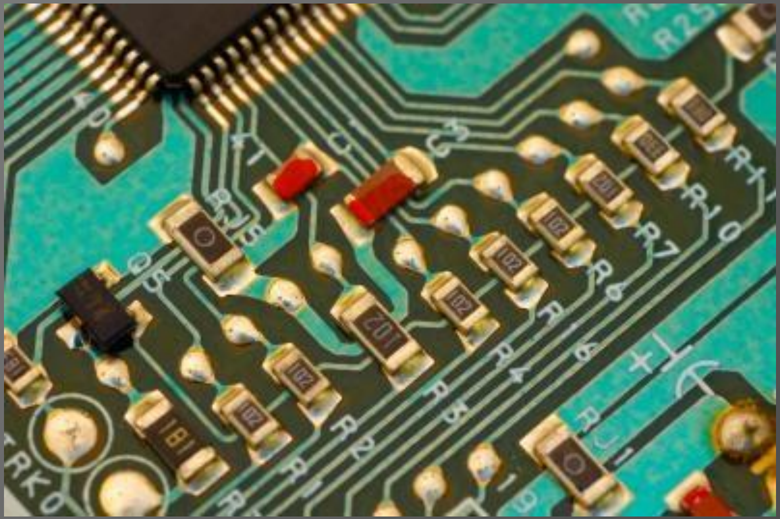
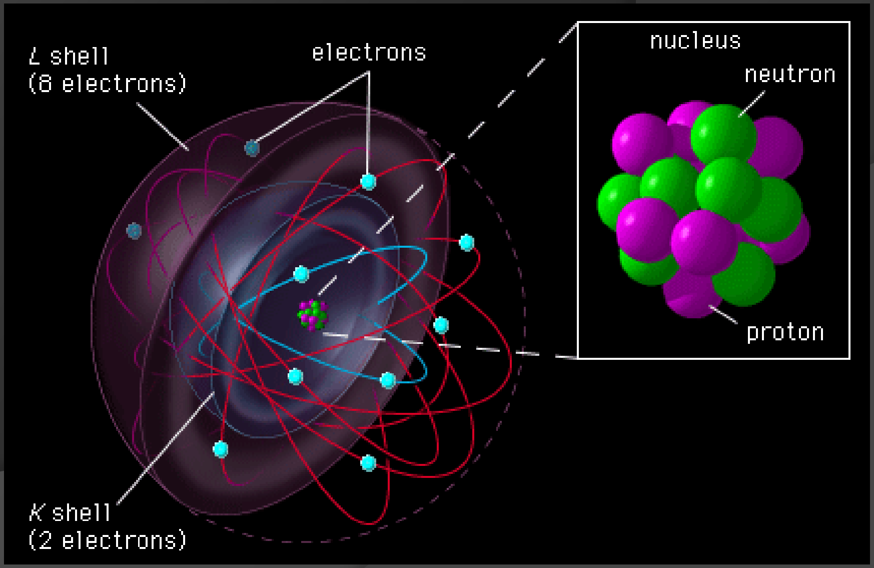


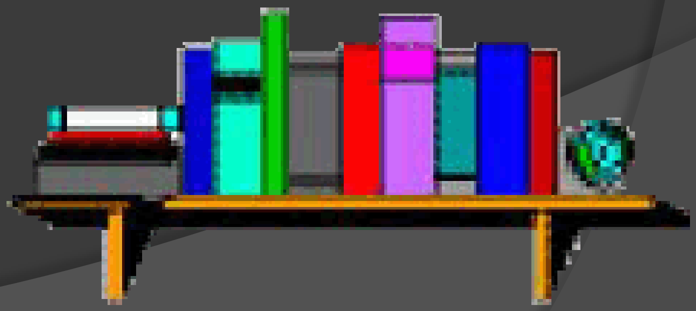
Characteristics, Types, Calculations, Units, & Analysis

CIRCUIT THEORY



Resources

- For more complete documentation, the following items are available from:
  - Robotics with the BOEBOT Version 2.2
  - Handouts
  - http://mfranzen.ca/index.html
  - http://www.allaboutcircuits.com/

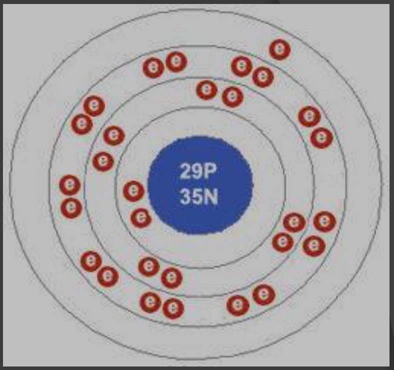


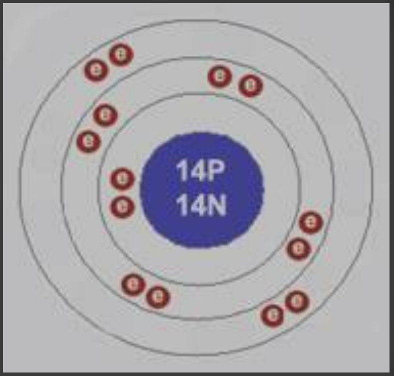
Overview

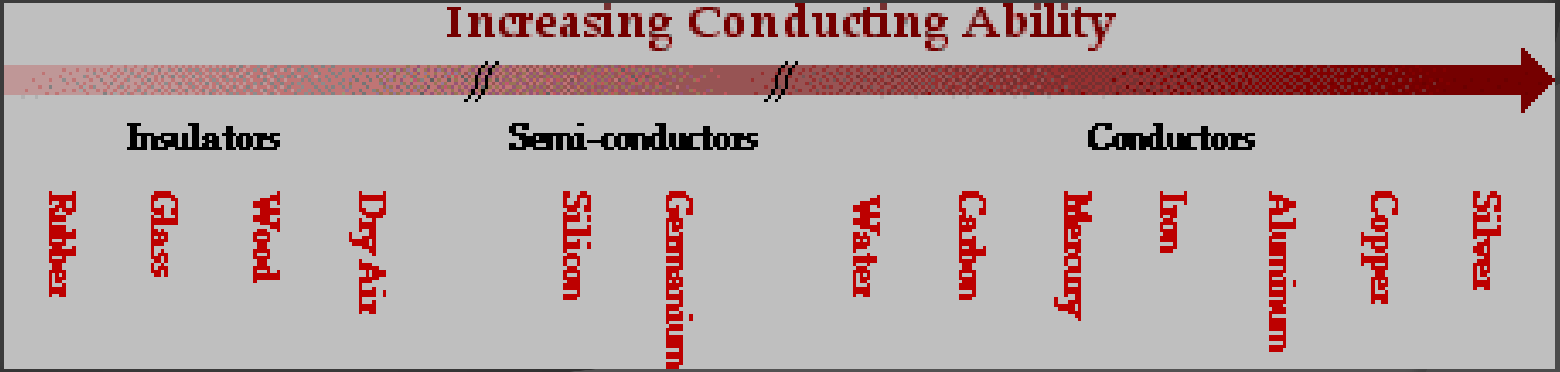
- Atomic structure of related materials
- Electricity and electron flow
  - Ohms law
  - Power
- Circuit Types
  - Series
  - Parallel
  - Combination
- Quantities and units of measure

Atomic Structure

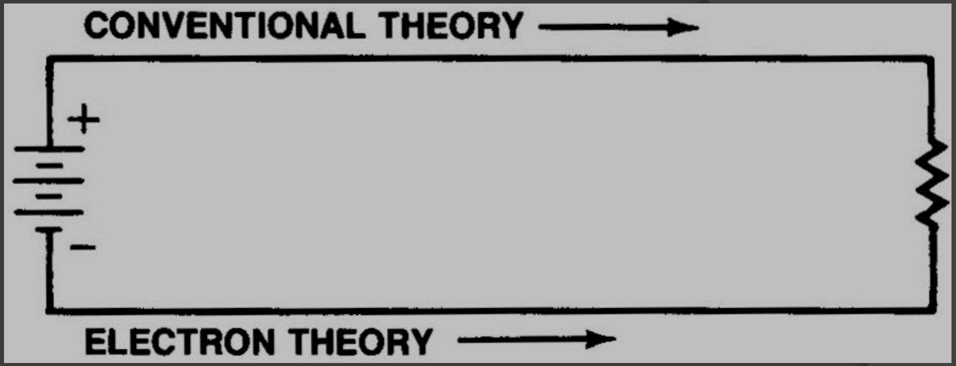
- Conductors
  - Metallic material with high conductivity and has few electrons (copper/silver)
- Insulators
  - Non Metallic with low conductivity and has many electrons (plastic/rubber)
- Semi-conductors
  - Some electrons with intermediate conductivity (silicon/germanium)





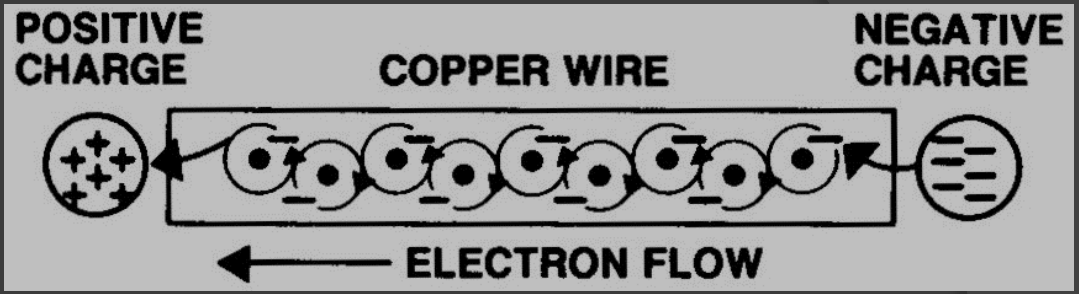


Electricity



- Two theories
  - Conventional
    - Electrons flows *from positive to negative*
    - Scientists originally used this theory
    - more convenient to use
  - Electron
    - Electrons flows *from negative to positive*
    - current theory used in electronics
    - most accurate in terms of explanation of this theory
  - Using either theory in circuit analysis,
    - THE ANSWERS COME OUT THE SAME!

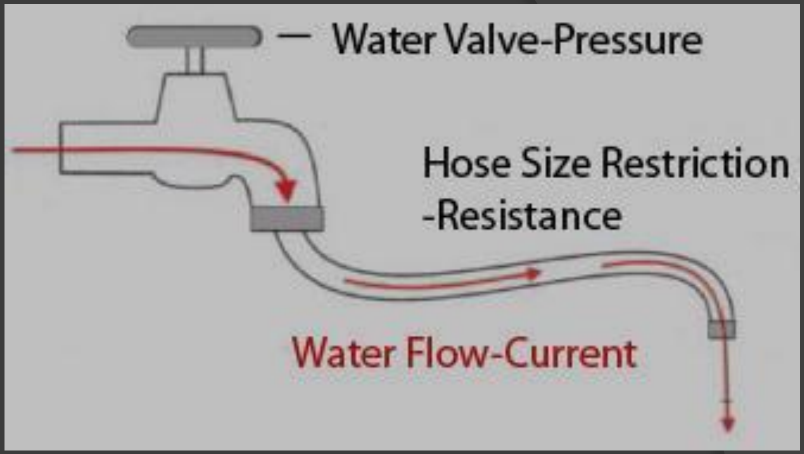
Electricity



- copper wire is a good conductor and it only has one *free electron* in its valence shell or ring
- electrons are forced into one end (*pressure or voltage*) which continues to push adjacent free electrons from one atom to the next and so on (battery)
- *The amount/flow of electrons* going though this conductor is known as the current
- The larger the conductor size the more electrons can flow through *(less resistance)* which is known as the resistance
- Understanding this theory sums up *electricity as:*
  - The controlled and directed flow of free electrons from atom to atom in a conductor

Ohms Law

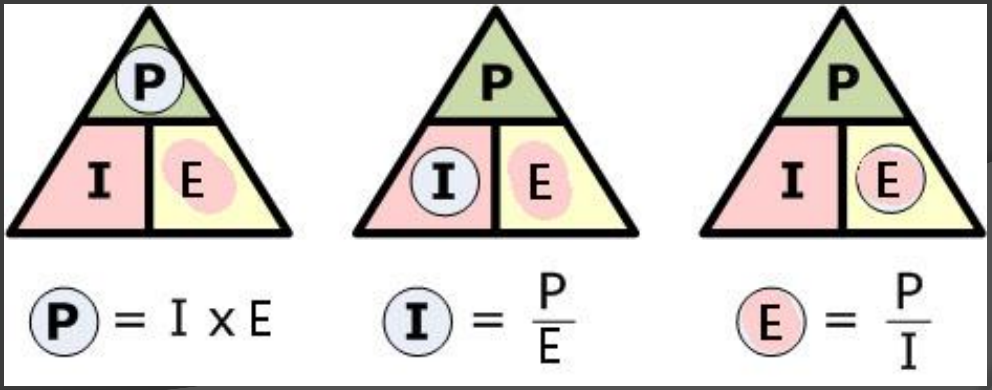
- All circuits have common traits
  - Pressure = Voltage E
  - Flow = Current A
  - Restriction = Resistance R



- Using the water hose analogy, how these traits relate can be easily understood (E=I*R)
  - With a water hose attached to an outlet, the valve acts as the pressure, the hose size as the restriction, and the water is the flow
  - Turn the valve on half a turn, pressure, and water flow are present
  - Turn the valve to full turn, pressure doubles, and water flow also doubles
  - Now if someone steps on the hose allowing only a quarter flow of the water through, pressure also will drop, but the amount/flow of water will be the same (just slower because of the restriction)

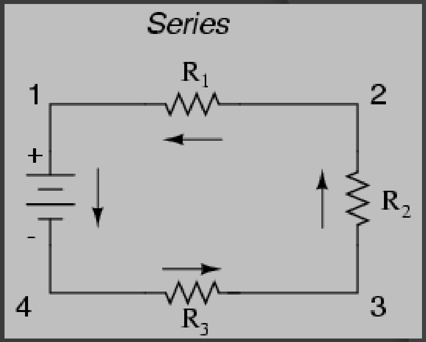
Power

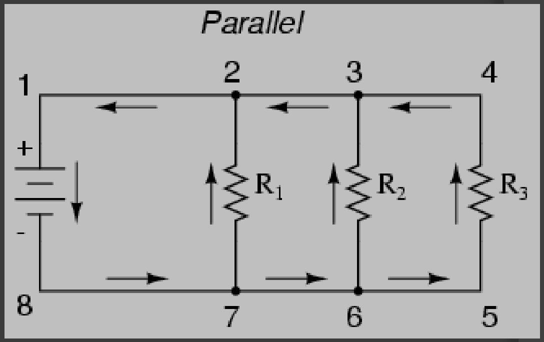
- Power in general is the measure of how much work can be done in a given amount of time
- In electric circuits it is a function of both voltage and current similar where Voltage is the specific work (or potential energy) per unit charge, while current is the rate at which electric charges move through a conductor
- Power is equal to the Voltage times the Current (P=E*I), similar to ohms law and is measured in Watts (W)

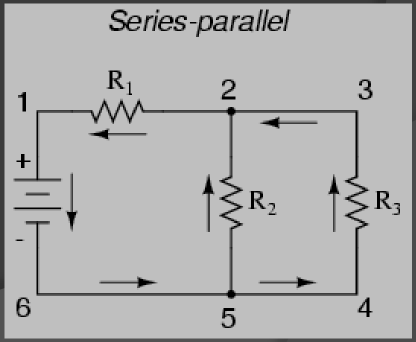


Circuit Types

- Series Circuits
  - Current has only one path to flow
- Parallel Circuits
  - Current has more than one path to flow
- Complex Circuits
  - Combination of series and parallel paths for current to flow

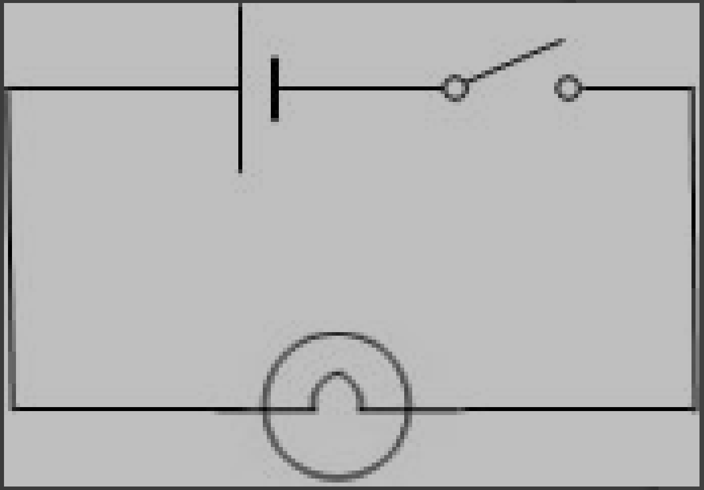


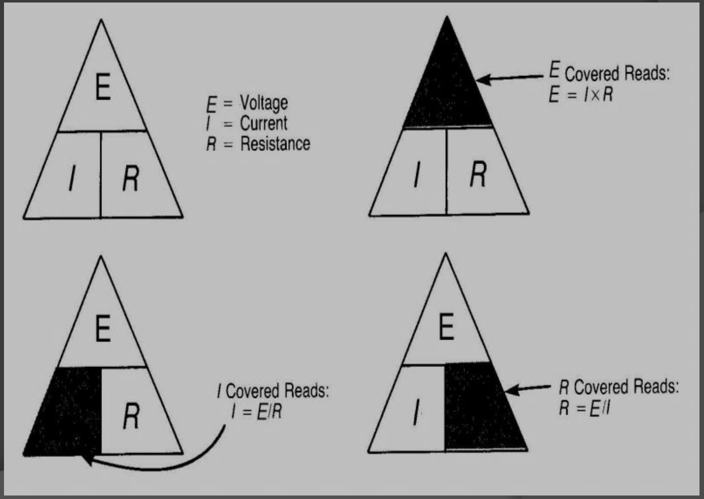


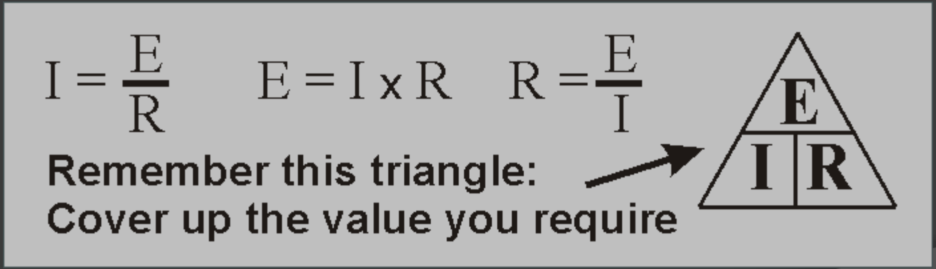


Ohms Law

- A simple circuit with a power supply, switch (not necessary to draw in) and a single load/resistance
- Calculations are used to troubleshoot, double check, and understand what is happening in an electrical circuit
- With E=I*R, you can use a graphic triangle formula to figure out which formula to use if two of the three variables are known

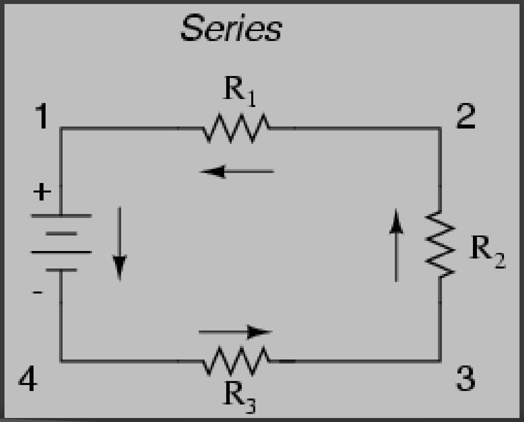






Series Circuits

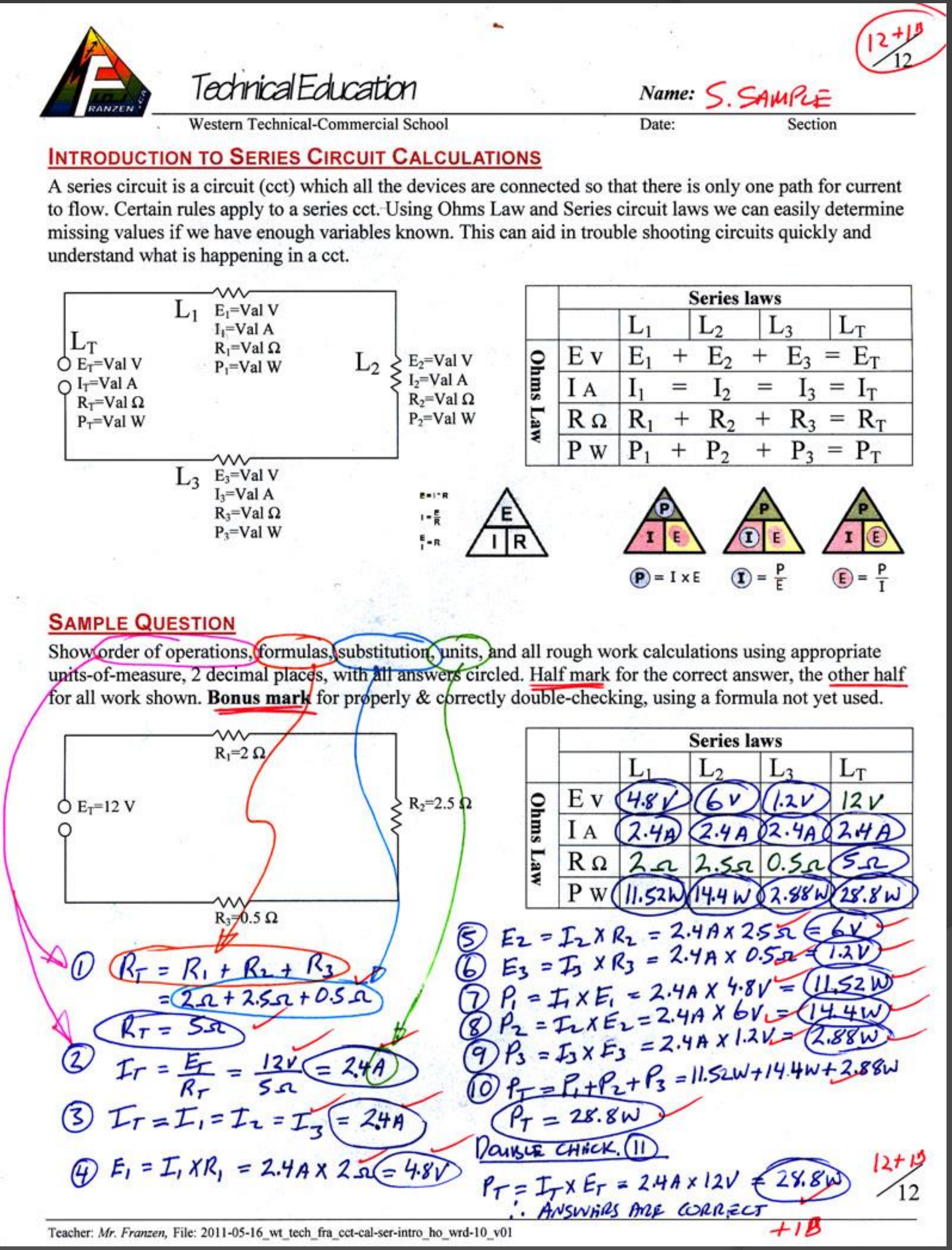
- In a series circuit with multiple loads/resistances and only one path, you will find these formulas work if you have one variable missing
- Total voltage is the sum of the individual voltage drops
  - $E_T = E_1 + E_2 + E_3 \ldots$
- Total current is equal as there is only one path
  - $I_T = I_1 = I_2 = I_3 \ldots$
- Total resistance is the sum of all individual resistances
  - $R_T = R_1 + R_2 + R_3 \ldots$
- Each load is identified by a subscript
- Use a EIRP Table to find solutions easily



	Series/Parallel laws				
		L_1	L_2	L_3	L_T
Ohms Law	E in Volts				
	I in Amps				
	R in Ohms				
	P in Watts				

Series Cct. Calculation Sample

- Here is an sample done by a student showing the basic steps
- Shows given info, diagram, EIRP table (without the Power), rough calculations, and double check



Technical Education — Western Technical-Commercial School

Name: S. SAMPLE — Date: — Section

$\frac{12+1B}{12}$

INTRODUCTION TO SERIES CIRCUIT CALCULATIONS

A series circuit is a circuit (cct) which all the devices are connected so that there is only one path for current to flow. Certain rules apply to a series cct. Using Ohms Law and Series circuit laws we can easily determine missing values if we have enough variables known. This can aid in trouble shooting circuits quickly and understand what is happening in a cct.

Ohms Law	Series laws			
	L1	L2	L3	LT
E v	E_1 +	E_2 +	E_3 =	E_T
I A	I_1 =	I_2 =	I_3 =	I_T
R Ω	R_1 +	R_2 +	R_3 =	R_T
P w	P_1 +	P_2 +	P_3 =	P_T

SAMPLE QUESTION

Show order of operations, formulas, substitution, units, and all rough work calculations using appropriate units-of-measure, 2 decimal places, with all answers circled. Half mark for the correct answer, the other half for all work shown. **Bonus mark** for properly & correctly double-checking, using a formula not yet used.

Ohms Law	L1	L2	L3	LT
E v	4.8 V	6 V	1.2 V	12 V
I A	2.4 A	2.4 A	2.4 A	2.4 A
R Ω	2 Ω	2.5 Ω	0.5 Ω	5 Ω
P w	11.52 W	14.4 W	2.88 W	28.8 W

1. $R_T = R_1 + R_2 + R_3 = 2\Omega + 2.5\Omega + 0.5\Omega$, $R_T = 5\Omega$
2. $I_T = \frac{E_T}{R_T} = \frac{12V}{5\Omega} = 2.4A$
3. $I_T = I_1 = I_2 = I_3 = 2.4A$
4. $E_1 = I_1 \times R_1 = 2.4A \times 2\Omega = 4.8V$
5. $E_2 = I_2 \times R_2 = 2.4A \times 2.5\Omega = 6V$
6. $E_3 = I_3 \times R_3 = 2.4A \times 0.5\Omega = 1.2V$
7. $P_1 = I_1 \times E_1 = 2.4A \times 4.8V = 11.52W$
8. $P_2 = I_2 \times E_2 = 2.4A \times 6V = 14.4W$
9. $P_3 = I_3 \times E_3 = 2.4A \times 1.2V = 2.88W$
10. $P_T = P_1 + P_2 + P_3 = 11.52W + 14.4W + 2.88W$, $P_T = 28.8W$

DOUBLE CHECK (11): $P_T = I_T \times E_T = 2.4A \times 12V = 28.8W$

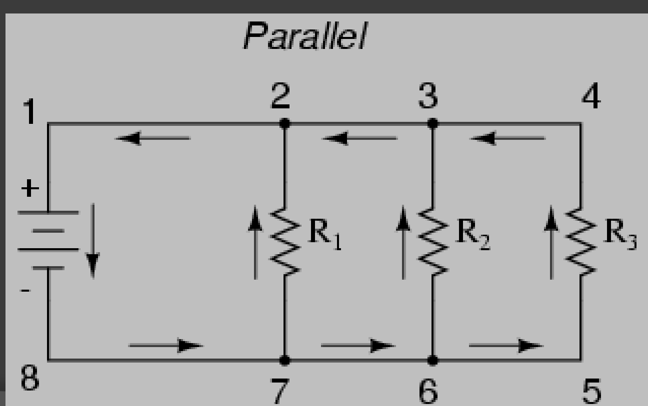
∴ ANSWERS ARE CORRECT

$\frac{12+1B}{12}$ +1B

Teacher: Mr. Franzen, File: 2011-05-16_wt_tech_fra_cct-cal-ser-intro_ho_wrd-10_v01

Parallel Circuits

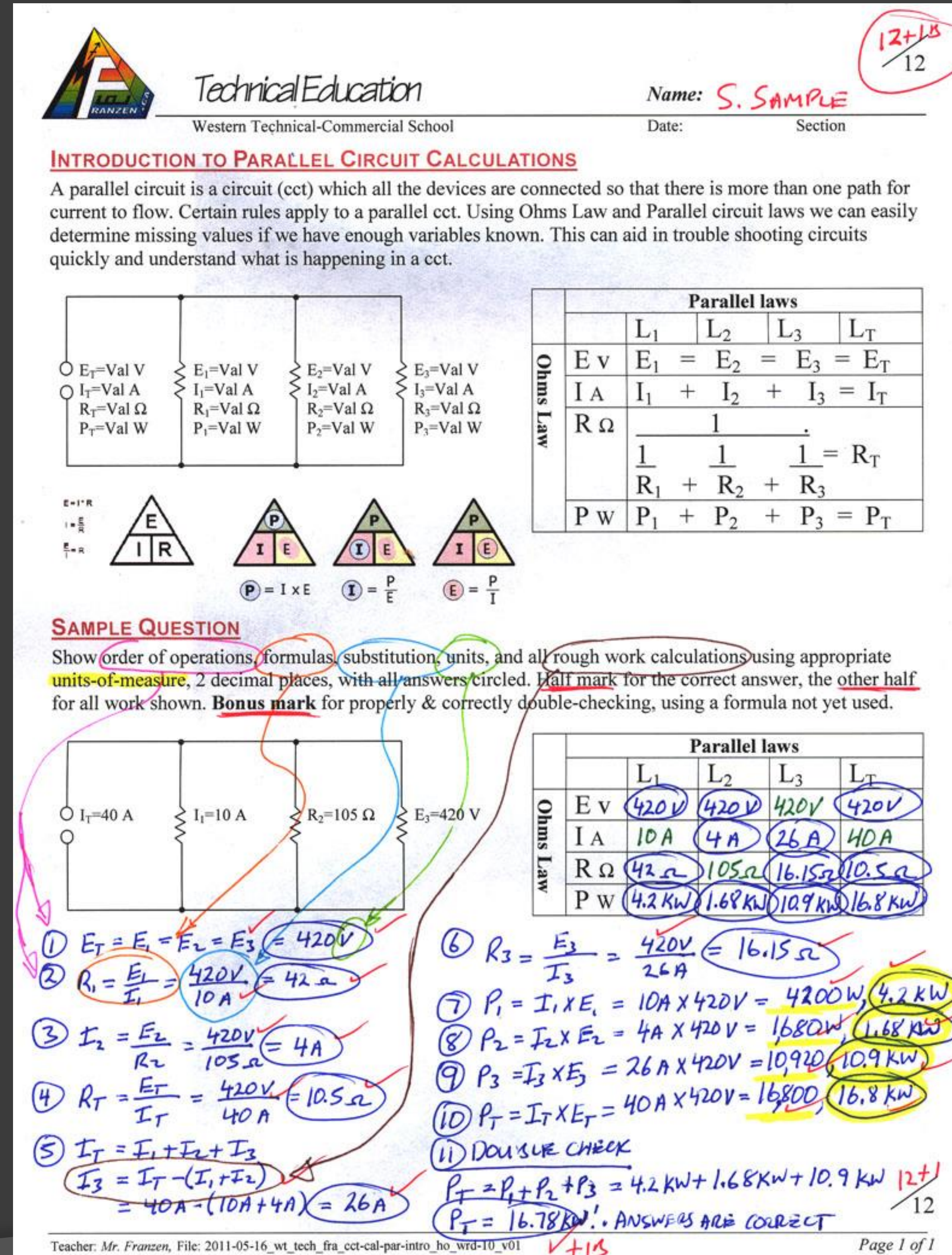
- In a parallel circuit with multiple loads/resistances and more than one path, you will find these formulas work if you have one variable missing
- The potential difference across all branches of a parallel circuit must have the same amount
  - $E_T = E_1 = E_2 = E_3 \ldots$
- Total current in a parallel circuit is equal to the sum of the currents in the separate branches
  - $I_T = I_1 + I_2 + I_3 \ldots$
- The reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the separate resistances in parallel
  - $R_T = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$
- Each load is identified by a subscript
- Use a EIRP Table to find solutions easily



Ohms Law	Series/Parallel laws				
		L_1	L_2	L_3	L_T
	E in Volts				
	I in Amps				
	R in Ohms				
	P in Watts				

Parallel Cct. Calculation Sample

- Here is an sample done by a student showing the basic steps
- Shows given info, diagram, EIRP table (without the Power), rough calculations, and double check



Technical Education — Western Technical-Commercial School

Name: S. SAMPLE Date: Section

12+1B / 12

INTRODUCTION TO PARALLEL CIRCUIT CALCULATIONS

A parallel circuit is a circuit (cct) which all the devices are connected so that there is more than one path for current to flow. Certain rules apply to a parallel cct. Using Ohms Law and Parallel circuit laws we can easily determine missing values if we have enough variables known. This can aid in trouble shooting circuits quickly and understand what is happening in a cct.

E_T=Val V, I_T=Val A, R_T=Val Ω, P_T=Val W; E_1=Val V, I_1=Val A, R_1=Val Ω, P_1=Val W; E_2=Val V, I_2=Val A, R_2=Val Ω, P_2=Val W; E_3=Val V, I_3=Val A, R_3=Val Ω, P_3=Val W

Parallel laws (Ohms Law)

	L_1	L_2	L_3	L_T
E v	$E_1 =$	$E_2 =$	$E_3 =$	E_T
I A	$I_1 +$	$I_2 +$	$I_3 =$	I_T
R Ω	$\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} = R_T$			
P w	$P_1 +$	$P_2 +$	$P_3 =$	P_T

E=I*R, I=E/R, E/I=R

$P = I \times E$ $I = \frac{P}{E}$ $E = \frac{P}{I}$

SAMPLE QUESTION

Show order of operations, formulas, substitution, units, and all rough work calculations using appropriate units-of-measure, 2 decimal places, with all answers circled. Half mark for the correct answer, the other half for all work shown. **Bonus mark** for properly & correctly double-checking, using a formula not yet used.

I_T=40 A, I_1=10 A, R_2=105 Ω, E_3=420 V

Parallel laws (Ohms Law)

	L_1	L_2	L_3	L_T
E v	420 V	420 V	420 V	420 V
I A	10 A	4 A	26 A	40 A
R Ω	42 Ω	105 Ω	16.15 Ω	10.5 Ω
P w	4.2 KW	1.68 KW	10.9 KW	16.8 KW

1. $E_T = E_1 = E_2 = E_3 = 420V$
2. $R_1 = \frac{E_1}{I_1} = \frac{420V}{10A} = 42\Omega$
3. $I_2 = \frac{E_2}{R_2} = \frac{420V}{105\Omega} = 4A$
4. $R_T = \frac{E_T}{I_T} = \frac{420V}{40A} = 10.5\Omega$
5. $I_T = I_1 + I_2 + I_3$; $I_3 = I_T - (I_1 + I_2) = 40A - (10A + 4A) = 26A$
6. $R_3 = \frac{E_3}{I_3} = \frac{420V}{26A} = 16.15\Omega$
7. $P_1 = I_1 \times E_1 = 10A \times 420V = 4200W$, 4.2 kW
8. $P_2 = I_2 \times E_2 = 4A \times 420V = 1680W$, 1.68 kW
9. $P_3 = I_3 \times E_3 = 26A \times 420V = 10,920$, 10.9 kW
10. $P_T = I_T \times E_T = 40A \times 420V = 16800$, 16.8 kW
11. Double check

$P_T = P_1 + P_2 + P_3 = 4.2kW + 1.68kW + 10.9kW$

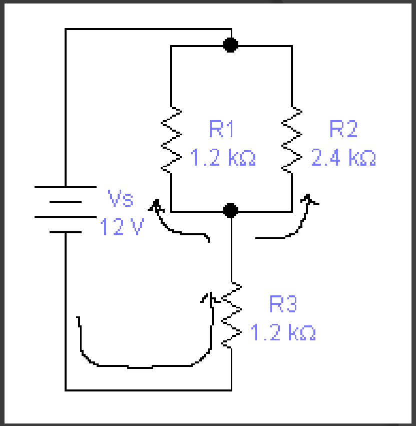
$P_T = 16.78kW$ ∴ Answers are correct

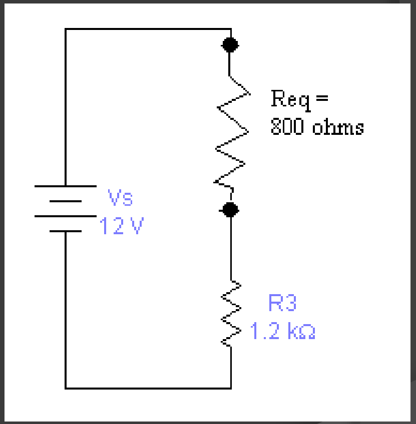
12+1 / 12 ✓+1B

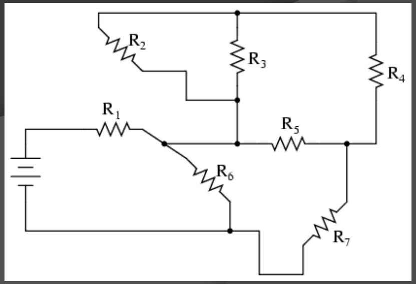
Teacher: Mr. Franzen, File: 2011-05-16_wt_tech_fra_cct-cal-par-intro_ho_wrd-10_v01 Page 1 of 1

Complex Series-Parallel Circuits

- These circuits must be broken down and analyzed into their respective series and parallel components
- Do this by redrawing the circuit by reducing it down to it's basic series and parallel components one step at a time
  - As you break it down, you calculate the related circuit types
  - Show your steps also in your EIRP table by making more columns
- For more detail steps see:
  - http://www.allaboutcircuits.com/vol_1/chpt_7/2.html







Sample Complex Circuit Analysis

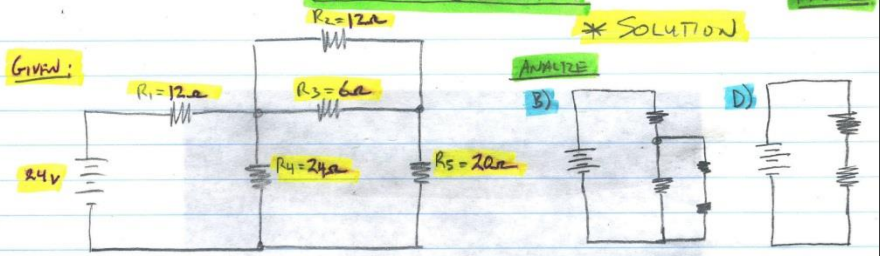
DIRECT CURRENT FUND. P. 181 #4

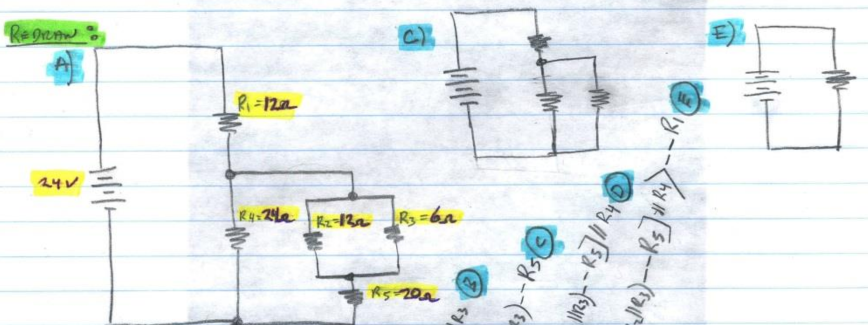
MR. FRANZEN

P1 OF 2

COMPLEX CCT CALCULATIONS

* SOLUTION





CHART

	L1	L2	L3	L4	L5	R2//R3	(R2//R3)--R5	[(R2//R3)--R5]//R4	[(R2//R3)--R5]//R4--R1
EV	12V	2V	2V	12V	10V				24V
IA	1A	166.67 mA	333.33 mA	0.5A	0.5A				1A
RΩ	12Ω	12Ω	6Ω	24Ω	20Ω	4Ω	24Ω	12Ω	24Ω
PW	12W	333.33 mW	666.66 mW	6W	5W				24W

DCF P.181 #4

P2 OF 2

COMPLEX CCT CALCULATIONS

CALCULATION STEPS

(1) $R_2 // R_3 = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{12\Omega \times 6\Omega}{12\Omega + 6\Omega} = \frac{72\Omega}{18\Omega} = 4\Omega$

(2) $(R_2 // R_3) -- R_5 = 4\Omega + 20\Omega = 24\Omega$

(3) $[(R_2 // R_3) -- R_5] // R_4 = (2)/2 = 24\Omega/2 = 12\Omega$

(4) $(3) -- R_1 = 12\Omega + 12\Omega = 24\Omega$

(5) $I_T = \frac{E_T}{R_T} = \frac{24V}{24\Omega} = 1A$

(6) $I_T = I_1, --, \therefore E_1 = I_1 \times R_1 = 1A \times 12\Omega = 12V$

(7) $\because E_1 = 12V \therefore E_4 = 12V$, $I_4 = \frac{E_4}{R_4} = \frac{12V}{24\Omega} = 0.5A$

(8) $\because I_4 = 0.5A \therefore$ (3) ALSO HAS 0.5A & $I_5 = 0.5A \therefore E_5 = I_5 \times R_5 = 0.5A \times 20\Omega = 10V$

(9) $\because E_5 = 10V \therefore$ 2V LEFT FOR (1)

(10) $I_2 = \frac{E_2}{R_2} = \frac{2V}{12\Omega} = 166.67mA$

(11) $I_3 = \frac{E_3}{R_3} = \frac{2V}{6\Omega} = 333.33mA$

(12) $I_5 = \frac{E_5}{R_5} = \frac{10V}{20\Omega} = 0.5A$

(13) E_2 & E_3 MUST $= 2V \because$ (9) $= 2V$

(14) $P_1 = E_1 \times I_1 = 12V \times 1A = 12W$

(15) $P_2 = E_2 \times I_2 = 2V \times 166.\overline{66}A = 333.\overline{33}mW$

(16) $P_3 = E_3 \times I_3 = 2V \times 333.\overline{33}A = 666.\overline{66}mW$

(17) $P_4 = E_4 \times I_4 = 12V \times 0.5A = 6W$

(18) $P_5 = E_5 \times I_5 = 10V \times 0.5A = 5W$

(19) $P_T = E_T \times I_T = 24V \times 1A = 24W$

Quantity, Units, & Symbols

- It is important to use the right quantities, units and symbols in order to properly calculate solutions

Quantity	Symbol	Unit of Measure	Symbol	Effect in a cct.
EMF or Electromotive force or Voltage or potential	E	Volt	V	Force producing electron flow in a circuit
Resistance or that which is against current flow	R	Ohm	Ω	Opposition to the flow of electrons
Current or how much	I	Ampere	A	The Flow of electrons through a circuit
Energy/work done	P	Watt	W	Work/energy used based on voltage and current

Units of Measure

- In the electronic industry, it is often necessary to use very large numbers possibly in the millions or very small numbers such as one millionth
- Using a prefix representing another size will reduce errors and having to write out very large or very small numbers

PREFIX	SYMBOL	MULTIPLIER	EXPONENT
exa	E	1, 000, 000, 000, 000, 000, 000	10^{18}
pera	P	1, 000, 000, 000, 000, 000	10^{15}
tera	T	1, 000, 000, 000, 000	10^{12}
giga	G	1, 000, 000, 000	10^{9}
mega	M	1, 000, 000	10^{6}
kilo	k	1, 000	10^{3}
hecto	h	100	10^{2}
deca	da	10	10^{1}
Basic Unit		1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0. 001	10^{-3}
micro	µ	0. 000, 001	10^{-6}
nano	n	0. 000, 000, 001	10^{-9}
pico	p	0. 000, 000, 000, 001	10^{-12}
femto	f	0. 000, 000, 000, 000, 001	10^{-15}
atto	a	0. 000, 000, 000, 000, 000, 001	10^{-18}

Common Units of Measure

- Prefixes commonly used in electronic/electrical industry are as shown in the tables
- When calculating solutions, always ensure you are working with the same units of measure
- Example: 8, 000 W = ? kW

  = 8 * 0.001

  = 8 kW

	micro	milli	units	kilo	Mega
micro		0.001	10^{-6}	10^{-9}	10^{-12}
milli	1, 000		0.001	10^{-6}	10^{-9}
units	10^{6}	1, 000		0.001	10^{-6}
kilo	10^{9}	10^{6}	1, 000		0.001
Mega	10^{12}	10^{9}	10^{6}	1, 000	

Prefix	Mega	kilo	Decimal Point	milli	micro
Symbol	M	k	.	m	μ
Relation to base unit	1, 000, 000	1, 000	1	0.001 or 1/1, 000	0.000, 001 or 1/1, 000, 000
Example	5 MΩ	8 kV	12 V,A or Ω	6 mV	12 μA
Pronounced	5 Megaohms (5, 000 kΩ or 5, 000, 000 Ω)	8 kilovolts (0.008 MV or 8, 000 V)	Volts Amps Ohms	6 millivolts (0.006 V)	12 microamps (0.012 mA or 0.000, 012 A)
# of spaces from decimal	6 ←	3 ←	0	3 →	6 →

Calculation Requirements

- In order to prove (get full marks) the solution, the following must be included in your assignments:
  - Circuit diagram showing simplified line diagram with symbols and given information
  - EIRP Table – with answers circled
  - Rough Calculations showing:
    - Order of Operation
    - Formula
    - Substitution
    - Units on all variables
    - Rounded off to two decimals after units of measure are applied
    - All answers circled
  - Include final double check, using a formula that you have not yet used confirming solution works

More Formulas

- These are more formulas derived from the original Ohms law formula E=I*R