>

- High voltage is used in power lines because it reduces the current through the transmission lines for a given power level resulting in decreased losses

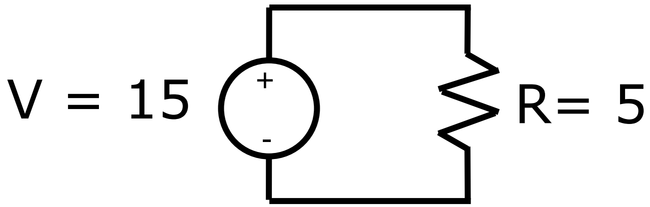
Example

- Find the power absorbed by the resistor



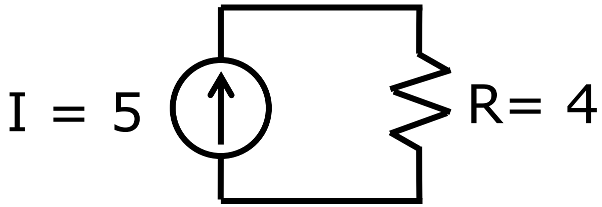
Example

- We know the voltage across the resistor, so use $P = V^2/R = 225/5 = 45W$
- If we used $P = IV$, it would require the additional step of first computing the current



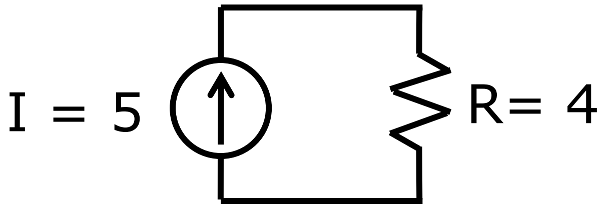
Example

- Find the power absorbed by the resistor



Example

- We know the current through the resistor, so use $P = I^2R = 25x4 = 100W$
- If we used $P = IV$, it would require the additional step of first computing the voltage

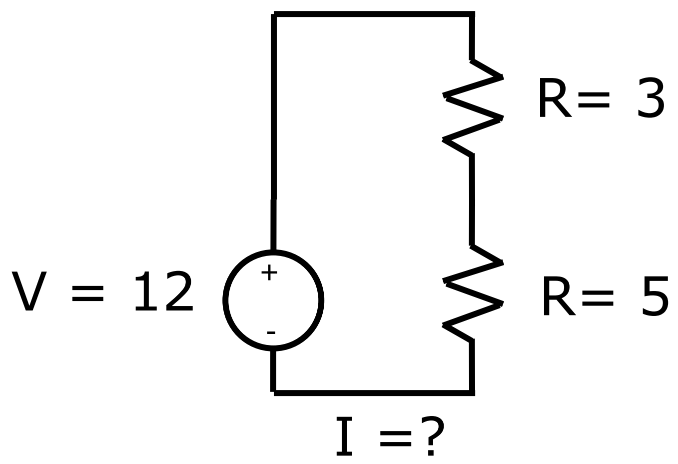


Power Computations

- Previous examples are simple: only one source, and one resistance
- What about when two or more resistors are present?

Multi-Resistor Circuits

- Consider the following circuit
- How do we apply Ohm's Law to find current?



Multi-Resistor Circuits

- Recall that Ohm's Law relates current with voltage across a resistor
  - Not the same as the voltage source