Fundamentals of Corrosion

Mathematics and Electricity

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Considerations

- This class concentrates on fundamental mathematical and electrical concepts
- All skills require practice regardless of what they are or how they're done
- To learn is to do
- By doing, it becomes easier

Agenda

- Units
- Circuit Theory
- Electrical Formulas
- Series and Parallel Circuit Theory

Units

- A unit is an object or thing regarded as stand alone and complete
- Can also be a component of a larger or more complex object or thing

Units

Examples of Common Units of Length

Imperial System	International System (SI)
• Inch (in)	• Millimeter (mm)
• Foot (ft)	• Centimeter (cm)
• Yard (yd)	• Meter (m)
• Mile (mi)	• Kilometer (km)

Units

Unit Nomenclature for US Money Denominations

Macro Unit		Fractional Unit
Two Dollars	One Dollar	Penny or Cent
Five Dollars		Nickel
Ten Dollars		Dime
Twenty Dollars	Multiply / Divide	Quarter
Fifty Dollars		Half-Dollar
One Hundred Dollars		

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Units

Concept #1

Any number multiplied by the number 1 always equals the same number.

Examples:

$$5 * 1 = 5$$
$$354 * 1 = 354$$
$$0.75 * 1 = 0.75$$

Examples:

$$5 * 1 * 1 = 5$$
$$354 * 1 * 1 * 1 = 354$$
$$0.75 * 1 * 1 * 1 * 1 = 0.75$$

Units

Concept #2

Any number divided by itself always equals 1.

Examples:

$$\frac{6}{6} = 1 \qquad \frac{87}{87} = 1 \qquad \frac{0.375}{0.375} = 1$$

Units

Unit Nomenclature for US Money Denominations

Unit — Multiply

- Two Dollars – (2)
- Five Dollars – (5)
- Ten Dollars – (10)
- Twenty Dollars – (20)
- Fifty Dollars – (50)
- One Hundred Dollars – (100)

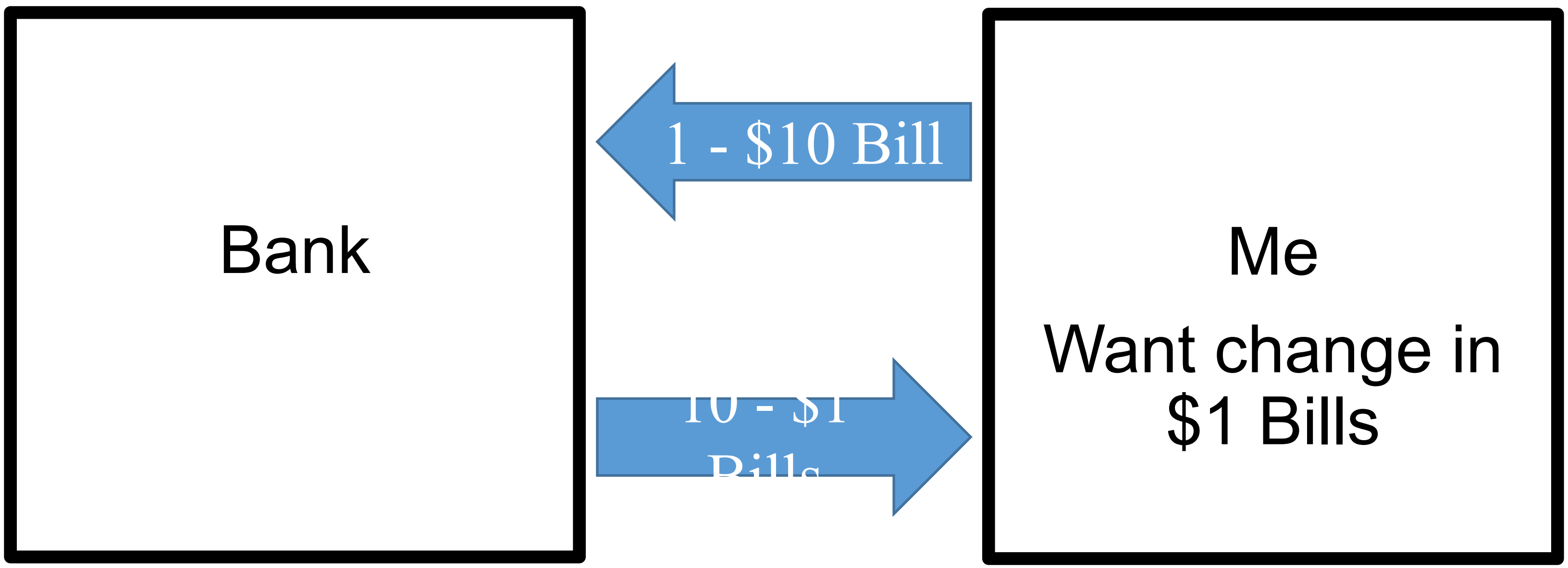
One Dollar

Unit — Divide

- (100) - Penny or Cent
- (20) – Nickels
- (10) - Dimes
- (4) - Quarter
- (2) - Half-Dollar

Units

Elaboration on Concept #2 – **Conversion Ratio**



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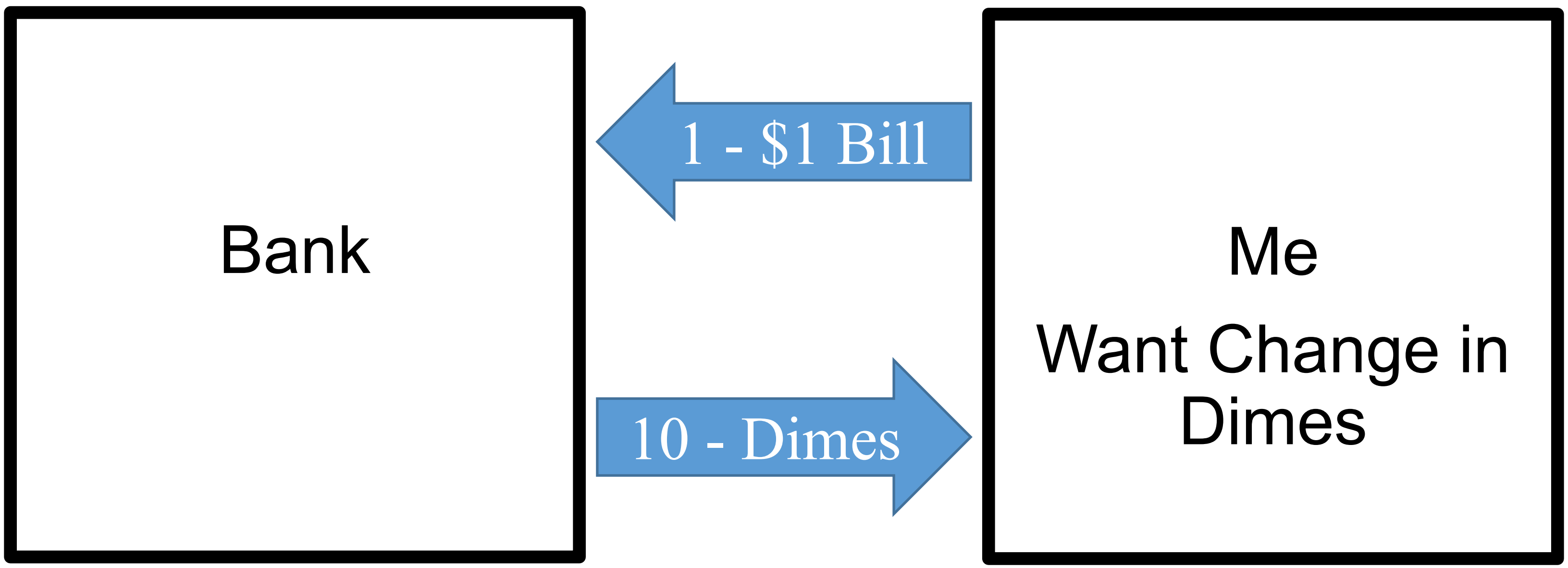
Units

Elaboration on Concept #2 – **Conversion Ratio**



Units

Units Make All The Difference – **Conversion Ratio**

$$\frac{\text{The Unit that you want goes on top}}{\text{The Unit you have goes on the bottom}}$$

Example

We know there are 5280 feet in 1 mile

Conversion Ratio = 1 mile / 5280 ft

= 0.0001894 miles per ft **OR** 0.0001894 miles/ft

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Units

Units Make All The Difference – **Conversion Ratio**

Conversion Ratio = 0.0001894 miles/ft

Question

How many miles are in 52, 864 ft?

Units

Units Make All The Difference – **Conversion Ratio**

Conversion Ratio = 0.0001894 miles/ft

We have feet and we want miles

Example

52,864 ft * 0.0001894 miles/ft

$$\frac{52{,}864\ \cancel{ft} * 0.0001894\ miles}{\cancel{ft}} = 10.0124\ miles$$

Units cancel.

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Units

Units Make All The Difference – **Conversion Ratio**

Conversion Ratio = 1 mile / 5280 ft

We have feet and we want miles

Example

52,864 ft * 1 mile / 5280 ft

$$\frac{52{,}864\ \text{ft} * 1\ \text{miles}}{5280\ \text{ft}} = 10.0124\ \text{miles}$$

Units cancel.

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Units

Units Make All The Difference – **Conversion Factor**

Conversion Ratio = 5280 ft /1 mile

We have miles and we want feet

Example – Conversion Applied Backward

52,864 ft * 5280 ft / 1 mi

$$\frac{52{,}864 \text{ ft} * 5280 \text{ ft}}{1 \text{ mi}} = \frac{279121920 \text{ ft}^2}{\text{mile}}$$

Units don't cancel!

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Units

Units Make All The Difference – **Conversion Ratio**

$$\frac{\text{The Unit that you want goes on top}}{\text{The Unit you have goes on the bottom}}$$

Example – Conversion

We have dollars and we want quarters

Ratio = 4 Quarters per Dollar

OR

4 Quarters / 1 Dollar

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Units

Units Make All The Difference – **Conversion Ratio**

How many quarters in \$37.75

Example – Conversion

$$\frac{\$37.75 \ * \ 4 \text{ Quarters}}{\$1} = 151 \text{ Quarters}$$

Units cancel.

Units

Multiple Conversion Ratios

- 6.425 miles of pipeline
- Convert to a distance in mm
- We know the following:
  - 5280ft / 1 mile
  - 12in / 1 ft
  - 25.4mm / 1 in

$$6.425 \not{mi} * \frac{5280 \not{ft}}{1 \not{mi}} * \frac{12 \not{in}}{1 \not{ft}} * \frac{25.4 \text{ mm}}{1 \not{in}} = 10{,}340{,}035 \text{ mm}$$

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Units cancel.

SI Units

The SI System and Layout

Getting Bigger

Prefix	Symbol	Magnitude	Multiplier
Tera	T	10^{12}	x 1,000,000,000,000
Giga	G	10^{9}	x 1,000,000,000
Mega	**M**	10^{6}	**x 1,000,000**
Kilo	**K**	10^{3}	**x 1000**
Hecto	H	10^{2}	x 100
Deka	Da	10^{1}	x 10
Unit	**--**	**1**	**x 1**

Getting Smaller

Prefix	Symbol	Magnitude	Multiplier
Unit	**--**	**1**	**x 1**
Deci	d	10^{-1}	x 0.1
Centi	**c**	10^{-2}	**x 0.01**
Milli	**m**	10^{-3}	**x 0.001**
Micro	**u**	10^{-6}	**x 0.000001**
Nano	**n**	10^{-9}	**x 0.000000001**
Pico	**p**	10^{-12}	**x 0.000000000001**

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SI Measurement Units

The SI System and Layout

Measurement	Unit	Symbol
Length	Meter	m
Mass	Gram	g
Volume	Liter	L
Time	Second	s
Voltage	**Volt**	**V**
Current	**Ampere**	**A**
Resistance	**Ohm**	**Ω**
Power	**Watt**	**W**
Temperature	Degree	C or K

SI Measurement Units

Electrical Measurement Terms

Voltage – Volt (V)	Current – Ampere (I)
• Named after Alessandro Volta (Italy) • Similar in function to pressure	• Named after Andre Ampere (French) • Similar in function to fluid flow
Resistance – Ohm (Ω)	**Power – Watt (W)**
• Named after Georg Ohm (Germany) • Similar in function to valve	• Named after James Watt (Scotland) • Identical in function to work

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SI Measurement Units

Electrical Measurement Terms

Voltage – Volt (V)	Current – Ampere (I)
• kV = 1000V • mV = 0.001V **OR** 1000mV per Volt • uV = 0.0000001V **OR** 1000uV per mV	• kA = 1000A • mA = 0.001A **OR** 1000mA per Amp • uA = 0.000001A **OR** 1000uA per mA
Resistance – Ohm (Ω)	**Power – Watt (W)**
• GΩ = 1,000,000,000Ω **OR** 1000MΩ • 1 MΩ = 1,000,000Ω • 1 kΩ = 1000Ω • 1 mΩ = 0.001Ω **OR** 1000mΩ per Ohm • 1 uΩ = 0.0000001Ω **OR** 1000uΩ per mV	• GW = 1,000,000,000W **OR** 1000MW • MW = 1,000,000W **OR** 1000kW • kW = 1000W • mW = 0.001W **OR** 1000mW per Watt • uW = 0.0000001W **OR** 1000uW per mW

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SI Measurement Units

Conversion Examples

$$\frac{\text{Unit you want}}{\text{Unit you have}}$$

$$-0.71A * \frac{1000mA}{1A} = -710mA$$

$$1.325kV * \frac{1000V}{1kV} = 1325V$$

$$956m\Omega * \frac{1\Omega}{1000m\Omega} = 0.956\Omega$$

$$1500W * \frac{1kW}{1000W} = 1.5kV$$

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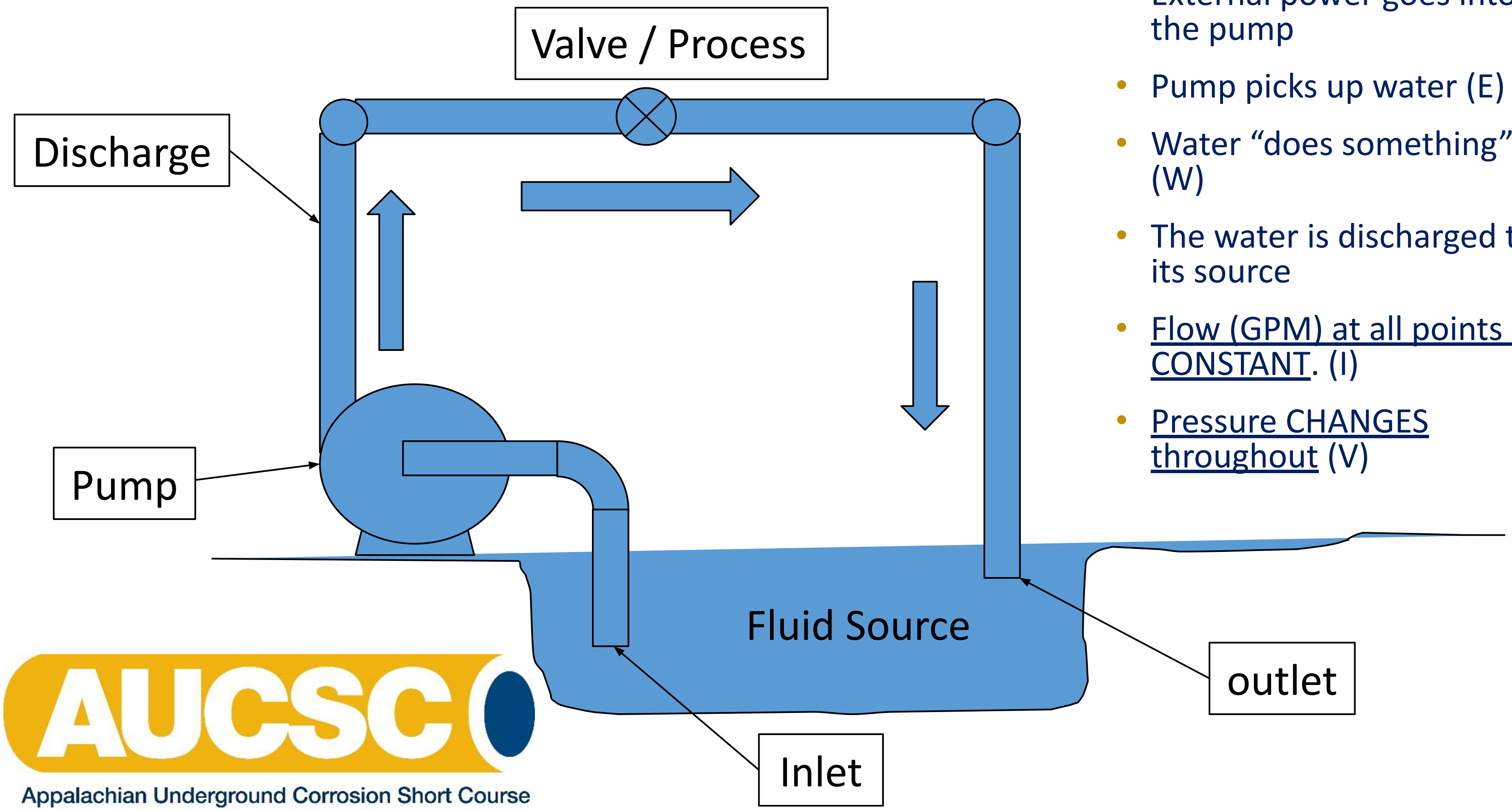
Review

- Topics
  - Skill requires practice
  - Different types of units and their relationships
  - How to derive a conversion ratio to achieve larger or smaller units of measure
  - Established some electrical units of measure

Circuits

Electric Circuits behave somewhat like fluid or pneumatic flow systems



- External power goes into the pump
- Pump picks up water (E)
- Water "does something" (W)
- The water is discharged to its source
- Flow (GPM) at all points is CONSTANT. (I)
- Pressure CHANGES throughout (V)

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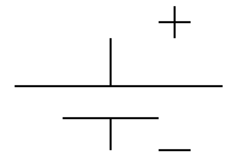
Circuits

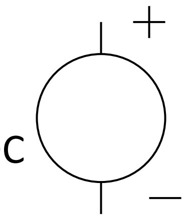
Electrical Symbols

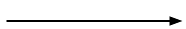
DC Voltage Source (Battery)

$E_s = 1.5V_{DC}$

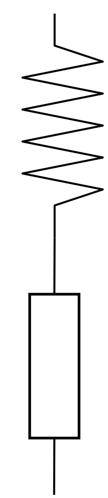


$E = 6V_{DC}$



Current flow – may be represented with an arrow  and an "I"

Resistance – may be represented with zig-zag image or a box with or without a resistance value. Usually labeled R



$R_1 = 60\Omega$

$R_L = 75\Omega$

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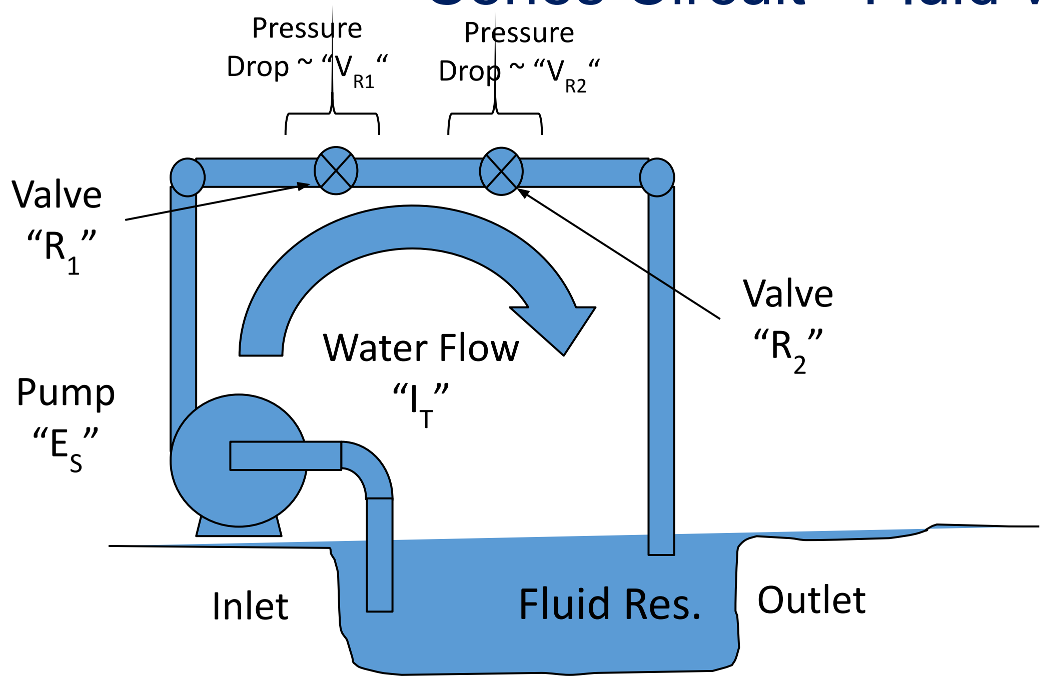
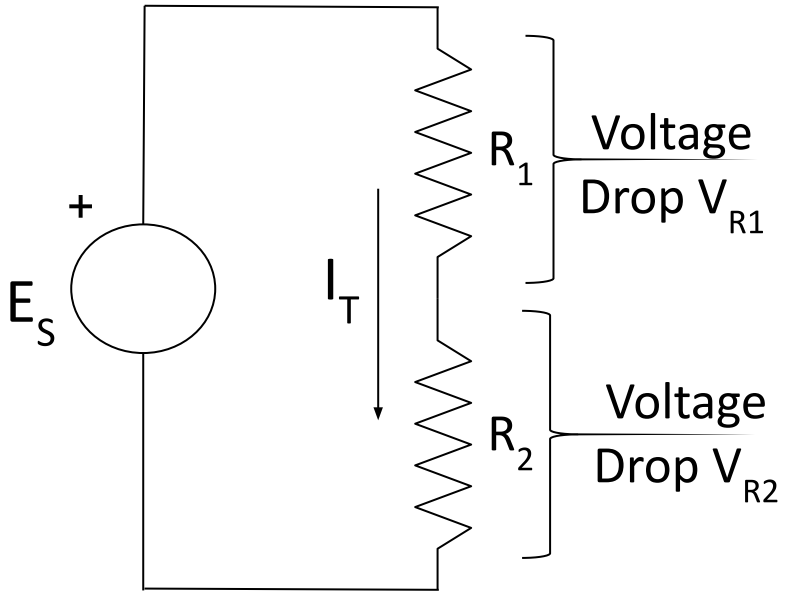
Circuits

Series Circuit - Fluid vs. Electricity



- Pump Pressure ~ Source Voltage
- Water Flow ~ Electrical Current
- Valve ~ Resistor



- Pressure around circuit changes
- Flow rate remains constant

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- Voltage around circuit changes
- Current flow remains constant

Circuits

Series Circuit - Water vs. Electricity

Fluids

- Pressure Drop
  - Pounds per Square Inch
  - Difference between one side of flow resistance and the other
- Flow
  - Gallons per minute
  - Measured by Diverting the Fluid Flow

Electricity

- Voltage Drop
  - Volts
  - Difference between one side of flow resistance and the other
- Current
  - Amps
  - Measured by Diverting the Current

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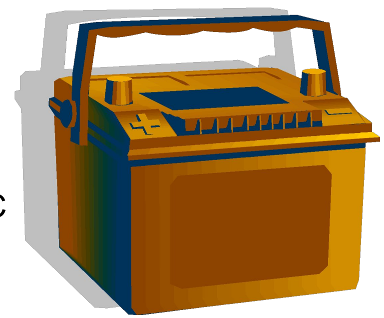
Circuits

Simple Series Circuit

- 12VDC Car Battery
- DC Lamp

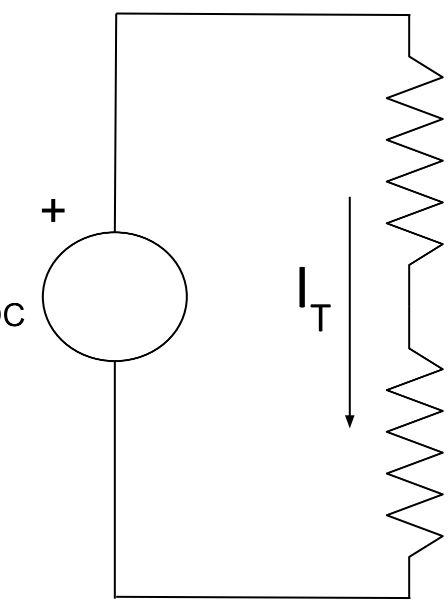
E_S = 12V_{DC}



R$_1$ = 12Ω

R$_2$ = 12Ω

Electrical current flows from battery (+) terminal through the light bulb filament back to the battery (-) terminal.

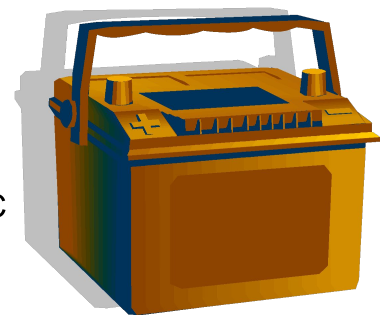


Circuits

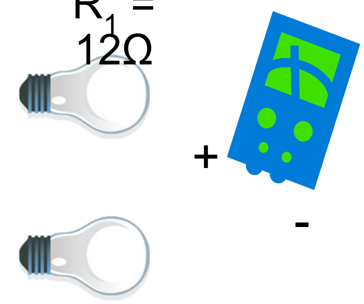
Voltage Measurement

- Measure difference in voltage across the "load" or "voltage drop"
- Circuit unbroken
- Voltmeter has very high resistance (10MΩ)

$E_S = 12V_{DC}$

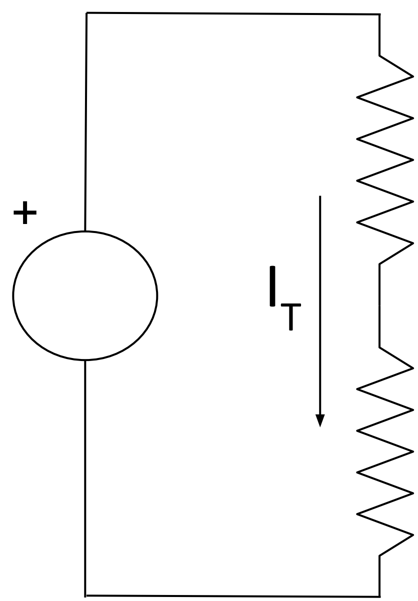


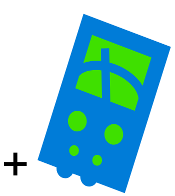
$R_1 = 12\Omega$



$R_2 = 12\Omega$

$V_{R2} = 6V_{DC}$





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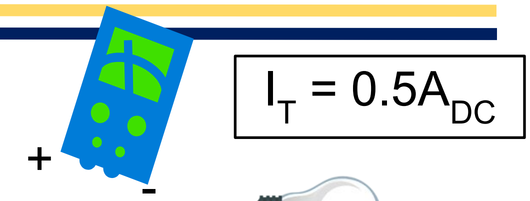
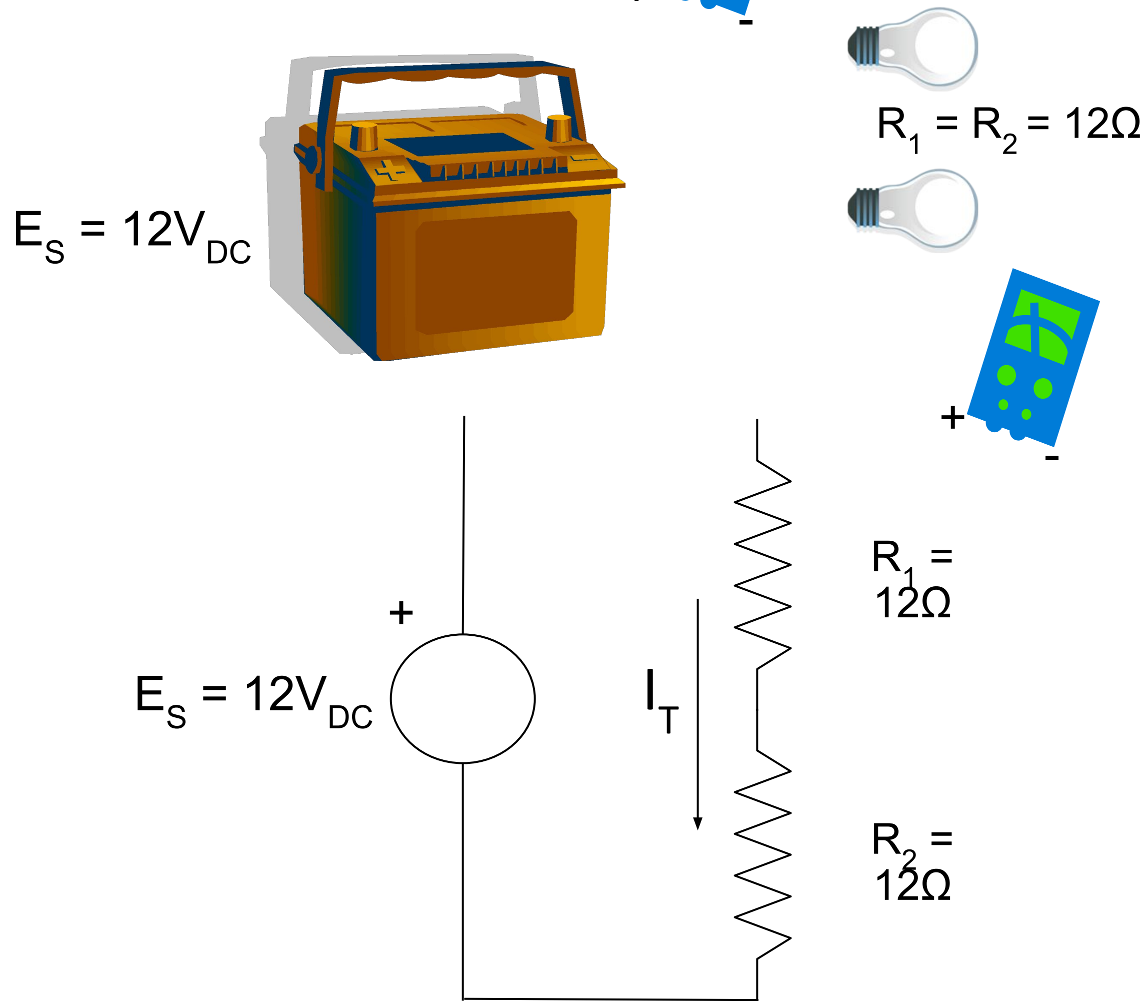
Circuits

Current Measurement



- To measure current, current must flow through the meter
- Circuit broken to insert meter
- Ammeter has very low resistance



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Circuits

Circuit Breakers

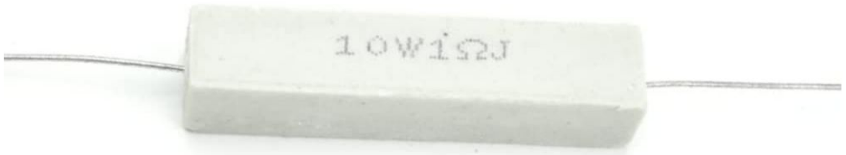
- Two Types of Circuit Breakers
  - “Normal” Circuit Breaker – Breaks the circuit when the current **exceeds** the rating of the circuit breaker (short circuit)
  - “Ground Fault” Circuit Breaker – Breaks the circuit when the “Hot Side” (Black) current is **different** than the “Neutral” (White) side of the circuit

Circuits

Resistors

- Resistors are generally provided with two basic pieces of information
  - The size of the resistor in ohms
  - The wattage or maximum power the resistor can dissipate before it starts to fail

10 Watt, 1Ω



100 Watt, 1Ω

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The Basic Electricity Formulas

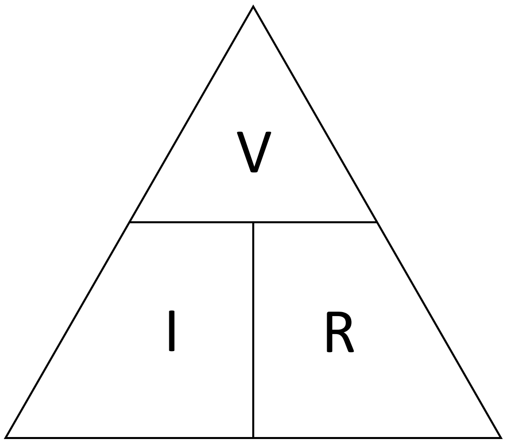
Ohms Law

A potential of 1 Volt across a resistance of 1 Ohm causes 1 ampere of current to flow

V = I * R

I = V / R

R = V / I



*V can be replaced with E

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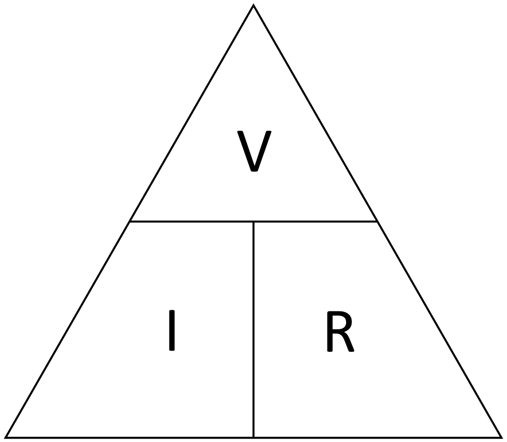
The Basic Electricity Formulas

Ohms Law

- Using the triangle
- Cover the unknown variable
- Known variables will be in the appropriate configuration



$V = I * R$

$I = V / R$

$R = V / I$

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The Basic Electricity Formulas

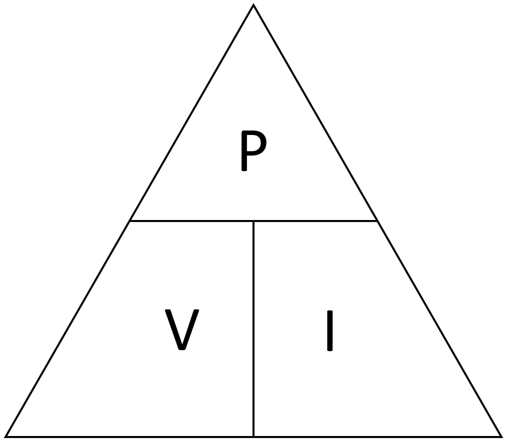
Joules Basic Power Triangle

A potential of 1 Volt across a resistance of 1 Ohm causes 1 ampere of current to flow and dissipates 1 Watt of Power

$P = V * I$

$I = P / V$

$V = P / I$



*V can be replaced with E

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The Basic Electricity Formulas

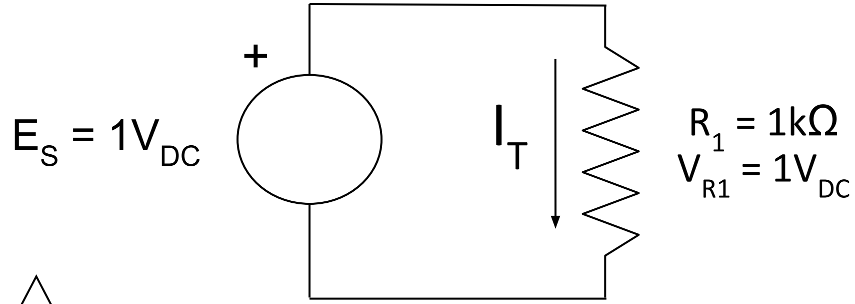
Units, Units, Units

- For ease of calculation
- **<u>Always</u>** convert units to Volts, Amps, Ohms, & Watts
- Convert millivolts, milliamps, kilohms, etc. to the parent unit

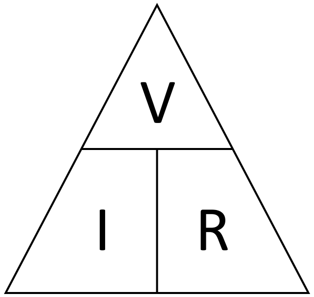
Circuit Analysis

The Formulas Applied – Example 1

- The voltage (V_{R1}) across the resistance is 1 Volt
- The resistance (R_1) is 1kΩ or 1000Ω

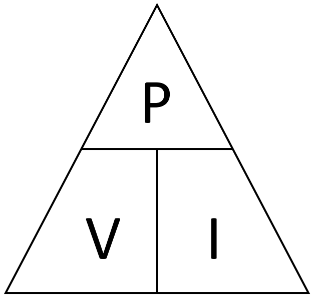


- What is the current through R_1?



- $I_T = V_{R1}/R_1$
- $I_T = 1V / 1000\Omega$
- $I_T = 0.001A$ **or** $1mA$

- What is the minimum wattage for R_1 that's required?



- $P_{R1} = V_{R1} * I_T$
- $P_{R1} = 1V * 0.001A$
- $P_{R1} = 0.001W$ **or** $1mW$

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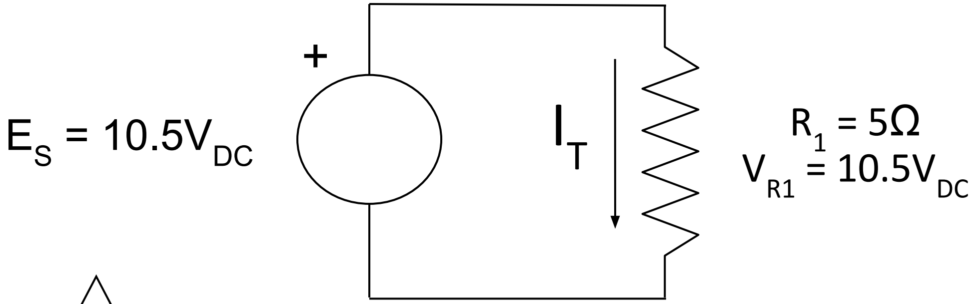
Circuit Analysis

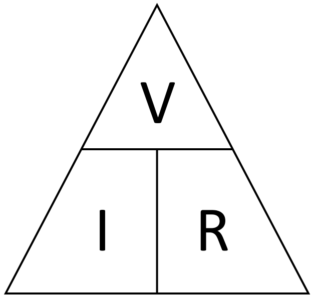
The Formulas Applied – Example 2

- The voltage (V_{R1}) across the resistance is 10.5 Volts
- The resistance (R_1) is 5Ω

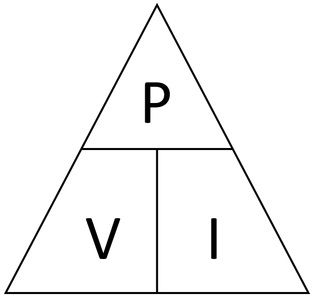
- What is the current through R_1?

- What is the minimum wattage for R_1 that's required?





- $I_T = V_{R1}/R_1$
- I_T = 10.5V / 5Ω
- I_T = 2.1A



- $P_{R1} = V_{R1} * I_T$
- P_{R1} = 10.5V * 2.5A
- P_{R1} = 26.25W

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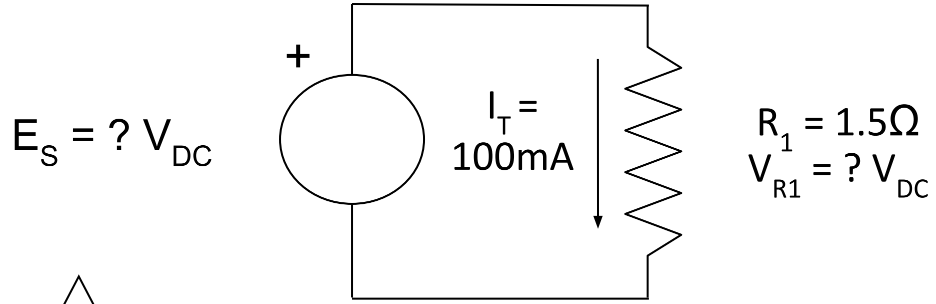
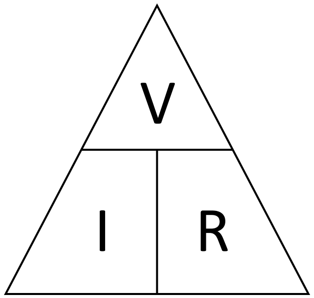
Circuit Analysis

The Formulas Applied – Example 4

- The total circuit current (I_T) is 100mA
- The resistance of R_1 is 1.5 Ω

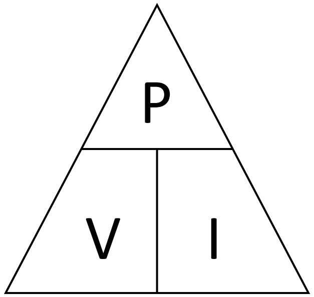


- What is the voltage across the resistance R_1?



- $V_{R1} = R_1 * I_T$
- $V_{R1} = 1.5\Omega * 0.1A$
- $V_{R1} = 0.15V$

- How many watts are being dissipated across R_1?



- $P_{R1} = V_{R1} * I_T$
- $P_{R1} = 0.15V * 0.1A$
- $P_{R1} = 0.015W$ **or** $15mW$

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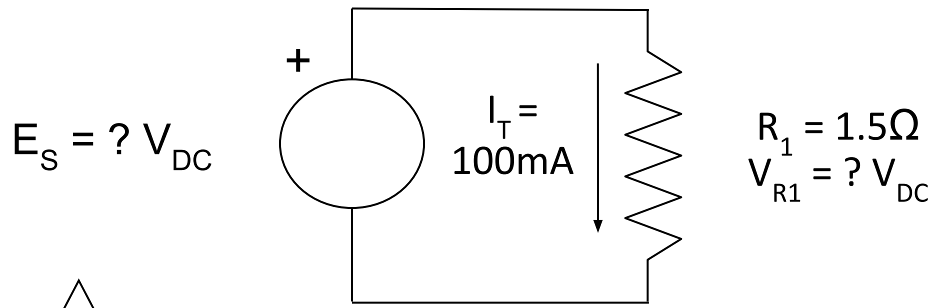
Circuit Analysis

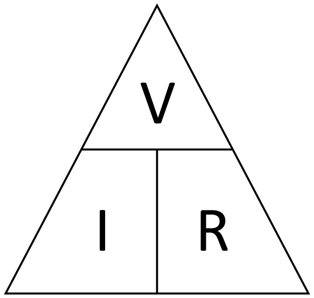
The Formulas Applied – Example 5 (Common Error)

- The total circuit current (I_T) is 100mA
- The resistance of R_1 is 1.5 Ω

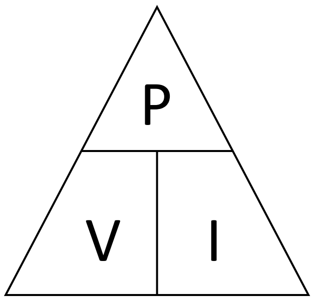
- What is the voltage across the resistance R_1?

- How many watts are being dissipated across R_1?





- $V_{R1} = R_1 * I_T$
- $V_{R1} = 1.5 * 100$
- $V_{R1} = 150V$



- $P_{R1} = V_{R1} * I_T$
- $P_{R1} = 150V * 100A$
- $P_{R1} = 15,000W$

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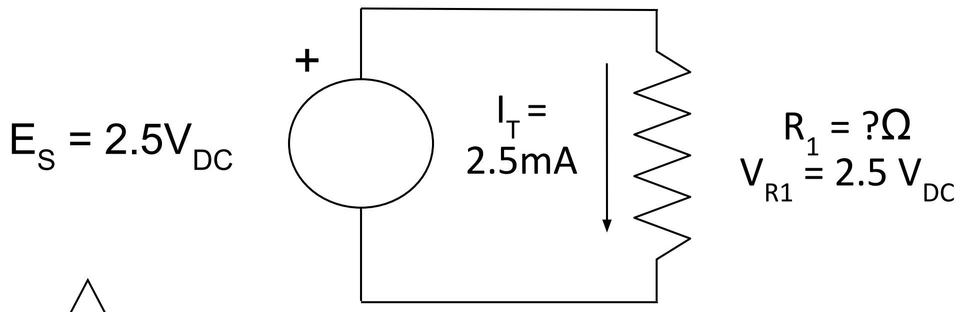
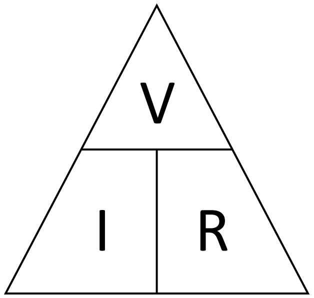
Circuit Analysis

The Formulas Applied – Example 6

- The total circuit current (I_T) is 2.5mA
- The voltage across R_1 is 2.5V

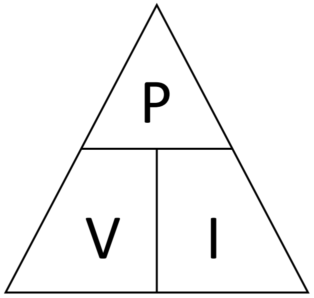


- What is the value of the resistance R_1?



- $R_1 = VR_1 / I_T$
- R_1 = 2.5V / 2.5mA
- R_1 = 1000Ω

- How many watts are being dissipated across R_1?



- $P_{R1} = V_{R1} * I_T$
- P_{R1} = 2.5V * 2.5mA
- P_{R1} = 0.00625W or 6.25mW

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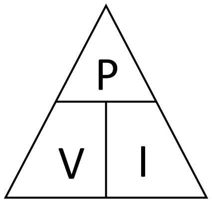
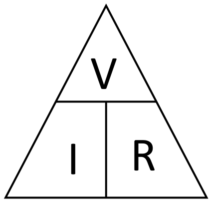
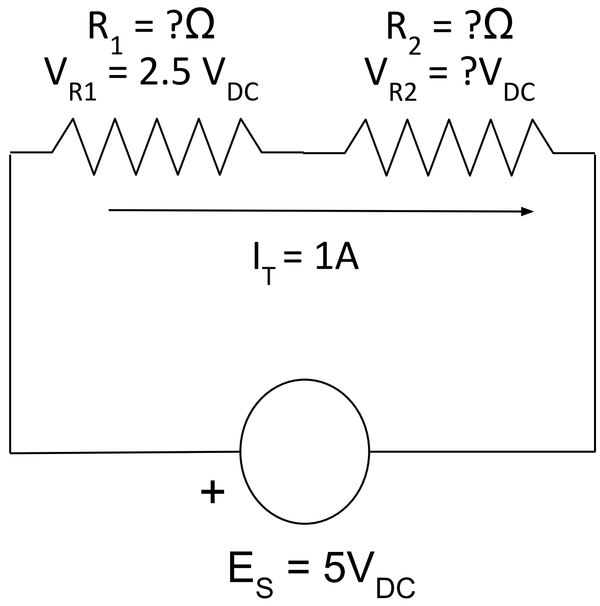
Circuit Analysis



The Formulas Applied – Example 7





- The total circuit current (I_T) is 1A
- The voltage across R_1 is 2.5V

- What is the value of the resistance R_2?

- How many watts are being dissipated across R_2?

- $R_1 = VR_1 / I_T$
- $R_1 = 2.5V / 1A$
- $R_1 = 2.5\Omega$

- $V_{R2} = E_S - V_{R1}$
- $V_{R2} = 5V - 2.5V$
- $V_{R2} = 2.5V$

- $V_{R1} = V_{R2}$; $R_1 = R_2$
- $R_2 = 2.5\Omega$

- $P_{R2} = V_{R1} * I_T$
- $P_{R2} = 2.5V * 1A$
- $P_{R2} = 2.5W$

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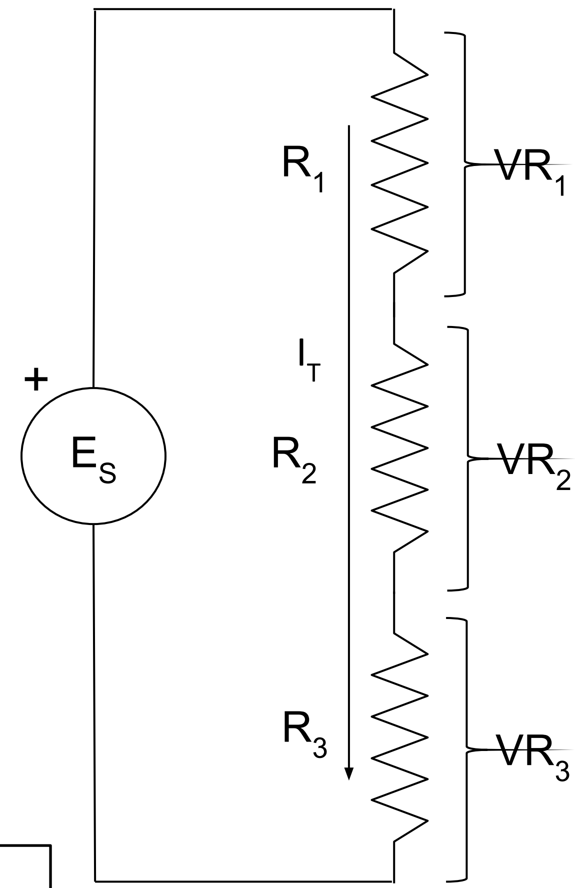
Circuit Analysis

Series Circuit Analysis

- A series circuit has all elements connected "end to end" forming a single loop with the power source
- **Current (I_T) is the same through all elements**
- Voltage Drops (V_{R1}, V_{R2}, etc.) may be different
- The sum of all voltage drops = the source voltage
- $V_{R1}+V_{R2}+V_{R3}+\ldots = E_S$
- Total or Equivalent circuit resistance (R_T or R_{EQ}) = the sum of all resistances



Total resistance (R_T) is always **larger** than the largest resistance

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Circuit Analysis

Parallel Circuit

- A parallel circuit has all elements "side by side" forming multiple loops with the power source

- **Total Current (I_T) is the sum of currents through all elements**

- Voltage Drops (V_{R1}, V_{R2}, etc.) are the same

- $I_{R1}+I_{R2}+I_{R3}+ \ldots\ldots = I_T$

- Total or Equivalent circuit resistance (R_T or R_{EQ}) = the inverse of the inverse sum of all resistances

$$R_T = \frac{1}{}$$

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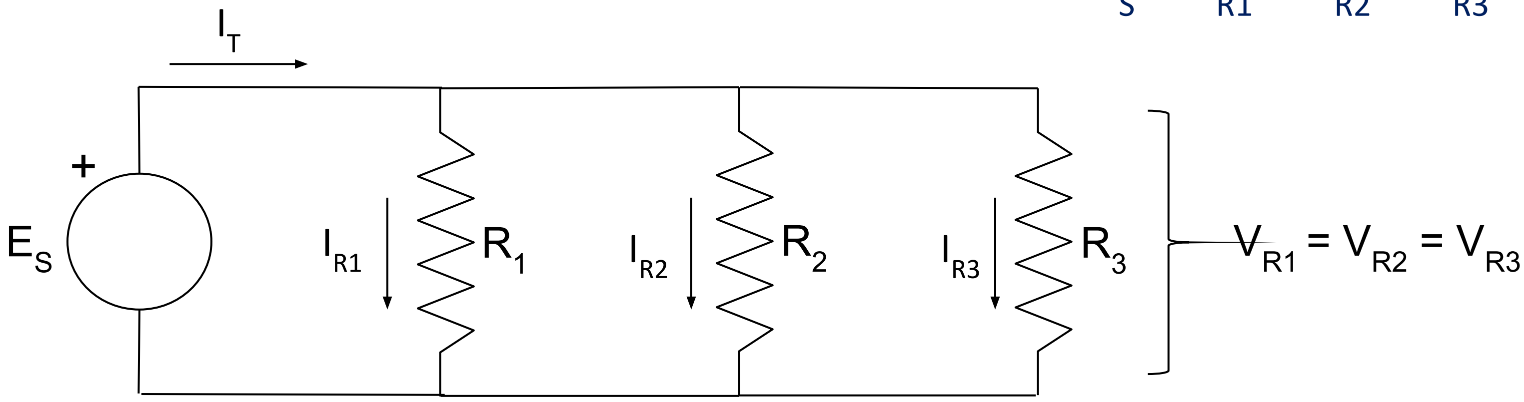
Circuit Analysis

Parallel Circuit

- Each parallel current is a different magnitude
- Voltage across each parallel path or resistance is the same

- $I_T = I_{R1} + I_{R2} + I_{R3}$
- $R_T = \dfrac{1}{((1/R_1)+(1/R_2)+(1/R_3))}$
- $E_S = V_{R1} = V_{R2} = V_{R3}$



Total resistance (R_T) is always **smaller** than the smallest resistance

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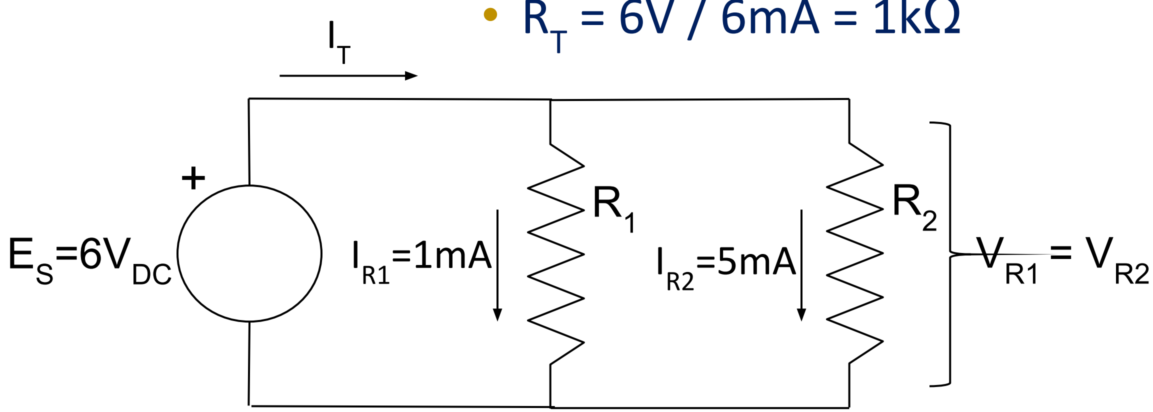
Circuit Analysis

The Formulas Applied - Example 8

- The total circuit current (I_T) is 6mA
- The current through R_1 is 1mA & R_2 is 5mA
- What is the value of the resistances R_1 & R_2 & R_T
- How would you verify R_T?

- $R_1 = V_{R1} / I_{R1}$
- $R_1 = 6V / 0.001A = 6k\Omega$
- $R_2 = V_{R2} / I_{R2}$
- $R_2 = 6V / 0.005A = 1.2k\Omega$
- $R_T = 1/((1/R_1)+(1/R_2))$
- $R_T = 1/(0.000167s+0.000833s)$
- $R_T = 1k\Omega$
- $R_T = E_S / I_T$
- $R_T = 6V / 6mA = 1k\Omega$



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Thank You!

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