Science Olympiad Circuit Lab

Key Concepts

- Circuit Lab Overview
- Circuit Elements & Tools
- Basic Relationships (I, V, R, P)
- Resistor Network Configurations (Series & Parallel)
- Kirchhoff's Laws
- Examples
- Glossary of Terms

Circuit Lab Overview

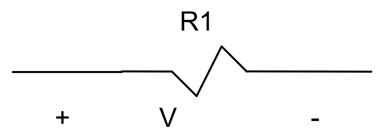
Teams of up to 2 students each will be evaluated on their knowledge of Direct Current (DC) Electrical Circuit. The event includes hand-on experiment and problem solving. Students may use non-programmable calculators. The approximate allotted time is 50 seconds.

Circuit Elements & Tools

- ➢ Independent DC Sources (V, Voltage & I, Current)
  - Current Source
    Produces constant Current (Amps), I

  - Voltage Source
    Produces constant Voltage (Volts), V

- ➢ Resistor (R, Ohms)



  - ▪ Resistor Color Bands

Band Colors	***Value Bands, 1^{st} & 2^{nd}***	***Mulitplier Color Band, 3^{rd}***
BLACK	0	x1
BROWN	1	x10
RED	2	x100
ORANGE	3	x1,000 or 1K
YELLOW	4	x10,000 or 10K
GREEN	5	x100,000 or 100K
BLUE	6	x1,000,000 or 1M
VIOLET	7	x10,000,000 or 10M
GRAY	8	x100,000,000 or 100M
WHITE	9	x1000,000,000 or 1G

Note: If third band is gold then divide by 10 and if silver divide by 100.

Resistor Tolerance Color Bands**:**

Band Colors	***Tolerance Color Band, 4^{th}***
GOLD	5%
SILVER	10%
NONE	20%

- ➢ Digital Multimeter
  - ▪ Voltmeter
    - Resistance Very large → infinite
    - Place in parallel to measure voltage

  - ▪ Ammeter
    - Resistance Very small → zero
    - Place in series to measure current

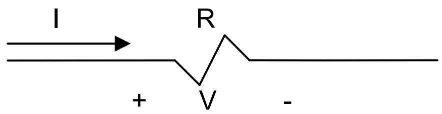
  - ▪ Ohmmeter Mode
    - Disconnect resistor from the circuit
    - Place in parallel to measure voltage

- ➢ Oscilloscope
  Displays Voltage vs. Time

Basic Relationships (I, V, R, P)

- Ohms Law (relating V, I and R)

    - $V = I * R$
    - $I = V / R$
    - $R = V / I$



- Power (Watts)

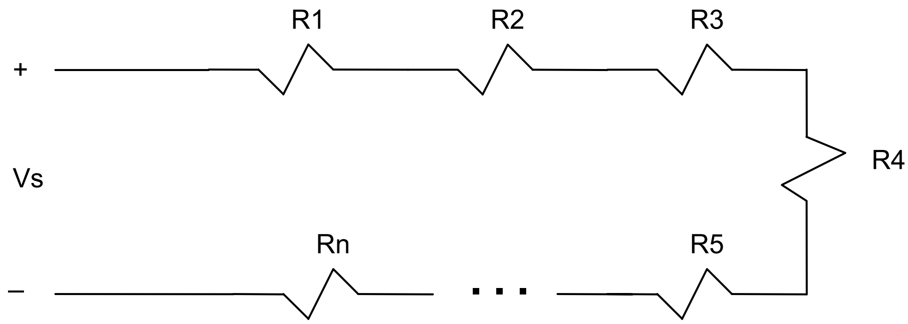
    - $P = V * I$
    - $P = V^2 / R$
    - $P = I^2 * R$

- Work or Energy (Joules)
  Power deliver over time

  $W = P * T$

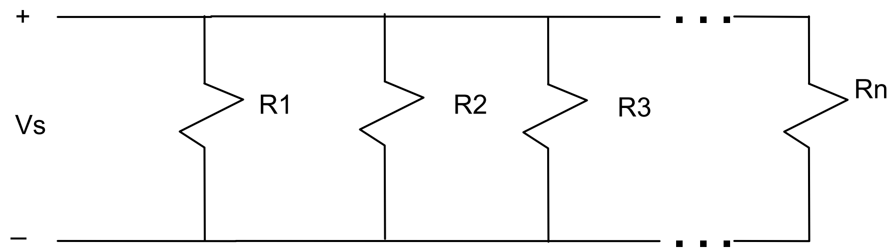
Resistor Network Configurations

- ➢ Resistors in Series (Same Current and share one terminal)



Req = R1 + R2 + … + Rn = $\sum_{i=1}^{n} R_i$

- ➢ Resistors in Parallel (Same Voltage & Share both terminal)

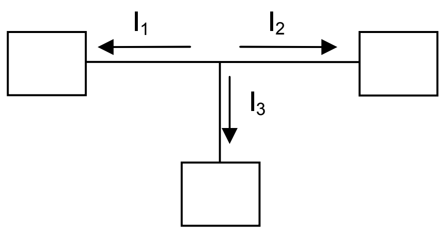


- 1/Req = 1/R1 + 1/R2 + 1/R3 + … + 1/Rn = $\sum_{i=1}^{n} \frac{1}{R_i}$
- Conductance (G=1/R) therefore
  Geq = G1 + G2 + … + Gn

Kirchhoff's Laws

- Kirchhoff's Current Law

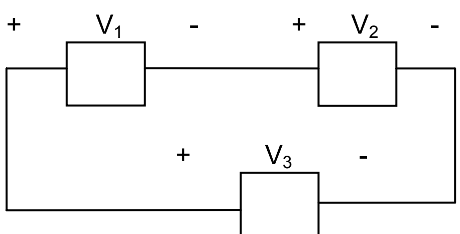
  Sum of all currents flowing out of a node is equal to zero. $\sum_{n=1}^{N} I_n = 0$



$I_1 + I_2 + I_3 = 0$

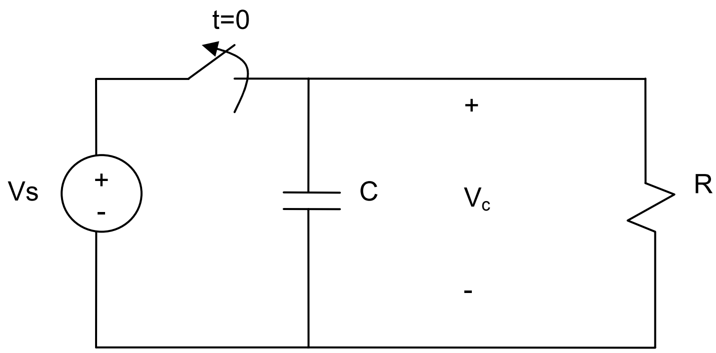
- Kirchhoff's Voltage Law

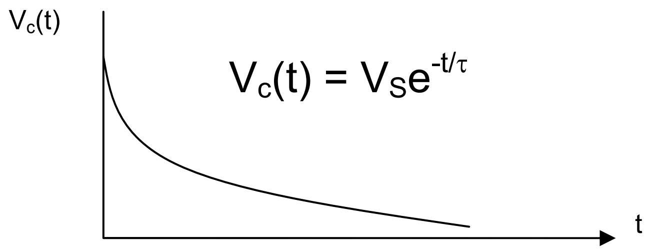
  Sum of all voltages around a loop is equal to zero. $\sum_{n=1}^{N} V_n = 0$



$V_1 + V_2 - V_3 = 0$

Capacitors and Time Constant

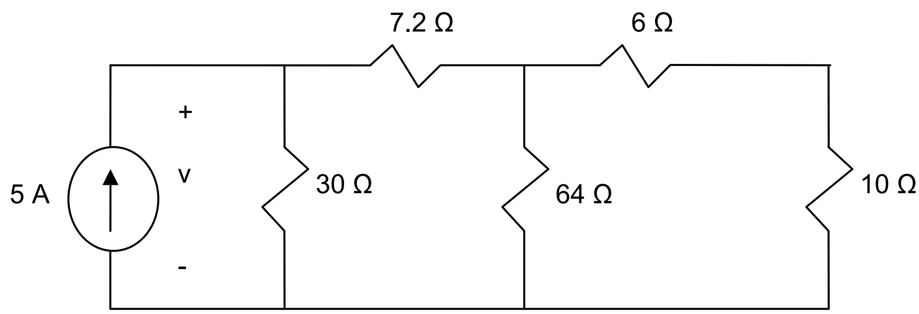




Time Constant, τ = R*C

τ is the time it takes to charge or discharge 63% of the maximum voltage.

Example 1



For the above circuit answer the following questions:

a) Find the equivalent resistance seen by the current source.
Hint: Combine Parallel & Series resistors.

b) Find the voltage across the 30 Ω Resistor.
Hint: use KVL

c) Find the current through the 30 Ω Resistor.
Hint: I=V/R

d) Find the power across the 30 Ω Resistor.
*Hint: P=I*V*

e) Measure the current and voltage across all the resistors in the circuit.
Hint: Use a Digital Multimeter

Other Examples

For additional examples and reference material refer to the following link:

http://web.clark.edu/ikhormaee/courseMaterial/engr251/index251.htm

Glossary of Terms

SI – International System of Units which are universally used for electrical measurements.

Electric Charge (q) – A fundamental physical property of matter which results in a force of attraction or a force of repulsion between objects each having a net electric charge.

Coulomb (C) – Unit of electric charge. 1 electron = -1.602×10^{-19} C

Types of Electric Charge – Only two different types of electric charge have been discovered:
Positive designates the type of net charge found in a nucleus of an atom
and
Negative designates the type of charge associated with an electron.

Law of Charges – **Like** Charges repel; **Unlike** Charges attract.

Coulomb Force Law – The **magnitude** of the force of interaction between two point charges is proportional to the product of the charges and inversely proportional to the distance squared between the two charges, i.e.

$$F = k\frac{q_1 q_2}{r^2} \quad \text{where} \quad k = 9\text{x}10^9 \frac{Nm^2}{C^2} \qquad \text{and}$$

the **direction** of the force is along the line connecting the two charges.

Electric Field – A region of space in which a electric charge experience a force.

The **magnitude** of the field is equal to the force experienced per unit charge
and
the **direction** of the field is the direction of the force on a positive charge.

Electric Field SI Unit = N/C or Volt/ m

Delta Symbol, (Δ) – the difference between values, $\Delta\,(\_\_) = (\_\_)_{\text{final value}} - (\_\_)_{\text{initial value}}$

Electric Potential Difference (Δ**V**) – the electric potential energy per unit charge.

Volt (**V**) – SI unit of Electric potential difference (1V = 1J/coul).

Electromotive Force (*EMF*) – any device which can establish an electric potential difference across a circuit, e.g. battery, generator, alternator, power supply, etc.

Electric Current (i)– the net movement of electric charge past a given location.

Electric Circuit – a continuous path along which an electric current can flow.

Requirements for an electric current:

An electric potential difference between **any two points** along the current path
and
electric charges **free to move at every point** along the current path.

Electron Current -- the net movement of negative electric charge past a given location.

Conventional Current – A positively charged current equal in magnitude to the electron current but moving in a direction opposite to the electron current.

Ampere (**A**) – SI unit of electric current, (1A = 1Coul/sec).

Electric Power delivered to a Circuit ($P = i \Delta V$)   SI Unit of Power = Watt (W)

Electrical Resistance (R) – The amount of potential difference across a circuit required to cause one Ampere of current to flow, i.e.

$$R = \Delta V / I$$

Note: Electrical Resistance converts Electrical Energy into heat.

Electrical Power converted into heat ($P_{heat} = i^2 R$)

Ohm (Ω) – SI unit of electrical resistance.   ($1\Omega = 1$ V/A)

Ohm's Law – If the electrical resistance remains constant, then the electric potential drop across a circuit is proportional to the current in the circuit, i.e.

$$\Delta V = R\, i$$

Internal Resistance (R_i) – the resistance associated with an *EMF*. Part of the potential drop produced by the *EMF* must be used to cause current in the circuit to also flow through the *EMF*. The actual potential drop available to the circuit outside the EMF is called the **Terminal Voltage** (V_T) is calculated by the following equation:

$$V_T = EMF - i R_i$$

.Note: As the current in a circuit is increased the terminal voltage available to the circuit decreases.   The internal resistance is in series with the total resistance of the circuit.

Electrical Capacitance (C) – the amount of charge which must be added or removed to change the electric potential difference by one volt, i.e.

$$C = \Delta q / \Delta V$$

Farad (F) – SI unit of electrical capacitance.   (1 F = 1 C/V)

RC Time Constant - the product of the resistance through which a capacitor is being charged or discharged and the capacitance. This product equals the time for 63% of the charging or discharging to occur.
Note: (Ohm)(Farad) = second

Galvanometer – A sensitive device used to measure very small currents.

Voltmeter – An instrument that is used for measuring electrical current. electrical potential (Voltage) differences.

Ammeter - An instrument that is used for measuring electrical current.

Multimeter – An instrument that is used for measuring a range of electrical potential differences, electrical currents, and resistance.

Battery – an EMF that converts chemical energy into electrical energy.

Generator / Alternator – an EMF that converts mechanical energy to electrical energy.

Power Supply - an EMF that converts electrical energy into a more useful form of electrical energy, usually a different electrical potential difference or from alternating current to direct current or vice versa.

Schematic Diagram – A symbolic representation of a circuit using standardized symbols for circuit components.