BEEE101L
Basic Electrical Engineering

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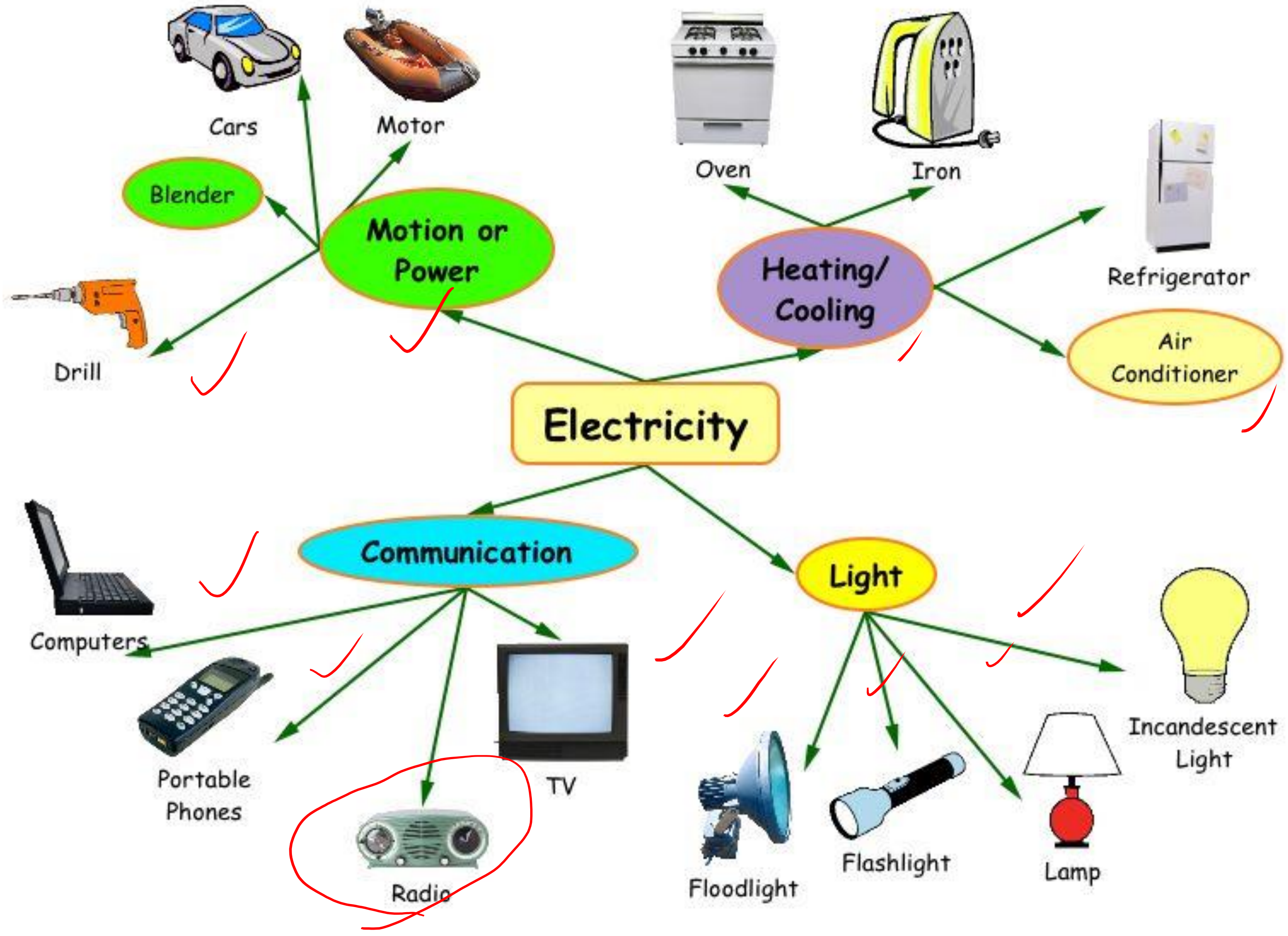
Some Guidelines

- Online Platform : Only Microsoft Teams
- Web Camera : Must be turned on when there is no presentation
- Microphone : Mute it always, unmute when u are communicating with me
- Syllabus , Text Books : Uploaded in Moodle / MS Teams
- Attendance: Online (MS Teams)
- Short Communication Public : MS Teams-General
- Short / Long Private Communication : Email (inayathullah.a@vit.ac.in)
- Emergency Communication : Mb:9894225688
- Recording of Video : Use OBS / MsTeams within 21 days

Some Guidelines

- Continuous Evaluation (CE)– Moodle (60 Marks)
  1. Weekly MCQ[10 Marks]
  2. Digital Assignment-1[10 Marks],
  3. Assignment-2[10 Marks],
  4. CAT-1 Exam [50 Marks- 15Mark],
  5. CAT-2 Exam [50 Marks- 15Mark],
- Final Assessment Test(FAT) – Moodle / Written Exam (40 Marks)
- Passing Marks : 50/100 (CE+FAT)

Uses Of Electricity In Our Daily Life



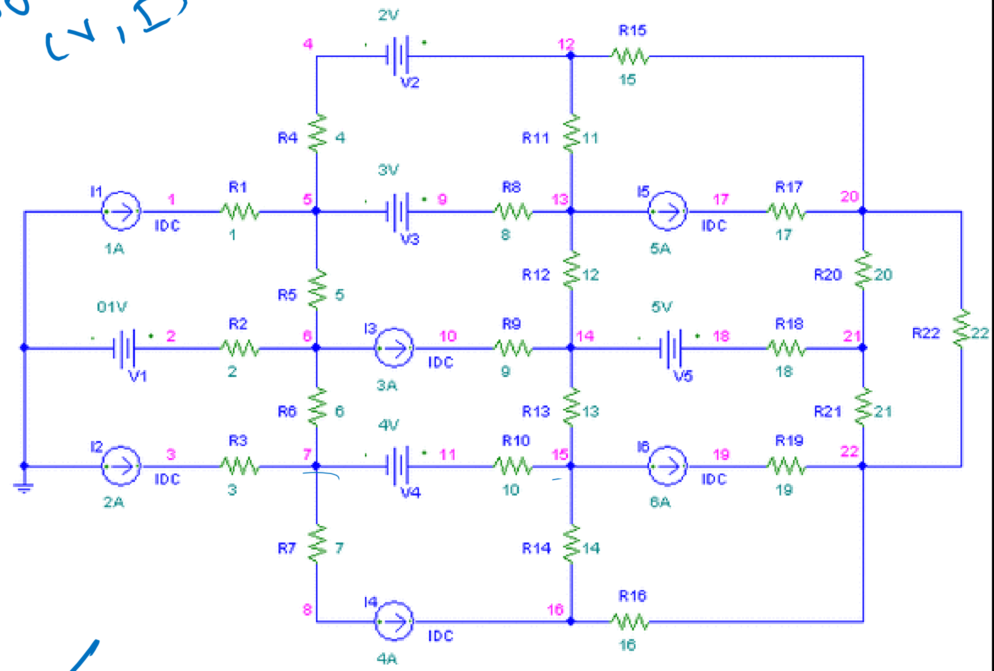
Source: https://drrajivdesaimd.com/wp-content/uploads/2012/08/electricity-use-in-life.jpg

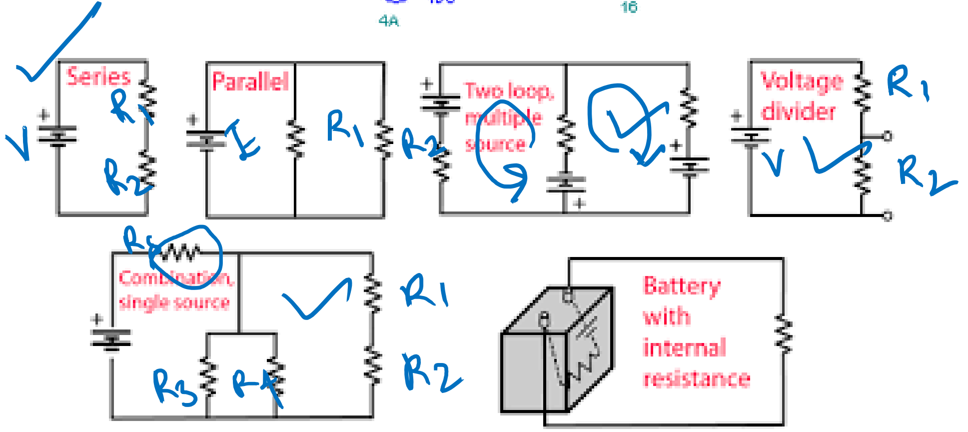
Module -1: DC circuits

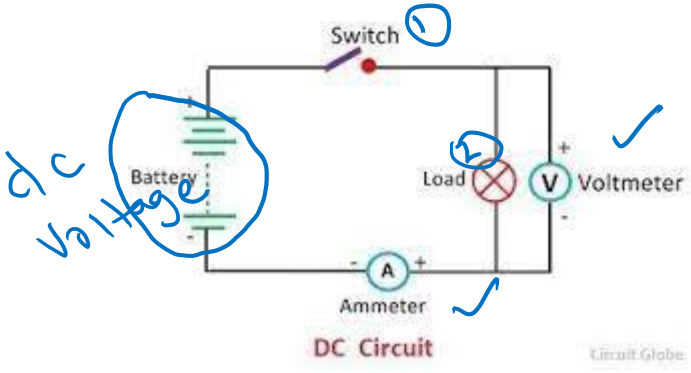
Direct current

R, L, C, Sources (V, I)

- Basic circuit elements and sources,
- Ohms law, Kirchhoff's laws,
- Series and parallel connection of circuit elements,
- Node voltage analysis, ← current
- Mesh current analysis, ← Voltage
- Thevenin's and Maximum power transfer theorem







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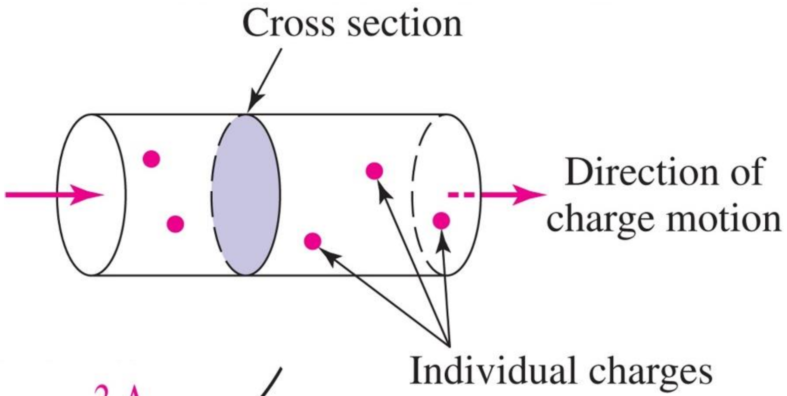
Electric Charge……………..Current

- Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. Electric charge can be positive or negative (commonly carried by protons and electrons respectively). A charge is conserved: it is neither created nor destroyed. Its symbol is Q or *q;* units are coulomb (C)
- The smallest *electronic charge*, is carried by an electron (−1.602 × 10-19 C) or a proton (+1.602 × 10-19 C)
- The charges in motion are electrons. Electric Current is the rate of charge flow: 1 ampere = 1 coulomb/second (or 1 A = 1 C/s).

$$i = \frac{dq}{dt}$$



- Current (designated by *I* or *i*) is the rate of flow of charge
- Current must be designated with both a direction and a magnitude
- These two currents are the same:

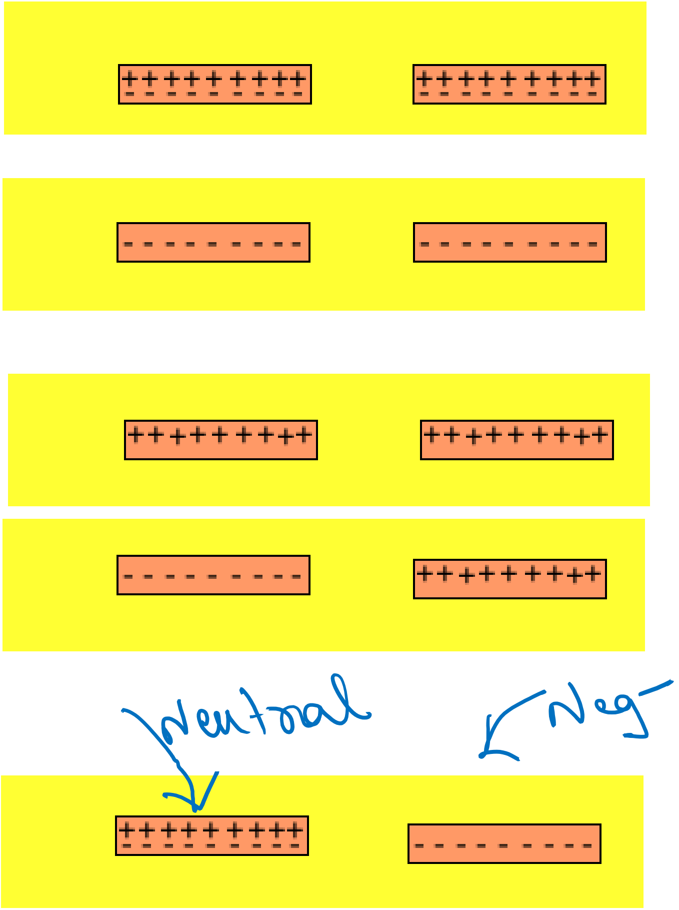
Electric Charge Behavior

Neutral particles contain equal number of positive and negative charges. No attraction or repulsion occurs between two neutral particles.

Similar charges repel each other.

Opposite charges attract

Neutral particles can be attracted by charged particles. When a negative charge is placed close to a neutral particle, the positive charges are attracted while the negative charges are repelled, as seen on the right.



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Current $= \frac{\partial q}{\partial t}$ / Voltage

$-5V$ $+2V$ $0V$ $0V$ B

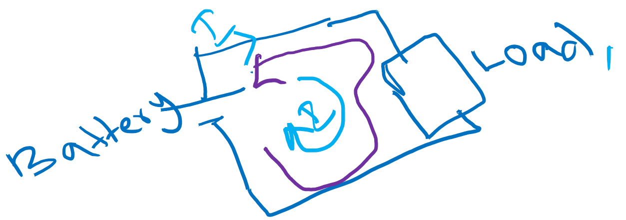
- Current is the flow of electric charge through a circuit.
- We use the symbol *I* or *i* to represent current.
- Current's unit of measure is the ampere, or amp (A).
- For example,
  - To say that a current is 2.5 amperes, we write

$$i = 2.5 \text{ A}$$

- Voltage is a measure of how forcefully charge is being pushed through a circuit.
- We use the symbol *V* or *v* to represent voltage.
- Voltage's unit of measure is the volt (V).
- For example,
  - To say that a voltage is 5 volts, we write

$$v = 5 \text{ V}$$

Basic circuit elements and sources



Cont. V, Variable current

Electric / Electronic Components

Active Components

An active component supplies energy to an electric circuit, and hence has the ability to electrically control the flow of charge

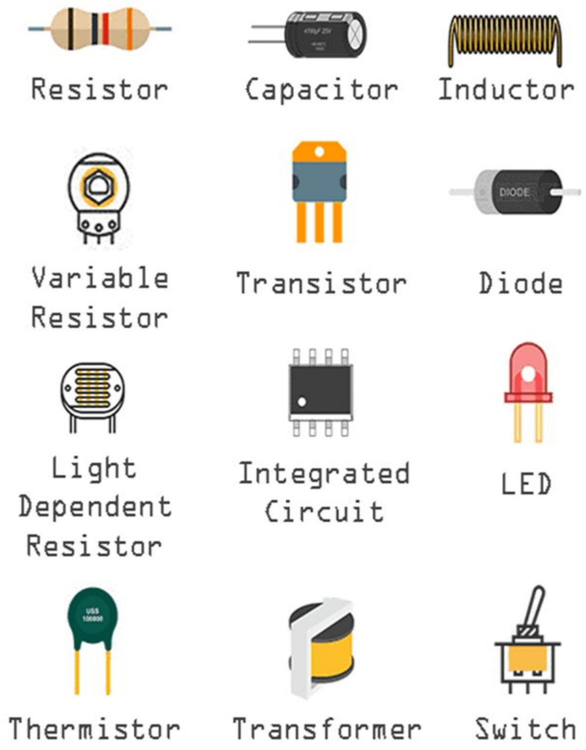
Passive Components

A passive component can only receive energy, which it can either dissipate or absorb.

Variable Voltage
Constant current,

- Current sources
- Voltage sources
- Generators (AC & DC generators)
- Transistors (such as bipolar junction transistors, MOSFETS, FETs, and JFET)
- Diodes (such as Zener diodes, photodiodes, Schottky diodes, and LEDs)

- heat → Resistors
- mag. field → Inductors
- Elect field → Capacitors
- Transformers



Active Elements

- **Circuit elements can be classified as active or passive, depending on whether they are capable of generating electric energy.**
- **Active elements *can* generate electric energy.**
  - **Examples:**
    - **Voltage sources**
    - **Current sources**

Passive Elements

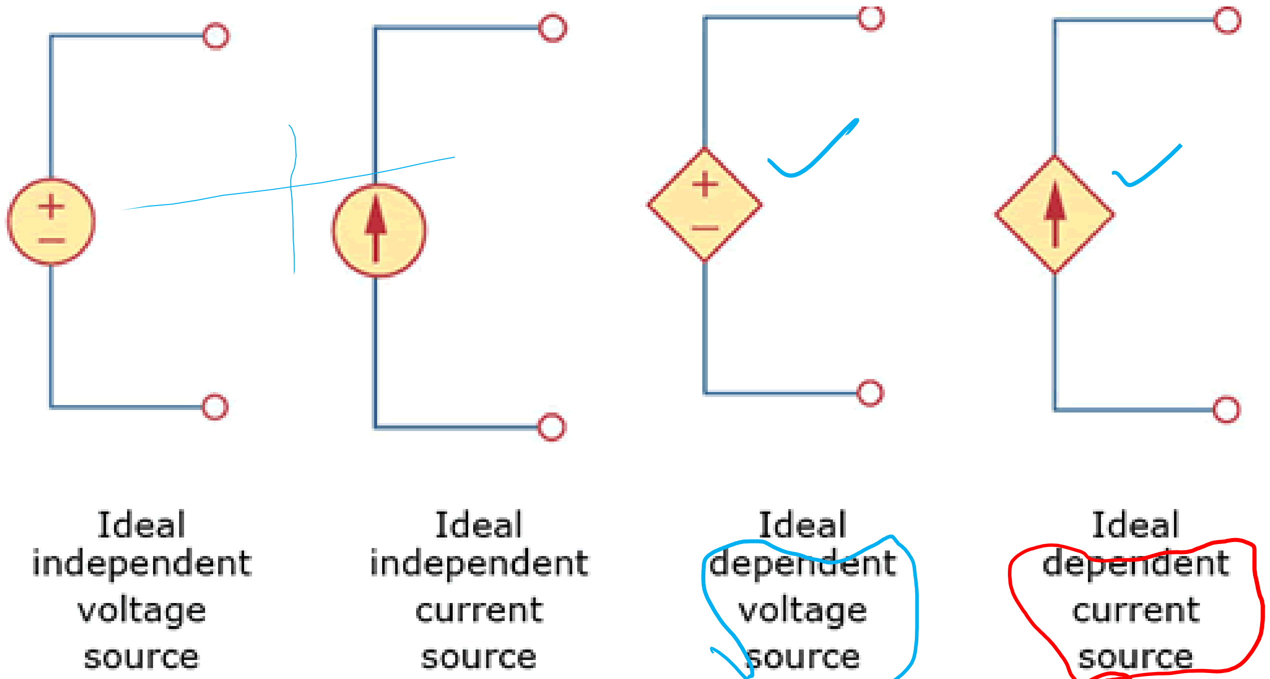
- **Passive elements *cannot* generate electric energy.**
  - **Examples:**
    - **Resistors**
    - **Capacitors**
    - **Inductors**
- **An important difference among these is that capacitors and inductors can store energy for later use. But resistors cannot store energy: they always dissipate energy as heat.**

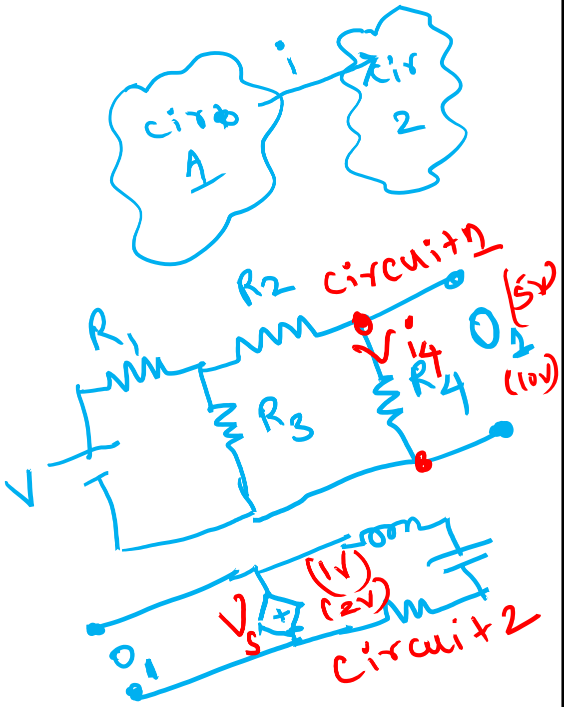
Passive Elements

- **Resistors** : It can only receive energy which it dissipate as heat as long as current flows through it.
- **Inductors** : It can store energy in it as a magnetic field, and can deliver that energy to the circuit, but not in continuous basis.
- **Capacitors** : It can store energy in it as electric field and can deliver that energy to the circuit.
- **Transformers** : When transformers step up (or step down) voltage, power and energy remain the same on the primary and secondary side. As energy is not actually being amplified a transformer is classified as a passive element.

Ideal Sources

- **The most important active elements are voltage sources and current sources.**

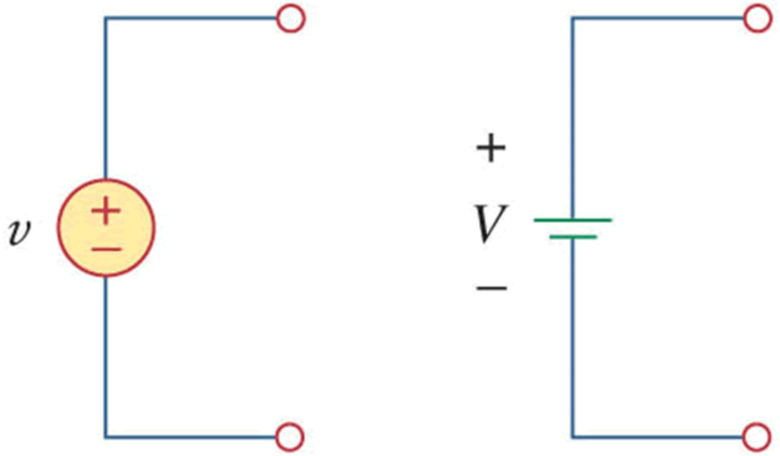




- **In each case the word "ideal" means that these are simplified models that ignore some of the effects present in real sources.**

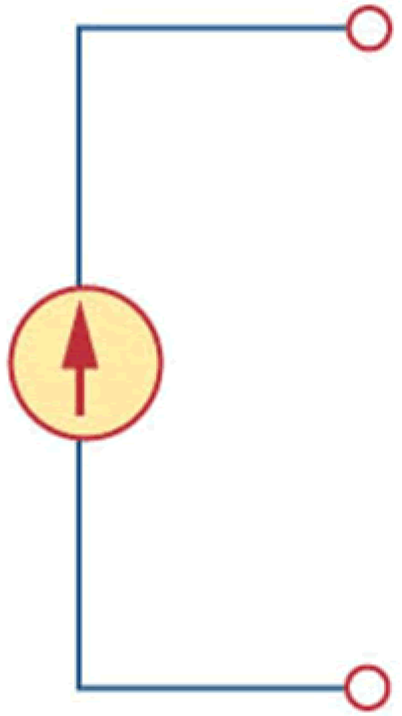
Ideal Independent Voltage Source

- **An ideal independent voltage source maintains a specified terminal voltage no matter what the rest of the circuit looks like.**



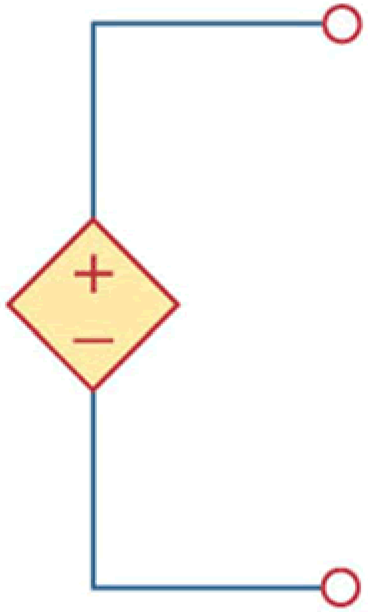
Ideal Independent Current Source

- An ideal independent current source supplies a specified current no matter what the rest of the circuit looks like.
- The arrow identifies it as a current source and shows the direction of positive current flow.



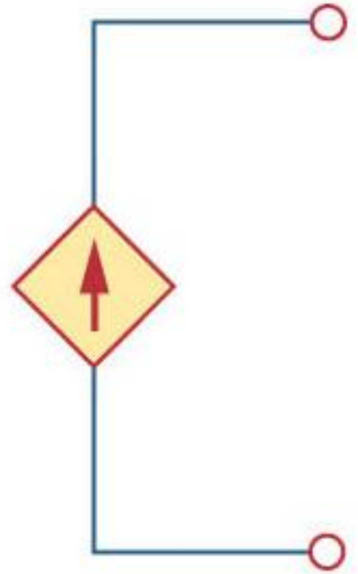
Ideal Dependent Voltage Source

- An ideal dependent voltage source maintains a terminal voltage whose value depends on a voltage or current somewhere else in the circuit.
- The diamond-shaped body tells us that it's a *dependent* source.
- The +/- inside tells us that it's a *voltage* source, and shows the voltage polarity.



Ideal Dependent Current Source

- **An ideal dependent current source supplies a current whose value depends on a voltage or current somewhere else in the circuit. The diamond-shaped body tells us that it's a *dependent* source.**

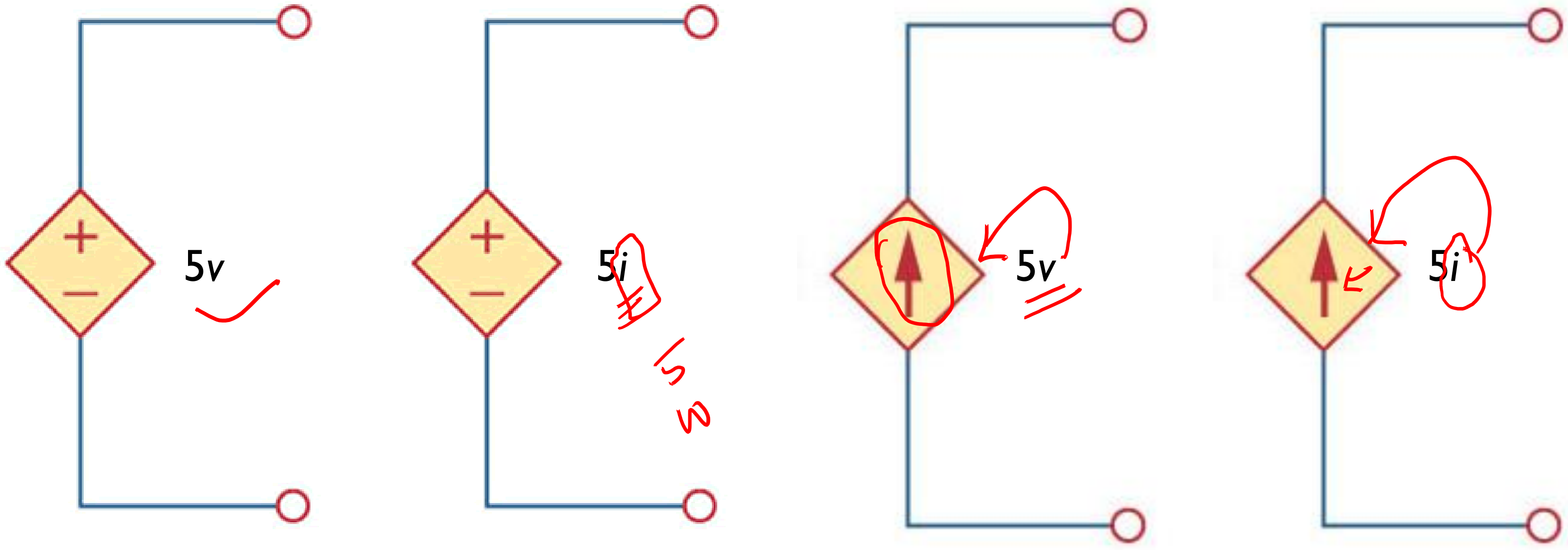


- **The arrow inside tells us that it's a *current* source and shows the direction of current flow.**

Four Kinds of Ideal Dependent Sources

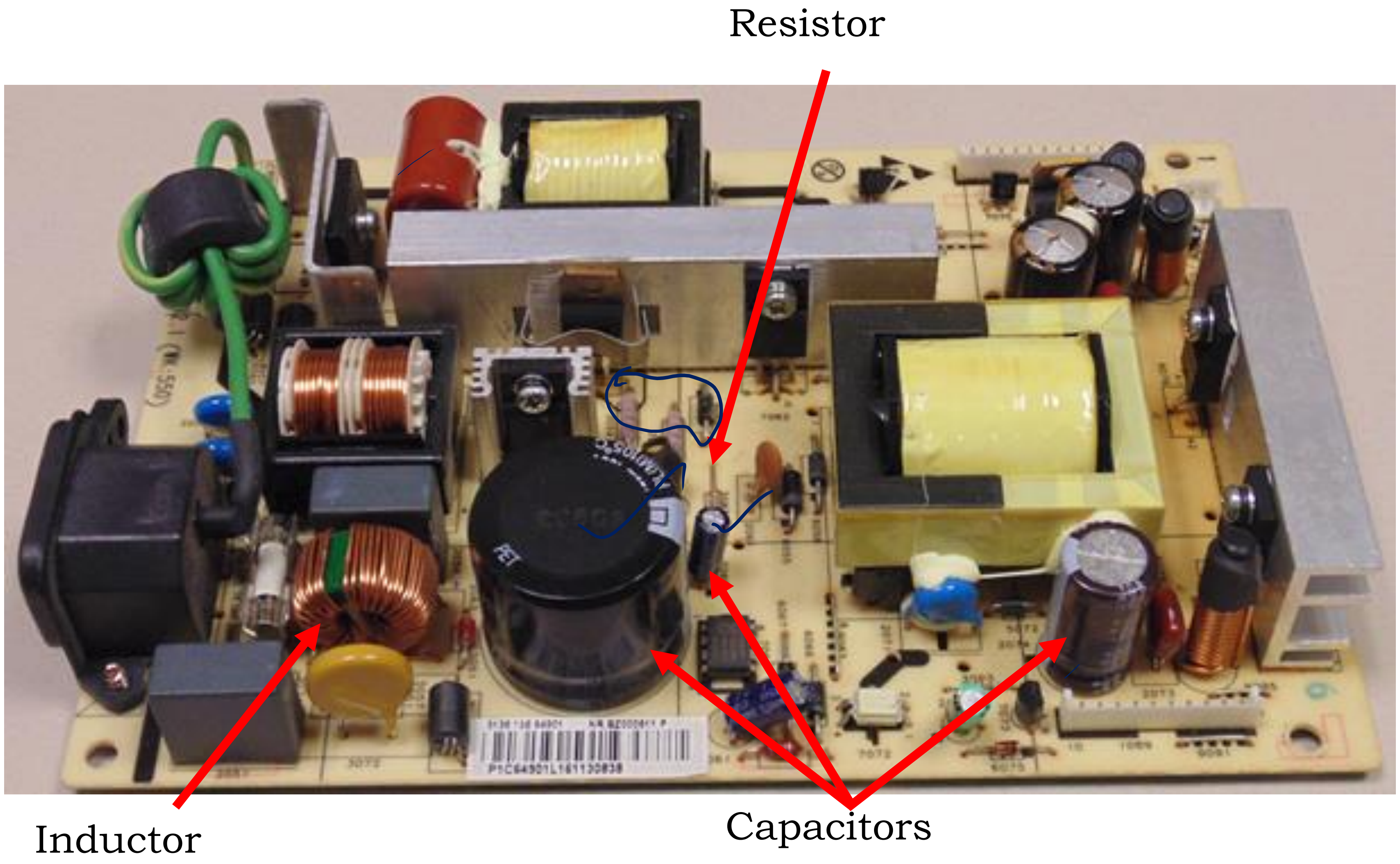
- Dependent sources are also called controlled sources.
- An ideal dependent source's value depends on a voltage or current somewhere else in the circuit, giving rise to four kinds:
  - A voltage-controlled voltage source.
  - A current-controlled voltage source.
  - A voltage-controlled current source.
  - A current-controlled current source.
- Text next to the symbol will tell exactly which kind it is….

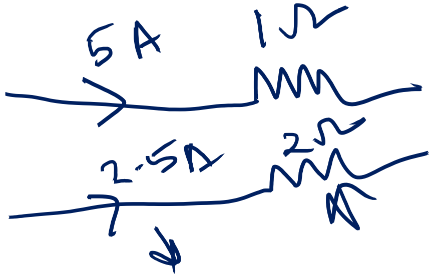
Examples of Symbols for Controlled (Dependent) Sources



Voltage-controlled voltage source	Current-controlled voltage source	Voltage-controlled current source	Current-controlled current source

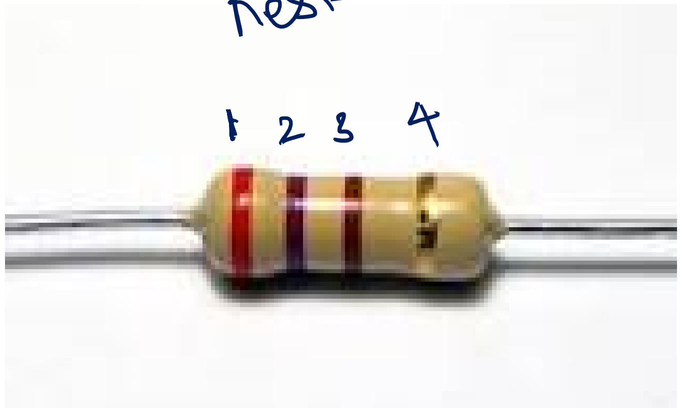
Example Circuit: A Power Supply from a Flat-Screen Television





Resistance

Resistor



- Resistance is opposition to the flow of electrons.
- Resistance's unit of measure is the ohm (Ω).
- A perfect conductor would have zero resistance and a perfect insulator would have infinite resistance.
- A resistor is a device manufactured to have a specific amount of resistance.

dig1 dig2 10^{dig}

- The resistors in our labs range in value from 10 Ω to 10,000,000 Ω.
- Instead of having the value printed in numbers on the case, our resistors are marked with a four-band color code to indicate the value.

Resistor Color Code (Cont'd.)

- The fourth band ("tolerance band") gives the percent variation from the nominal value that the actual resistance may have.

95

100

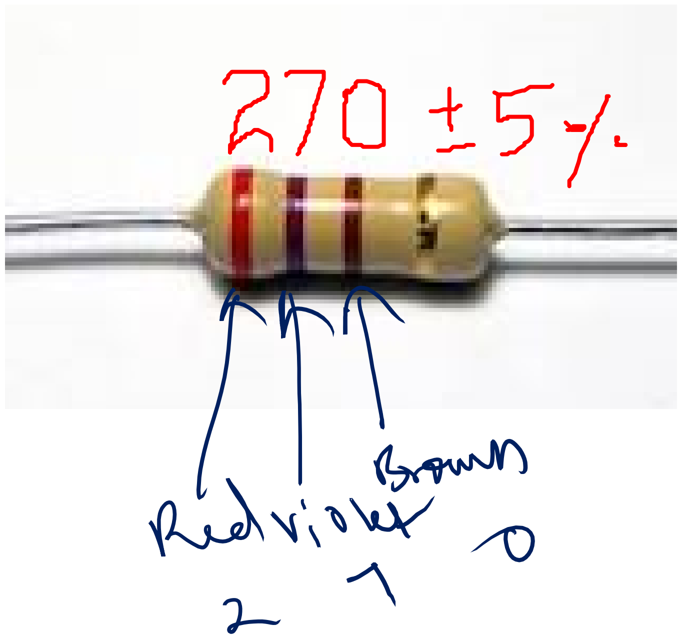
105

Tolerance	Color
5%	Gold
10%	Silver
20%	None

Resistor Color Code

- The first three color bands specify the resistance’s nominal value.

Digit	Color
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White



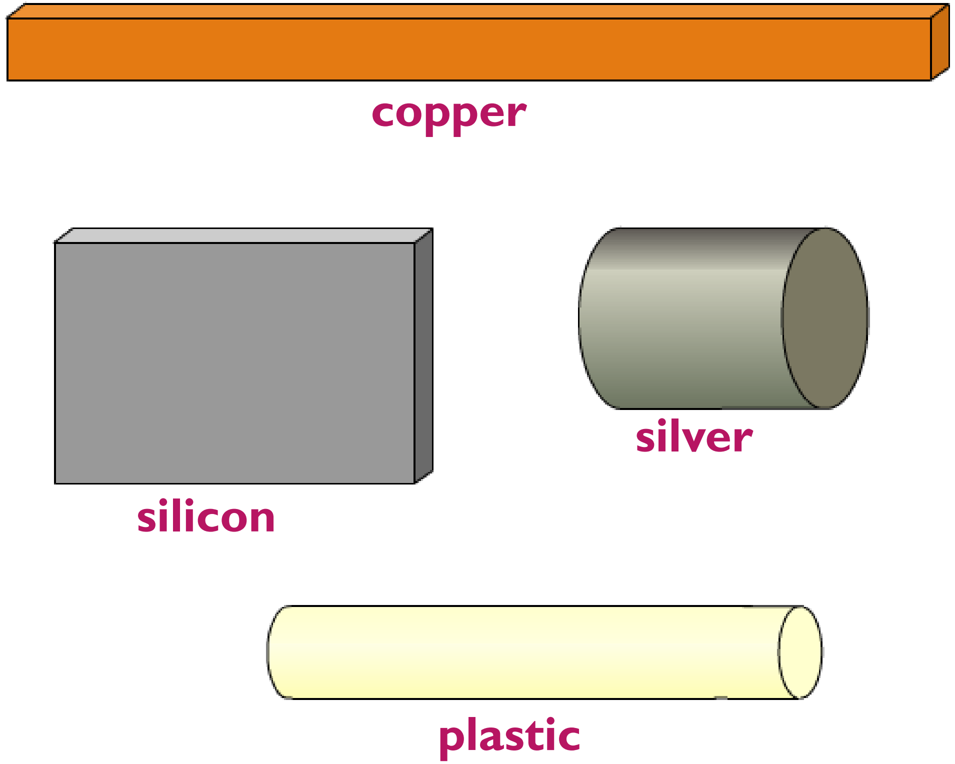
Resistor Color Code (Cont'd.)

- The fourth band ("tolerance band") gives the percent variation from the nominal value that the actual resistance may have.
-

Tolerance	Color
5%	Gold
10%	Silver
20%	None

What is resistivity?

Which of the four examples below has the largest resistance, and which has the smallest?



The resistance depends on the size and shape of the material (its cross-sectional area and length) and the material itself.

The measure of how much a particular material opposes electron flow is called the **resistivity** of the material.

Introducing the resistivity equation

Resistivity is usually given the symbol ρ (the Greek letter rho). Resistivity is calculated using the following equation:

$$\text{resistivity} = \frac{\text{resistance} \times \text{cross-sectional area}}{\text{length}}$$

$$\rho = \frac{RA}{L}$$

The units of resistivity are ohm metres (Ωm).

Resistivity for a particular material varies with temperature, so it is usually quoted for a particular temperature. This is because resistivity depends on resistance, and resistance varies with temperature.

Resistivity of Different Material

Material	Resistivity (ohm meters)	Common Use
silver	1.6×10^{-8}	conductor
copper	1.7×10^{-8}	conductor
aluminum	2.8×10^{-8}	conductor
gold	2.5×10^{-8}	conductor
carbon	4.1×10^{-5}	semiconductor
germanium	47×10^{-2}	semiconductor
silicon	6.4×10^{2}	semiconductor
paper	1×10^{10}	insulator
mica	5×10^{11}	insulator
glass	1×10^{12}	insulator
teflon	3×10^{12}	insulator

Problem on Resistance

- Resistance of a wire is r ohms. The wire is stretched to double its length, then its resistance in ohms is
    - **a)r / 2**
    - **b)4 r**
    - **c)2 r**
    - **d)r / 4.**

Answer:

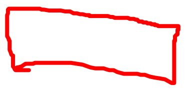
Resistance R=ρL/A

Now length get doubled L'=2L therefore, area get halved=A/2

New resistance (R')=ρ(2L) / (A/2)

R'=4 ρ L/A

R'=4 R



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

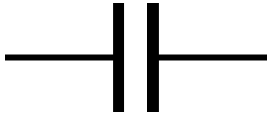
$$R_1 = \frac{\rho(2L)}{(A/2)} = \frac{\rho 4L}{A} = 4R$$

$$R_1 = \frac{\rho\left(\frac{L}{2}\right)}{2A} = \frac{\rho L}{4A} = \frac{R}{4}$$

Summary of Some Electrical Quantities, Units, and Symbols

Quantity	Symbol	SI Unit	Symbol for the Unit
Current	I or i	ampere	A
Voltage	V or v	volt	V
Resistance	R	ohm	Ω

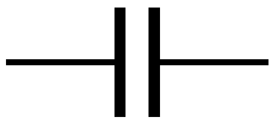
Capacitors



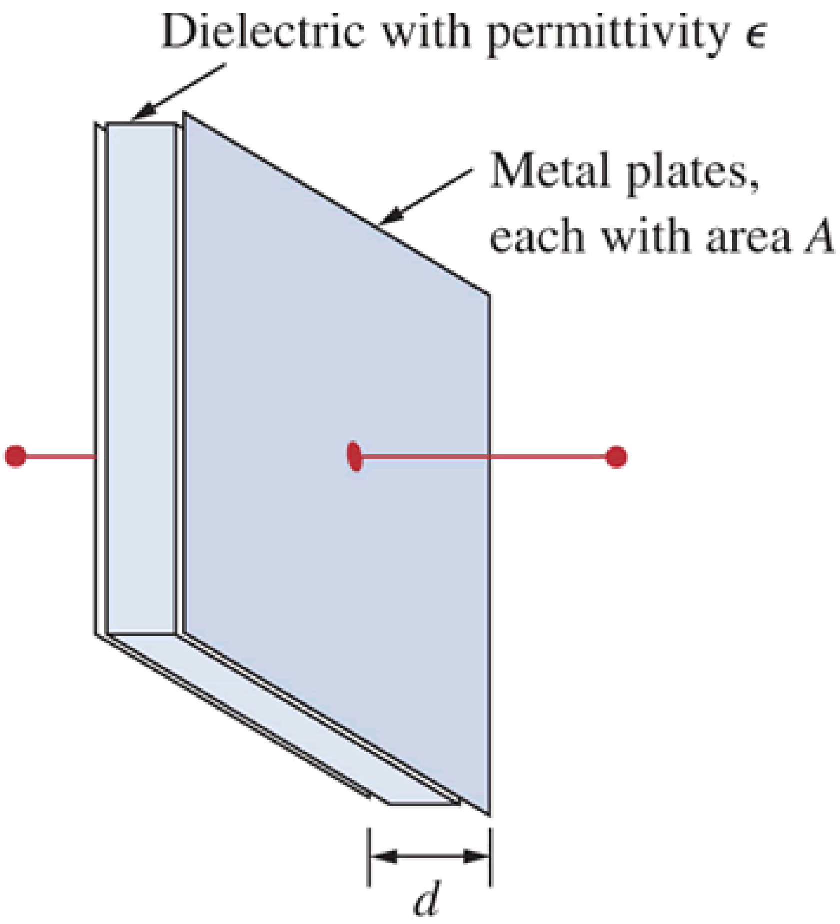
- A capacitor is a passive device designed to store energy in its electric field.

Image from Wikipedia.

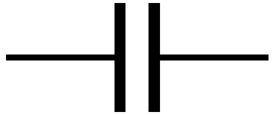
Parallel-Plate Capacitor



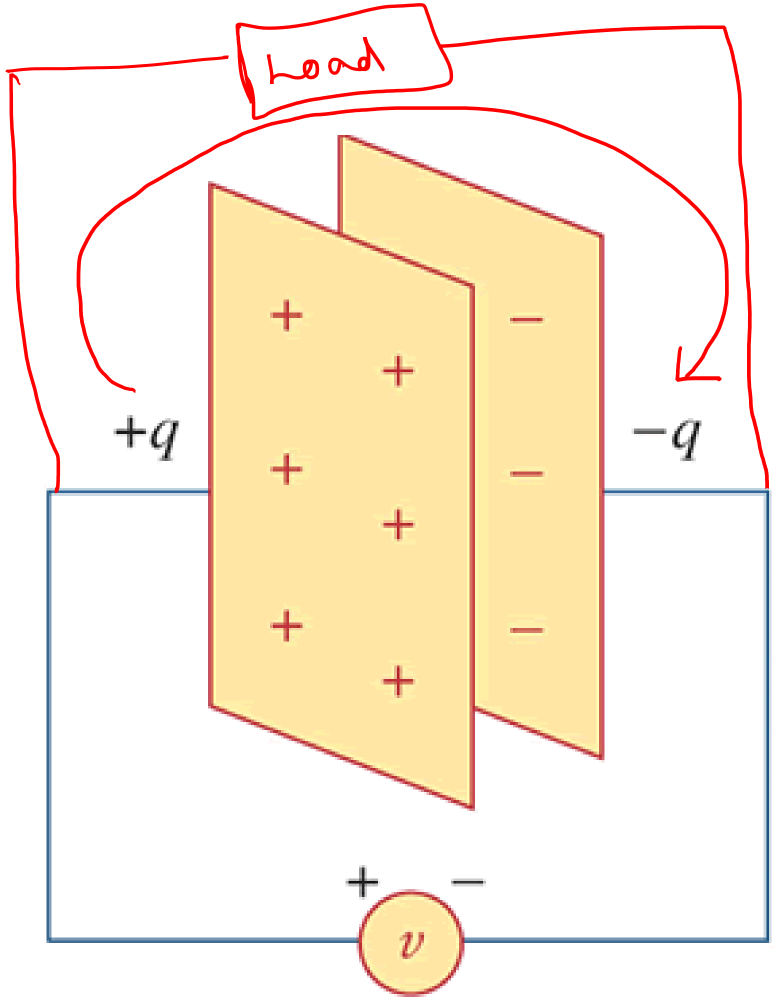
- A capacitor typically consists of two metal plates separated by an insulator.
- The insulator between the plates is called the dielectric.



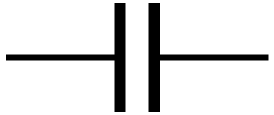
Charging a Capacitor



- When a capacitor is connected across a voltage source, charge flows between the source and the capacitor's plates until the voltage across the capacitor is equal to the source voltage.
- In this process, one plate becomes positively charged, and the other plate becomes negatively charged.



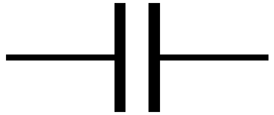
Units of Capacitance



- Capacitance is the measure of a capacitor’s ability to store charge.
- Capacitance is abbreviated *C*.
- The unit of capacitance is the farad (F).
- Typical capacitors found in electronic equipment are in the picofarad (pF), nanofarad (nF), or microfarad (μF) range.

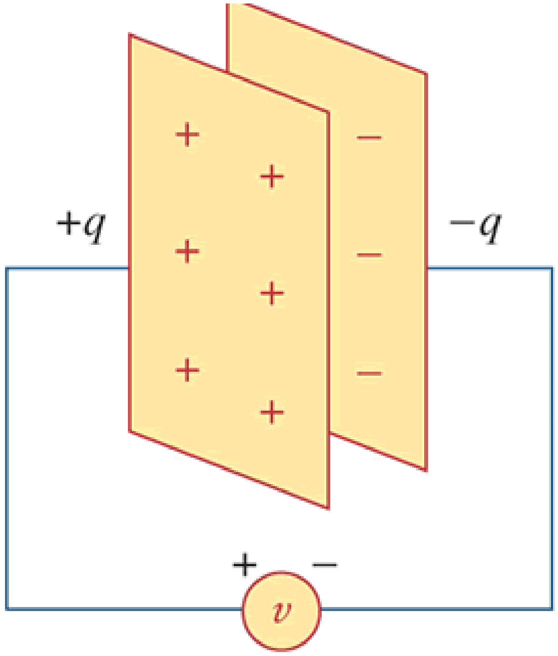
$C = \frac{q}{V}$ charge per Voltage

Capacitance = Charge per Voltage



- Mathematically, capacitance is equal to the ratio of the charge stored on a capacitor's plate to the voltage across the two plates:

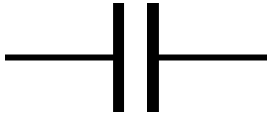
$$C = \frac{q}{v}$$



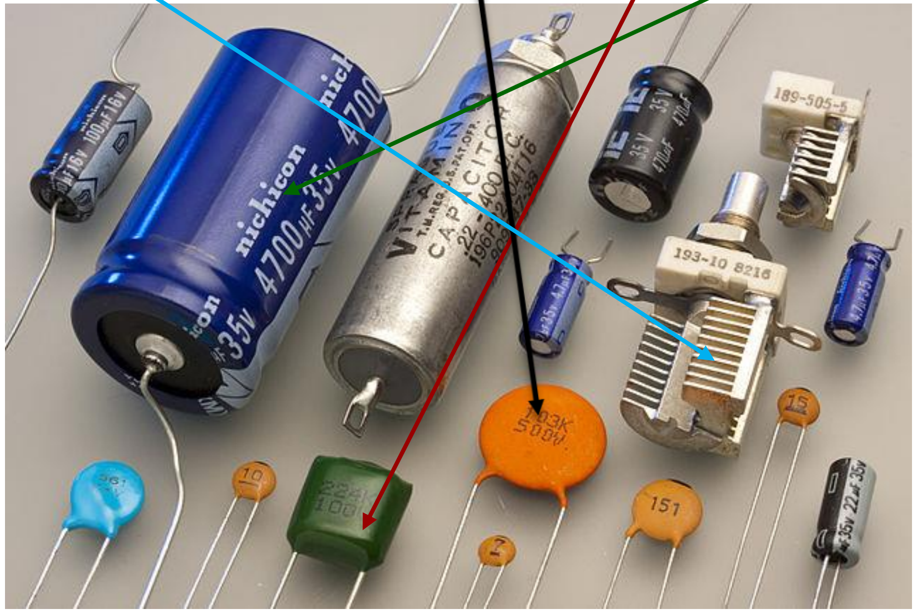
where C is in farads, q is in coulombs, and v is in volts.

- Thus one farad equals one coulomb per volt.

Capacitor Types



- Capacitors can be classified by the materials used for their dielectrics (such as air, paper, tantalum, ceramic, plastic film, mica, electrolyte).
- Each type has its own tradeoffs in practical use.
- Variable capacitors are also available.



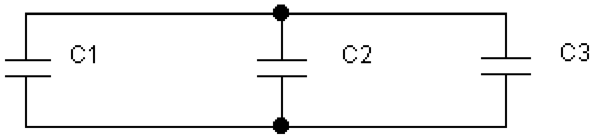
Capacitors Store Energy

- Recall that energy is dissipated as heat when current flows through a resistance.
- An ideal capacitor does not dissipate energy. Rather it stores energy, which can later be returned to the circuit.
- The energy w stored in a capacitor is given by

$$\boxed{w = \frac{1}{2}\underline{C}\,\underline{v}^2}$$

where C is the capacitor's capacitance and v is the voltage across the capacitor.

Capacitors in Parallel:
Equivalent Capacitance

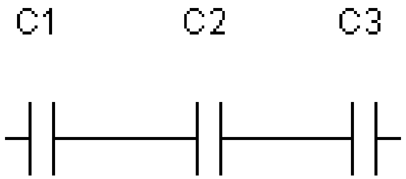


- **The equivalent capacitance of capacitors in parallel is the sum of the individual capacitances:**

$$C_{\mathbf{eq}} = C_1 + C_2 + C_3 + \ldots + C_N$$

- **Similar to the formula for resistors in series.**

Capacitors in Series:
Charge, Voltage, and Energy



- Series-connected capacitors have the same charge:

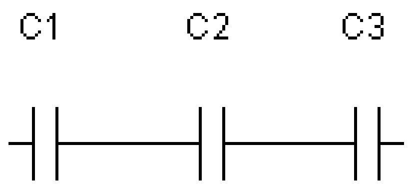
$$q_1 = q_2 = q_3 = \ldots$$

- If you know the capacitor's charges, you can find each capacitor's voltage and energy by applying the formulas

$$v = \frac{q}{C} \quad \text{and} \quad w = \frac{1}{2}Cv^2$$

to each capacitor.

Capacitors in Series:
Equivalent Capacitance



- The equivalent capacitance of capacitors in series is given by the reciprocal formula:

$$C_{\mathrm{eq}} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}}$$

- For two capacitors in series, we can use the product-over-sum rule:

$$C_{\mathrm{eq}} = \frac{C_1 C_2}{C_1 + C_2}$$

- Similar to the formulas for resistors in parallel.

Update: Some Quantities and Their Units

Quantity	Symbol	SI Unit	Symbol for the Unit
Current	I or i	ampere	A
Voltage	V or v	volt	V
Resistance	R	ohm	Ω
Charge	Q or q	coulomb	C
Time	t	second	s
Energy	W or w	joule	J
Power	P or p	watt	W
Conductance	G	siemens	S
Capacitance	C	farad	F
Inductance	L	henry	H

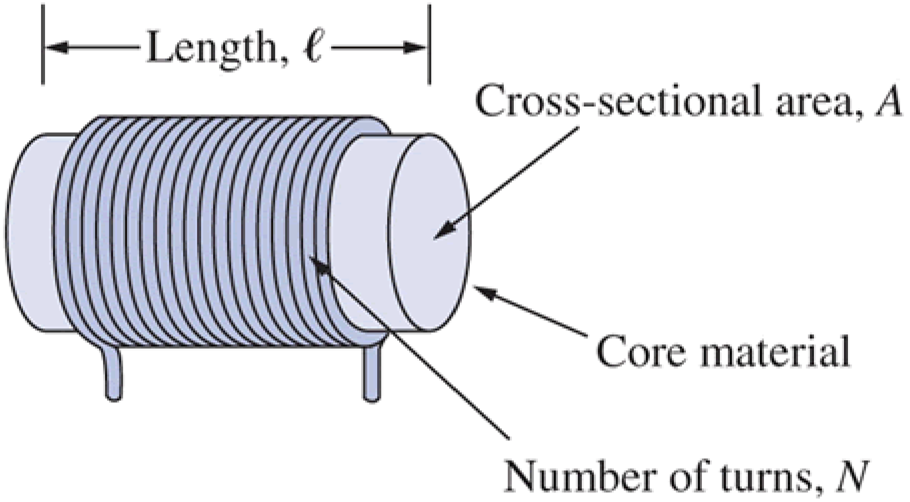
Inductors

- An inductor is a passive device designed to store energy in its magnetic field.

Image from Wikipedia.

Building an Inductor

- An inductor typically consists of a cylindrical coil of wire wound around a core, which is a rod usually made of an iron alloy.
- When the current in a coil increases or decreases, a voltage is induced across the coil that depends on the rate at which the current is changing.
- The polarity of the voltage is such as to oppose the change in current.
- This property is called self-inductance, or simply inductance.



Units of Inductance

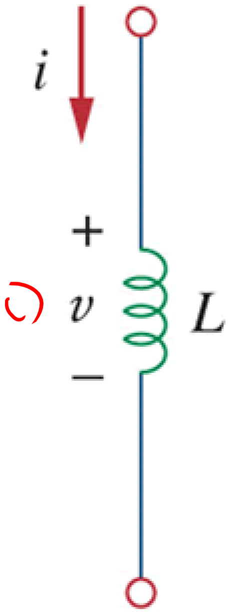
- Inductance is abbreviated ***L*.**
- **The unit of inductance is the henry (H).**
- **Typical inductors found in electronic equipment are in the microhenry (μH) or millihenry (mH) range.**

Voltage-Current Relationship for an Inductor

- The voltage across an inductor is proportional to the rate of change of the current through it:

$$v = L\frac{di}{dt} \to 0$$

$\frac{di}{dt} = 0$ (DC)

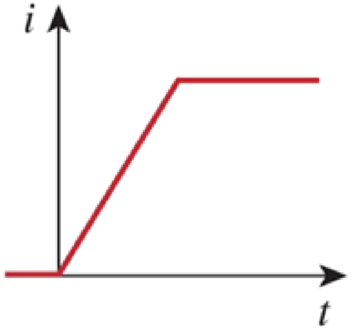


- This equation assumes the passive sign convention (current flows into the positive end).

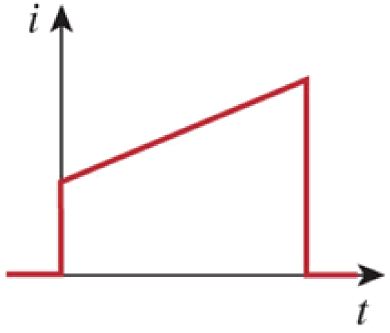
$v = 0$

No Abrupt Current Changes for Inductors

- An inductor's current cannot change "abruptly" or "instantaneously."
- By this we mean that the graph of an inductor's current cannot be vertical, as in the right-hand graph.



Allowed



Not Allowed!

- Why not? Because $\boxed{\frac{di}{dt} = \infty}$ for a vertical line, so $v = L\frac{di}{dt}$ means we would need an infinite voltage, which is impossible.

Inductors Store Energy

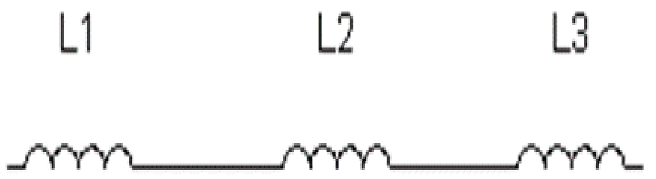
- Recall that energy is dissipated as heat when current flows through a resistance.
- An ideal inductor does not dissipate energy. Rather it stores energy, which can later be returned to the circuit.
- The energy *w* stored in an inductor is given by

$$w = \frac{1}{2} L i^2$$

$W = \frac{1}{2} C v^2$

where L is the inductor's inductance and i is the current through the inductor.
- Recall the units: w is in joules, L is in henries, and i is in amperes.

Inductors in Series:
Equivalent Inductance



- **The equivalent inductance of inductors in series is the sum of the individual inductances:**

$$L_{\mathrm{eq}} = L_1 + L_2 + L_3 + \ldots + L_N$$

Inductors in Parallel:
Equivalent Inductance

- **The equivalent capacitance of inductors in parallel is given by the reciprocal formula:**

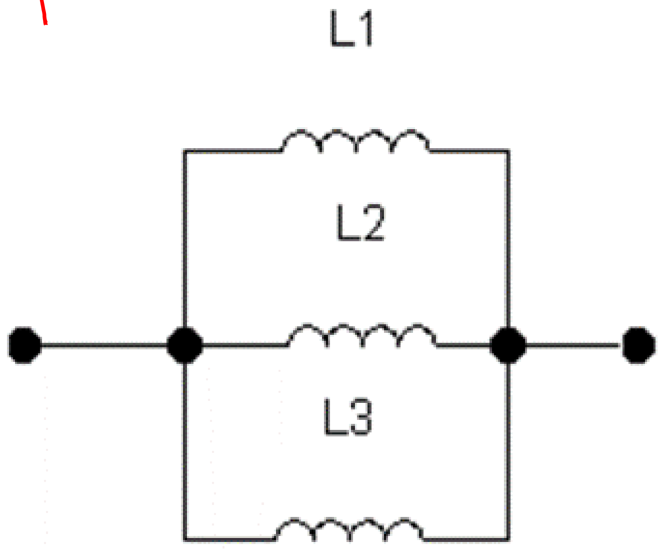
$$L_{\text{eq}} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}}$$

	R	C	L
Series	R_1+R_2	$L_{eq} = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}}$	L_1+L_2
Parallel	$R_{eq} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}\cdots}$	C_1+C_2	$L_{eq} = \frac{1}{\frac{1}{L_1}+\frac{1}{}}$

- **For two inductors in parallel, we can use the product-over-sum rule:**

$$L_{\text{eq}} = \frac{L_1 L_2}{L_1 + L_2}$$

- **Similar to the formulas for resistors in parallel.**



Update: Some Quantities and Their Units

Quantity	Symbol	SI Unit	Symbol for the Unit
Current	I or i	ampere	A
Voltage	V or v	volt	V
Resistance	R	ohm	Ω
Charge	Q or q	coulomb	C
Time	t	second	s
Energy	W or w	joule	J
Power	P or p	watt	W
Conductance	G	siemens	S
Capacitance	C	farad	F
Inductance	L	henry	H

Relation Characteristics of Basic Elements

Relation	Resistor (R)	Capacitor (C)	Inductor (L)
v-i:	$v = iR$	$v = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + v(t_0)$	$v = L\frac{di}{dt}$
i-v:	$i = v/R$	$i = C\frac{dv}{dt}$	$i = \frac{1}{L}\int_{t_0}^{t} v(\tau)d\tau + i(t_0)$
p or w:	$p = i^2R = \frac{v^2}{R}$	$w = \frac{1}{2}Cv^2$	$w = \frac{1}{2}Li^2$
Series:	$R_{eq} = R_1 + R_2$	$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
Parallel:	$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \frac{L_1L_2}{L_1 + L_2}$
At dc:	Same	Open circuit	Short circuit
Circuit variable that cannot change abruptly:	Not applicable	v	i

In scientific units: Volts = Amperes x Ohms

Alessandro Volta
1745 - 1827

potential
Voltage

Andre-Marie Ampere
1775 - 1836

Amps

Georg Simon Ohm
1789 - 1854

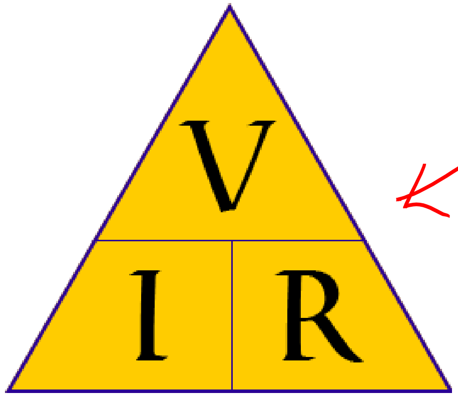
ohms

Ohms Laws

Georg Simon Ohm

- German physicist **Georg Simon Ohm** stated that

"The electric current flowing through a metallic wire is directly proportional to the potential difference across its ends, provided its temperature remains the same" . This law is called Ohm's law.



Ohmic Triangle

Potential difference ∝ Current

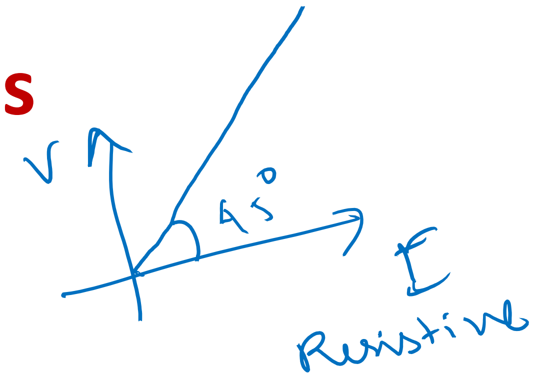
$V \propto I$ ✓

$V = IR$ $I = \frac{V}{R}$, $R = \frac{V}{I}$

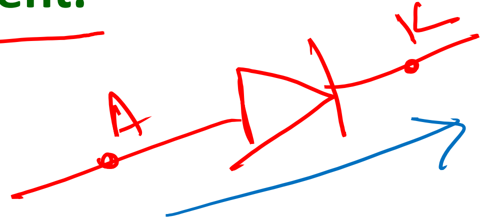
Where,

V is Voltage in volts (V), R is Resistance in ohm (Ω), I is Current in Ampere (A)

Ohms Law – Application and Limitations



- The applications of Ohm's law are:
  - **To determine the voltage, resistance or current of an electric circuit.**
  - **Ohm's law is used to maintain the desired voltage drop across the electronic components.**
  - **Ohm's law is also used in dc ammeter and other dc shunts to divert the current.**



- Limitations of Ohm's Law
  - **Ohm's law is not applicable for unilateral electrical elements like diodes and transistors as they allow the current to flow through in one direction only.**
  - **For non-linear electrical elements with parameters like capacitance, resistance etc the voltage and current won't be constant with respect to time making it difficult to use Ohm's law.**

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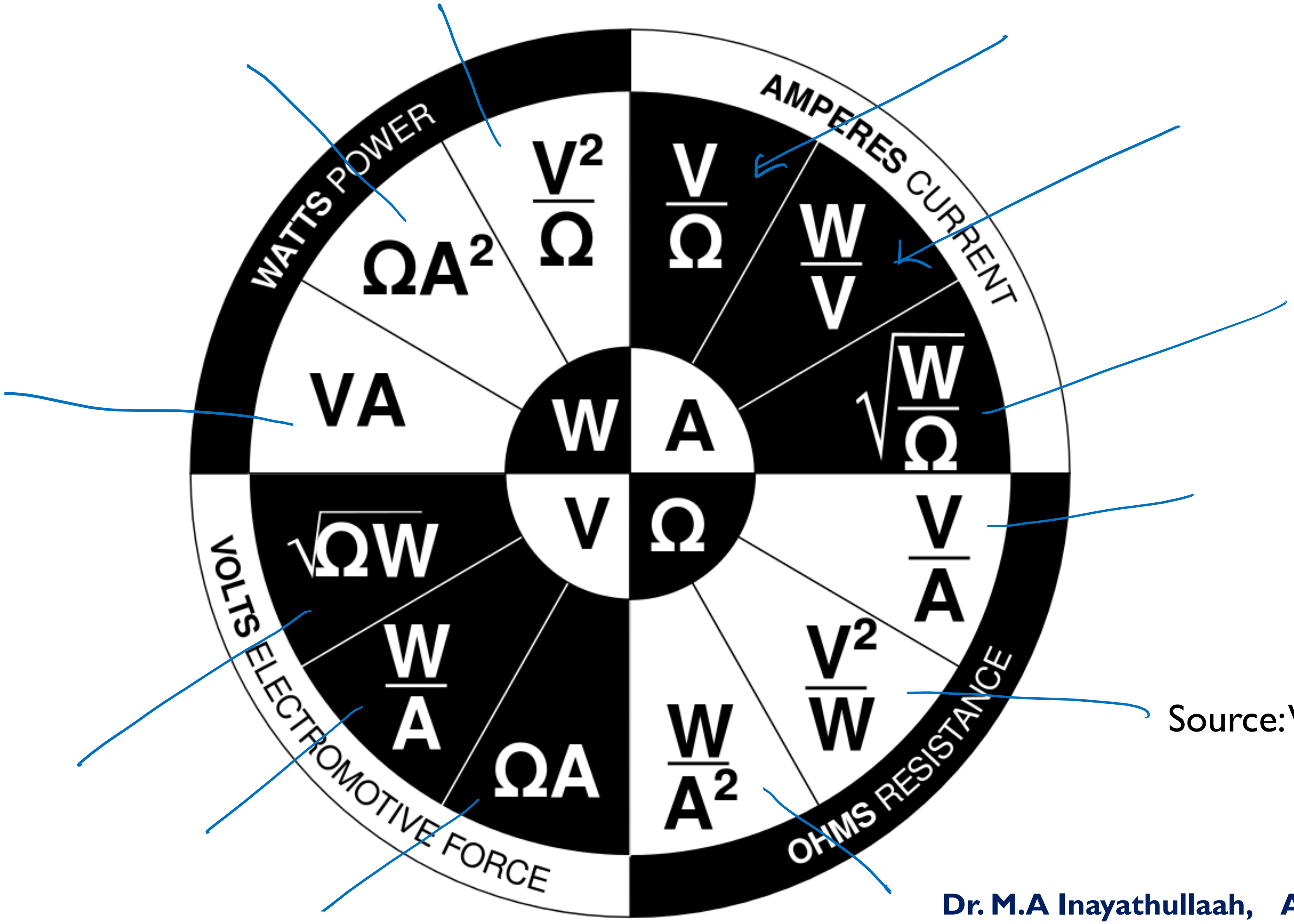
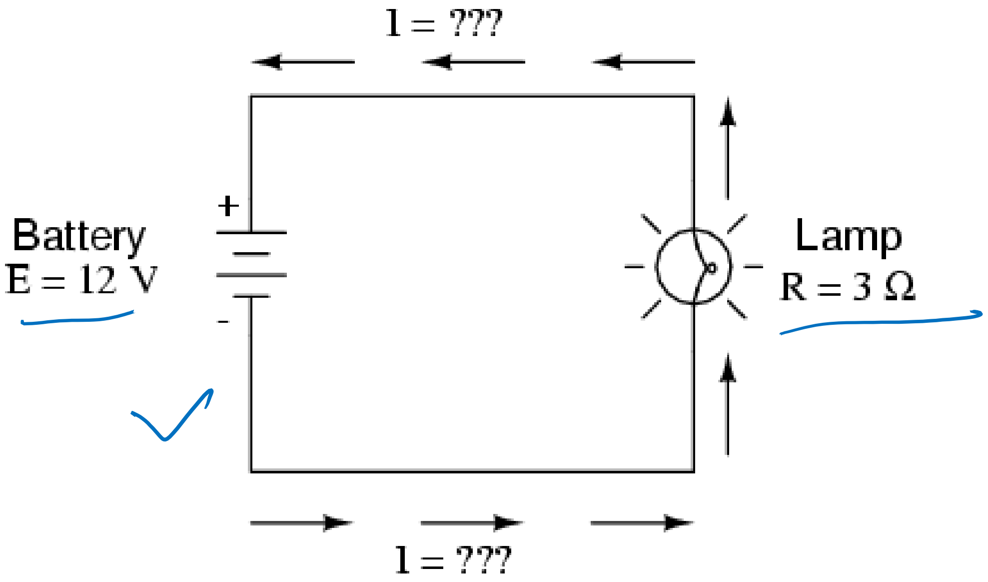
Ohm's Law Interpretations

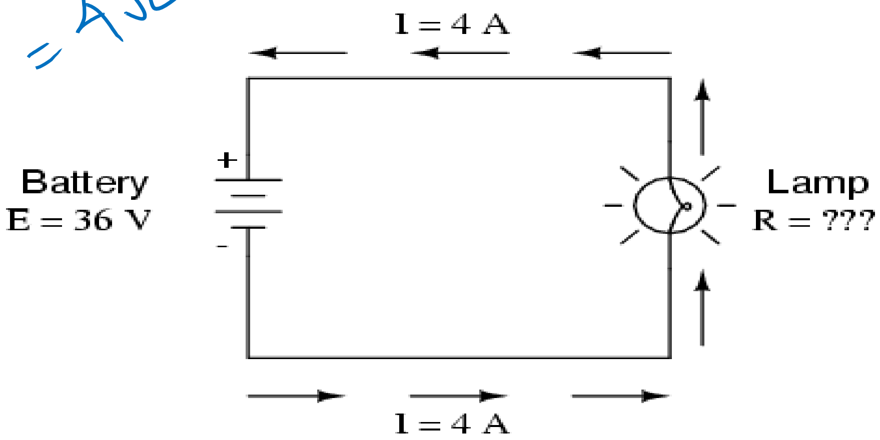


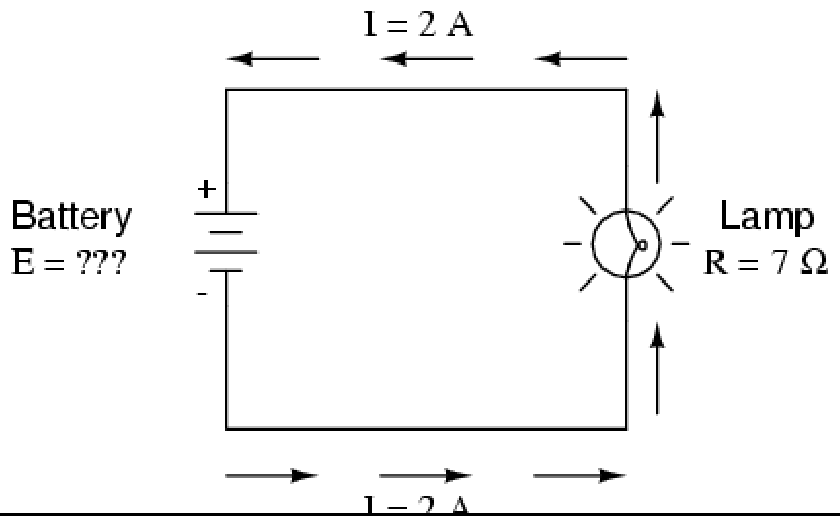
Source: Wikipedia

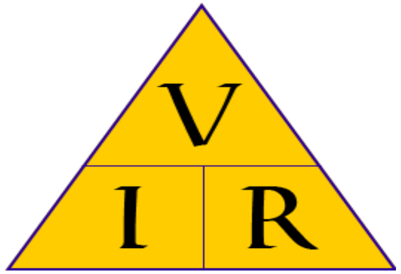
Problems



$R = \frac{V}{I} = \frac{12}{3} = 4\Omega$



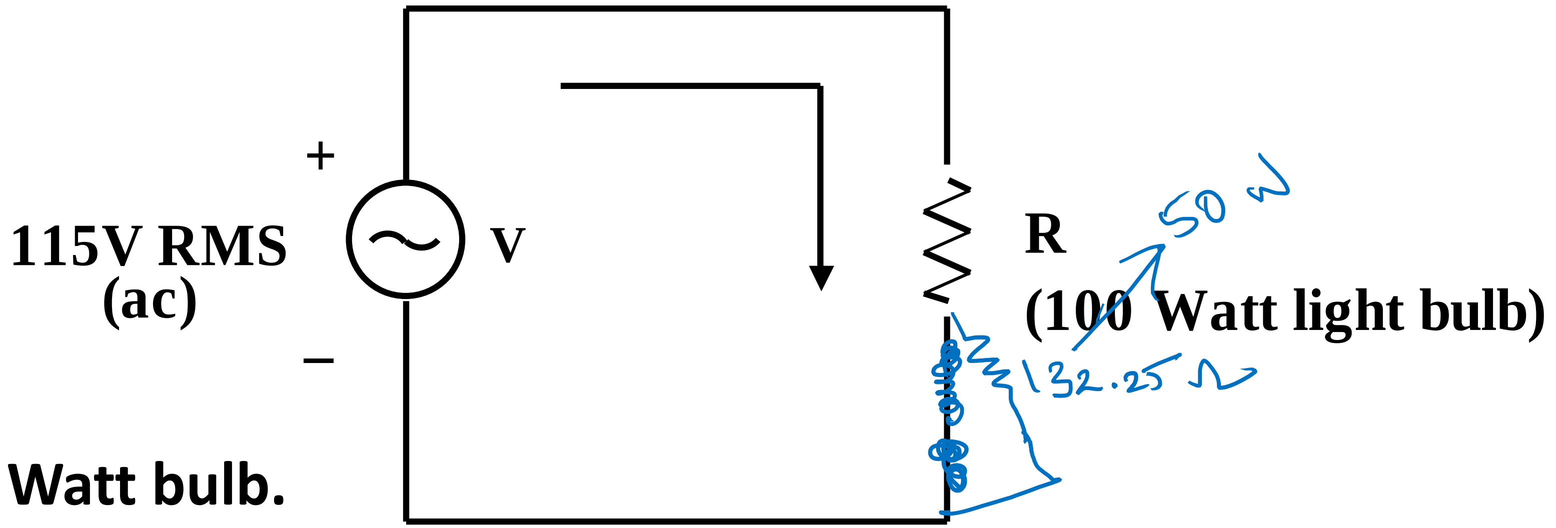




Problems

$R = \frac{V^2}{W} = \frac{115 \times 115}{50} = 264.5\,\Omega$

Consider the following circuit.



Determine the resistance of the 100 Watt bulb.

We know that

$$P = VI = \frac{V^2}{R} = I^2 R$$

$$R = \frac{V^2}{P} = \frac{115^2}{100} = 132.25\ ohms$$

V_{rms} (ac) = 115V

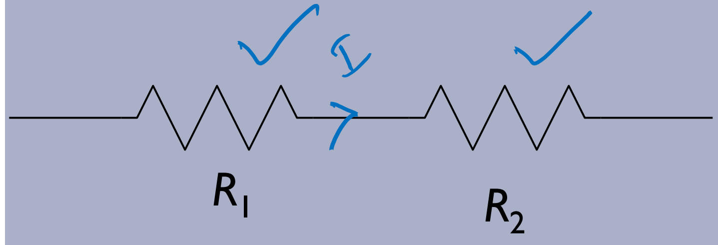
Power (P_{ac}) = 100W

Resistance (R) = $\frac{V^2}{W} = \frac{115 \times 115}{100} = \frac{13225}{100}$

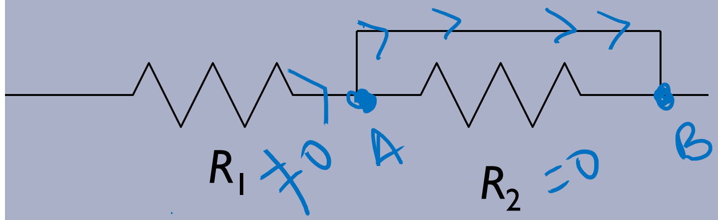
$= 132.25\,\Omega$

Series / Parallel Resistance

Two elements are in *series* if the current that flows through one must also flow through the other.

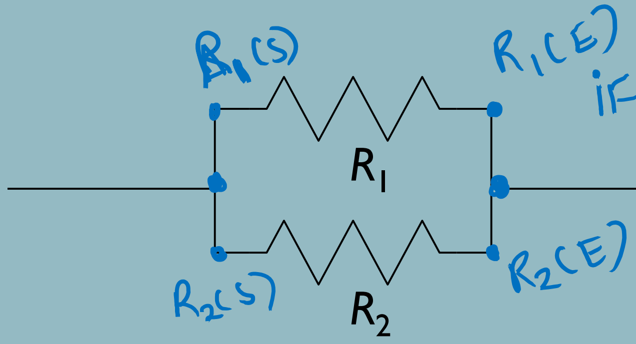


Series



Not Series

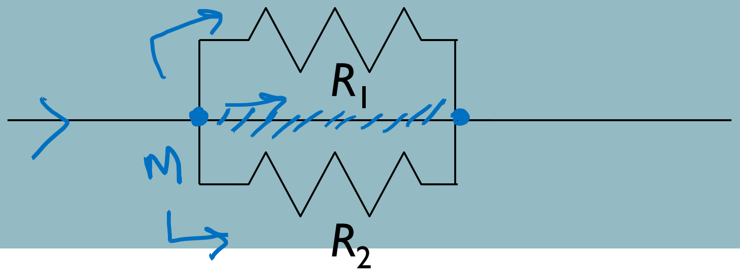
Two elements are in parallel if they are connected between (share) the same two (distinct) end nodes.



if $R_1 = R_2$ $\quad V_{R_1} = V_{R_2}$

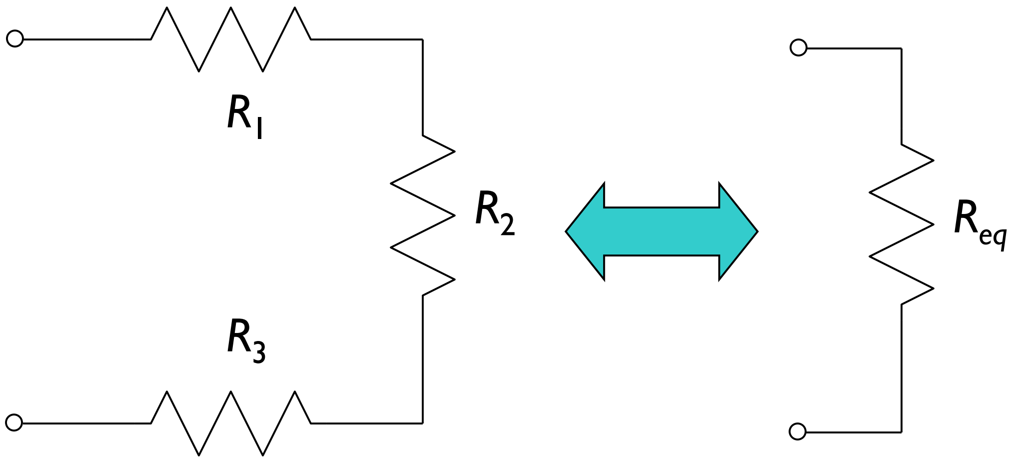
$R_1 \neq R_2$ $\quad V_{R_1} = V_{R_2}$

Parallel

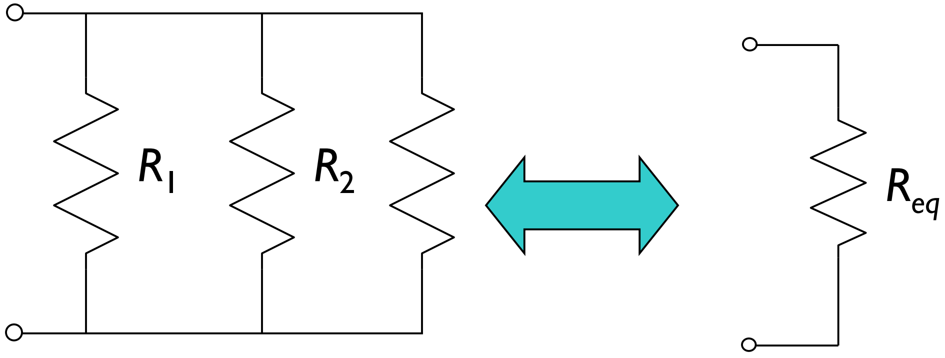


Not Parallel

Series / Parallel Resistance



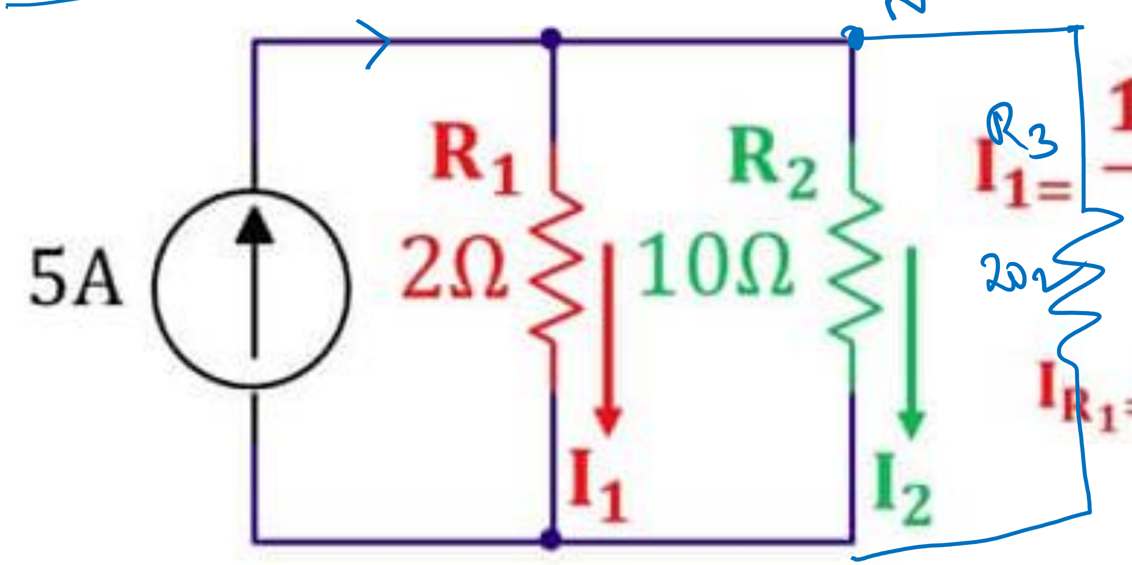
$$R_{eq} = R_1 + R_2 + R_3$$



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Current Divide rule

- Applicable only for parallel circuits where the voltage is constant
- Current in branch 1 = Total current * Resistance in branch 2 / Sum of the resistance of two branches



$$I_1 = \frac{\text{Total current} \times \text{opp. Res.}}{\text{Sum of Res.}}$$

$$I_1 = \frac{1.667\Omega}{2\Omega} * 5A = \frac{5 \times 10}{2+10}$$

$$I_2 = \frac{1.667\Omega}{10\Omega} * 5A \qquad \frac{50}{12} = 4.16\ A.$$

$$I_{R_1} = 4.1675\ A = \frac{5 \times 2}{2+10} = \frac{10}{12} = 0.83\ A. \qquad I_{R_2} = 0.8335\ A$$

Voltage Divide rule

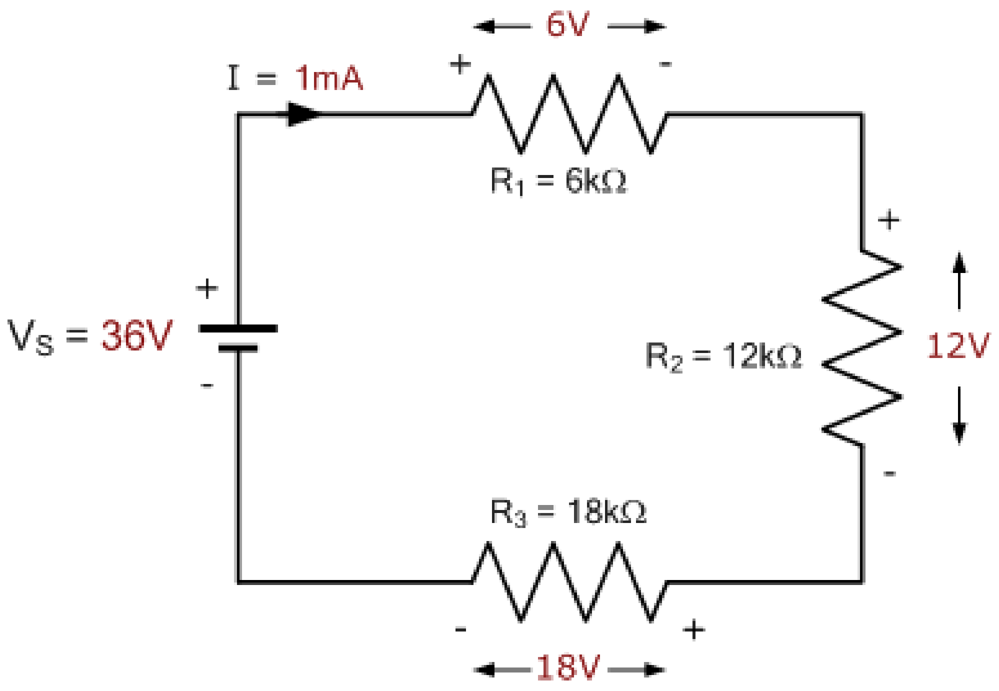
$$V_{R_1} = \frac{\text{Total voltage} \times \text{Same Resistance}}{\text{Sum of Resistances}}$$

- **Applicable only for series circuits, where the current is constant**
- **Voltage in branch 1 = Total voltage * Resistance in branch 1 / Sum of the resistance of two resistance**

$$V_{R_1} = \frac{36 \times 6 \times \cancel{10^3}}{(6+12+18)\times \cancel{10^3}} = \frac{216}{36} = 6V$$

$$V_{R_2} = \frac{36 \times 12 \times \cancel{10^3}}{(6+12+18)\times \cancel{10^3}} = \frac{432}{36} \quad 12V$$

$$V_{R_3} = \frac{\cancel{36} \times 18 \times \cancel{10^3}}{\cancel{36} \times \cancel{10^3}} = 18V$$



- **V1=36*6/36 = 6V**
- **V2=36*12/36=12V**
- **V3=36*18/36=18V**

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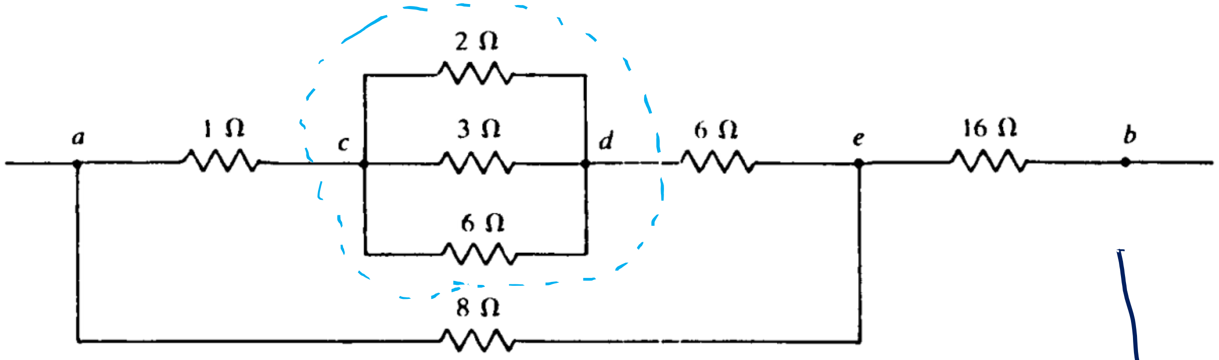
SERIES PARALLEL REDUCTION

$X_c = \frac{1}{2\pi f C}$

$X_C = \infty$

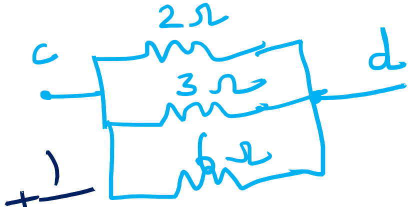
Ans: 20Ω

Reduce the circuit between the terminals *a* and *b*.



Solution

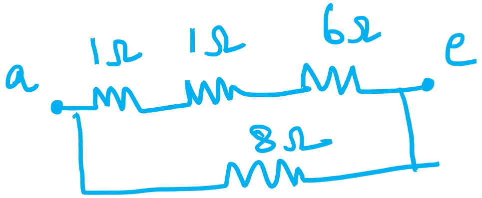
* node c & d

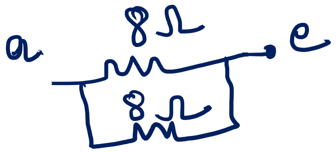


$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$

$= 1\Omega$

* node a & e





$R_{eq} = 1+1+6 = 8$

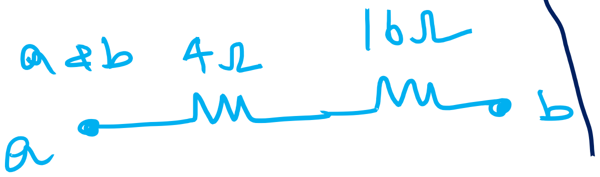
$R_{eq(a,e)} = \frac{R_1 R_2}{R_1 + R_2}$

$= \frac{8 \times 8}{8+8}$

$= \frac{64}{16}$

$= 4\Omega$

* node a & b



$R_{eq(a,b)} = 4 + 16$

$= 20\Omega$

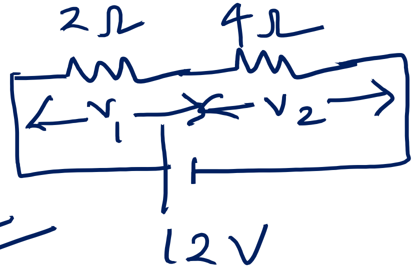
SERIES PARALLEL REDUCTION

How much current will flow through a 2-Ω resistor connected in series with a 4-Ω resistor, and the combination connected across a 12-V source? What is the voltage across each resistor?

Ans: 2A, 8V, 4V

By Voltage division rule $V_1 = \frac{12 \times 2}{2+4} = \frac{24}{6} = 4V$

$V_2 = \frac{12 \times 4}{2+4} = \frac{48}{6} = 8V$



A 2-Ω resistor is connected in parallel with a 4-Ω resistor and the combination across a 12-V source. Find the current through each resistor and the total current supplied by the source.

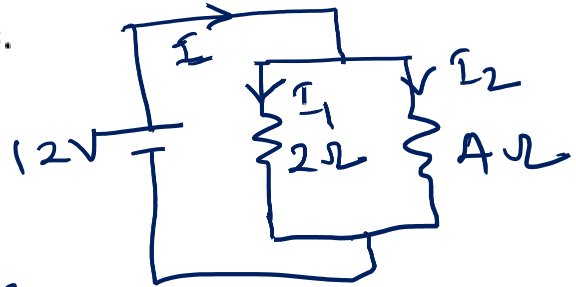
Ans: 6A, 3A, 9A

By ~~current division rule~~

By Ohm's law, $I_1 = \frac{12}{2} = 6A$

$I_2 = \frac{12}{4} = 3A$

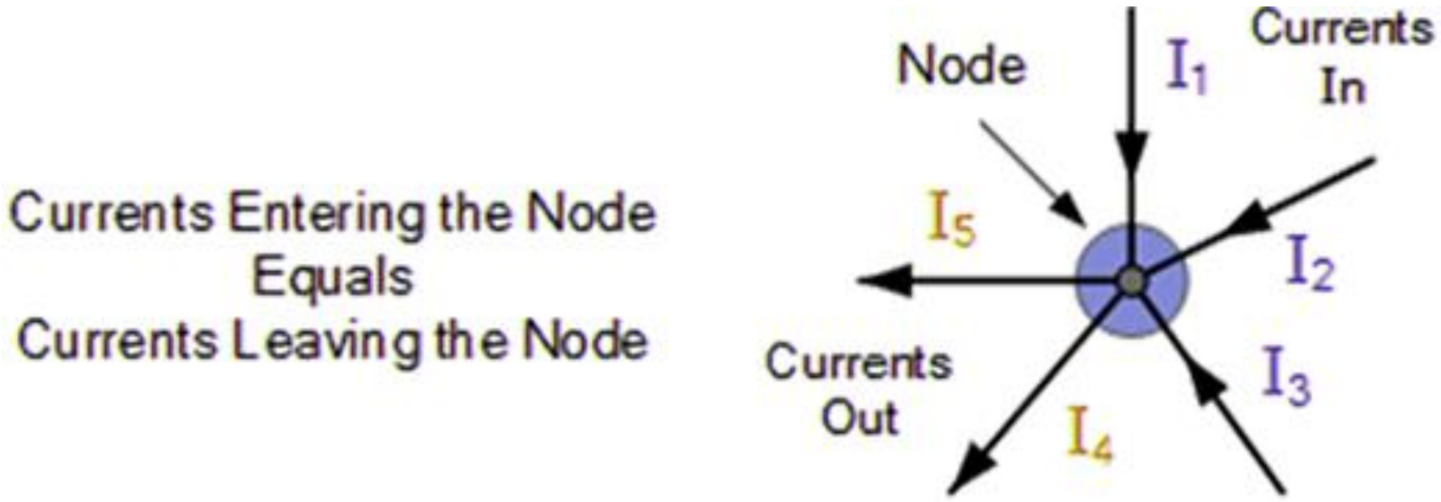
we know that $I = I_1 + I_2 = 6+3 = 9A$



Kirchhoff's Current Law

Kirchhoff's Current Law also called as Kirchhoff's First Law and Kirchhoff's Junction Rule.

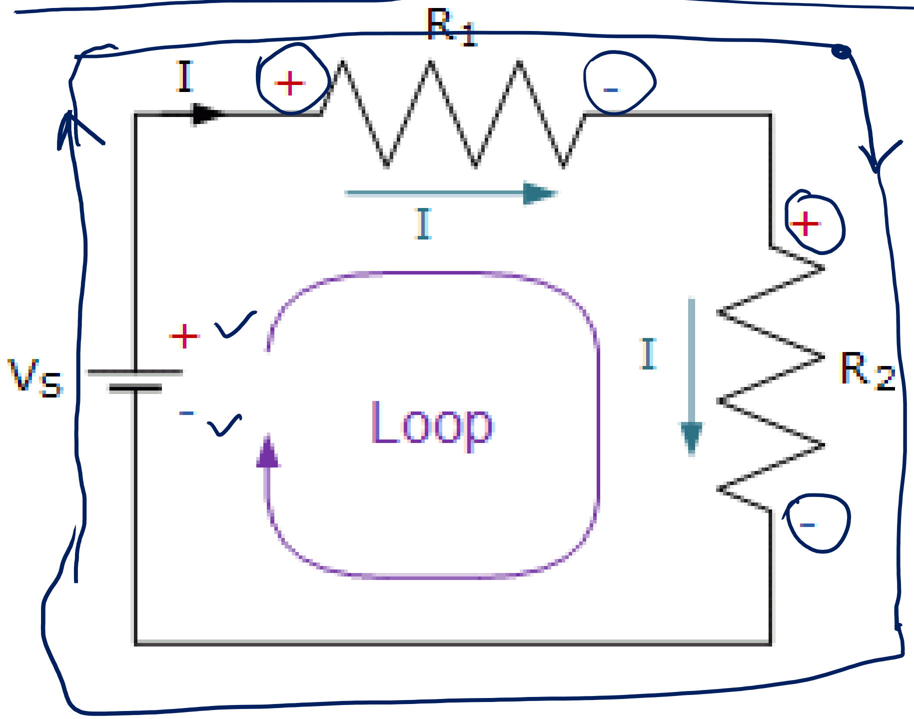
According to the Junction rule, "In a circuit, the total of the currents in a junction is equal to the sum of currents outside the junction", in other words "The total current entering a junction or a node is equal to the charge leaving the node as no charge is lost"



$$I_1 + I_2 + I_3 = I_4 + I_5 \quad \text{or} \quad \boxed{I_1 + I_2 + I_3 - I_4 - I_5 = 0}$$

Kirchhoff's Voltage Law

Kirchhoff's Voltage Law also called as Kirchhoff's Second Law and Kirchhoff's Loop Rule. According to the loop rule, "the sum of the voltages around the closed loop is equal to null" or "The voltage around a loop equals to the sum of every voltage drop in the same loop for any closed network and also equals to zero".



$V_s + (-IR_1) + (-IR_2) = 0$ or $V_s = +IR_1 + IR_2$

For Current I

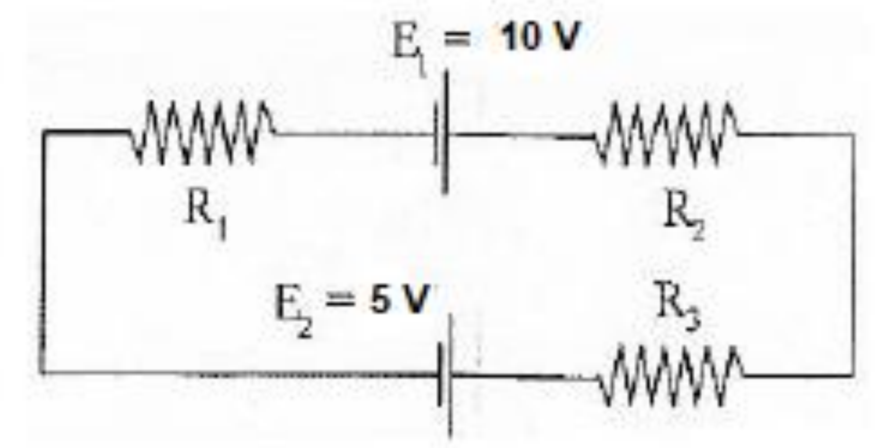
Applying KVL to the loop current I,

$$+V_S - IR_1 - IR_2 = 0$$

$$V_S = IR_1 + IR_2$$

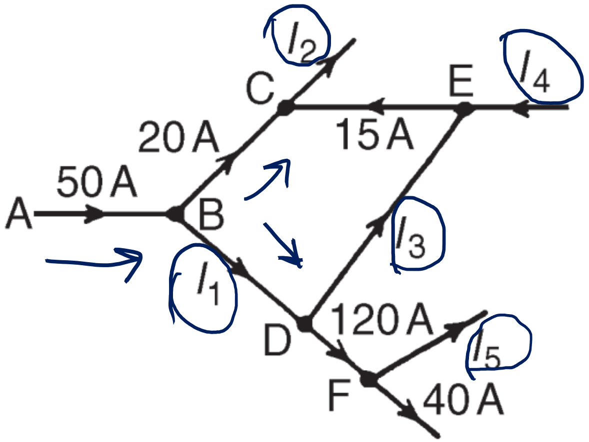
Problems

If $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 6\Omega$, determine the electric current that flows in the circuit below.



Ans : I = 0.416 A

Problems



Find the unknown currents marked in Figure

* Applying KCL to node B $\quad 50 = 20 + I_1 \quad \boxed{I_1 = 30A}$

* Applying KCL to node D $\quad I_1 = 120 + I_3$

$30 = 120 + I_3 \quad \boxed{I_3 = -90A}$

* Applying KCL to node C $\quad 20 + 15 = I_2 \quad \boxed{I_2 = 35A}$

* Applying KCL to node E $\quad I_3 + I_4 = 15$

$-90 + I_4 = 15 \quad \boxed{I_4 = +105}$

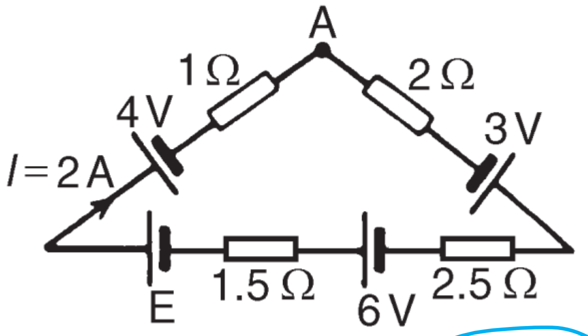
* Applying KCL to node F

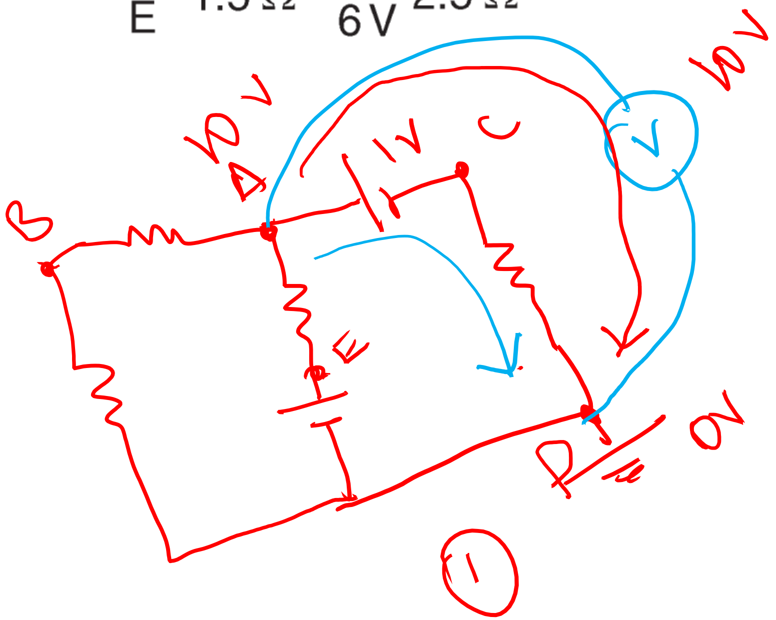
$120 = I_5 + 40$

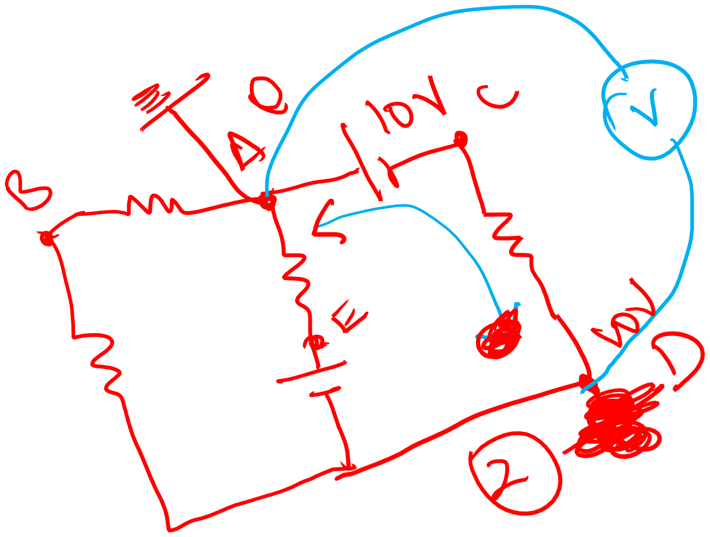
$\boxed{I_5 = 80A}$

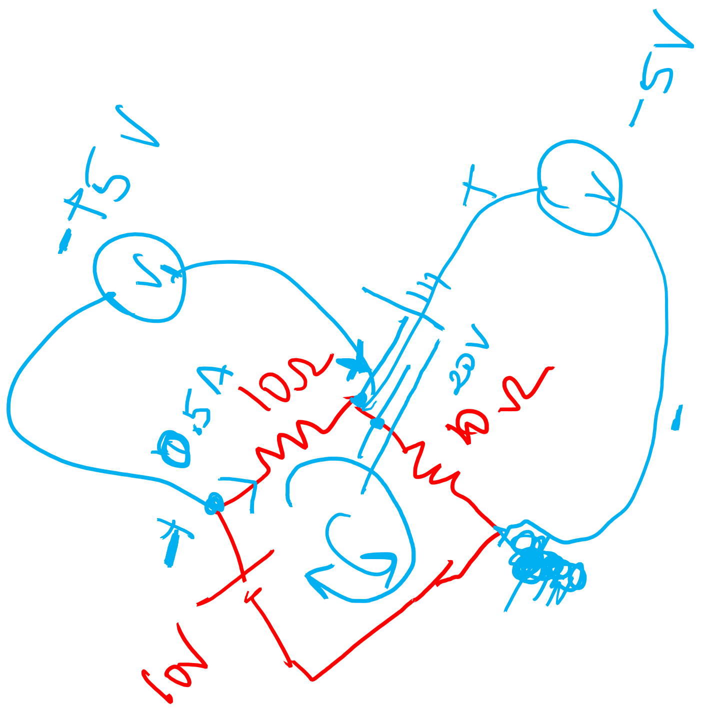
Problems

Determine the value of e.m.f. E in Figure





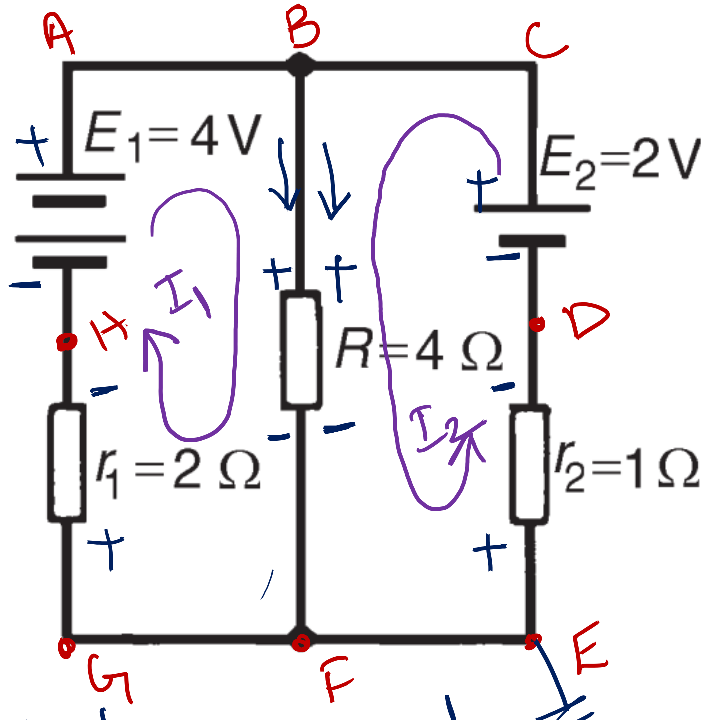




Mesh Current Analysis - Problems

Use Kirchhoff's laws to determine the currents flowing in each branch of the network shown in Figure .

Ans: [I_1=0.286A, I_2=0.857A]



* Name the node

* Assume current direction

* Apply KVL to all Independent loop

Solution

* Applying KVL to the loop ABFGHA (I_1)

$$\cancel{V_{AB}} + V_{BF} + \cancel{V_{FG}} + V_{GH} + V_{HA} = 0$$

$$-4(I_1 + I_2) - 2(I_1) + 4 = 0$$

$$-4I_1 - 4I_2 - 2I_1 + 4 = 0$$

$$-6I_1 - 4I_2 = -4 \quad \text{--- (1)}$$

* Applying KVL to the loop BCDEFB (I_2)

$$\cancel{V_{BC}}^{0} + V_{CD} + V_{DE} + \cancel{V_{EF}}^{0} + V_{FB} = 0$$

$$V_{BF} + V_{FE} + V_{ED} + V_{DC} + V_{CB} = 0$$

$$-4(I_2 + I_1) + 0 + (-1) I_2 + 2 = 0$$

$$-4I_2 - 4I_1 - I_2 = -2$$

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$$-4I_1 - 5I_2 = -2 \quad — (2)$$
$$-6I_1 - 4I_2 = -4 \quad — (1)$$

from (2) $-4I_1 = -2 + 5I_2$

$$I_1 = \frac{-2+5I_2}{-4} \quad — (3)$$

(3) in (1) $-6\left[\frac{-2+5I_2}{-4}\right] - 4I_2 = -4$

$$+\frac{6}{4}(2+5I_2) - 4I_2 = -4$$

$$3 + \frac{30I_2}{4} - 4I_2 = -4$$

$$I_2 = -\frac{2}{7} = -0.285A$$

from (3)

$$I_1 = \frac{-2+5(-0.285)}{-4}$$

$$= \frac{10}{21} = 0.857\ A$$

$$\boxed{I_1 = 0.857A}$$

$$V_{2\Omega} = 2 \times I_1 = 2 \times 0.857 = 1.71V$$

$$V_{1\Omega} = 1 \times I_2 = 1 \times 0.285 = 0.285V$$

$$V_{4\Omega} = 4 \times (I_1 - I_2)$$

$$= 4 \times (0.857 - 0.285) =$$

$$= 2.286V$$

SERIES PARALLEL REDUCTION

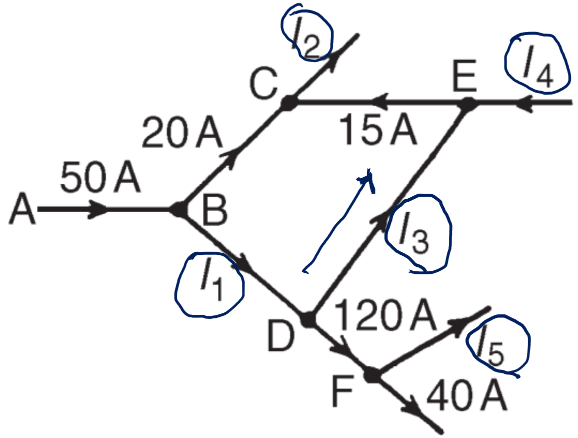
A 3-Ω and a 6-Ω resistor are connected in parallel and the combination in series with an 8-Ω resistor. Calculate the total resistance.

Ans: 10Ω

Determine the current through and the voltages across three resistors of ohmic values 5, 7, and 8 Ω, connected in series and across a 100-V source.

Ans: 5A

Problems



Find the unknown currents marked in Figure

Solution

Apply KCL to the node B $\quad 50 = 20 + I_1 \quad \boxed{I_1 = 30A}$

Apply KCL to the node D $\quad 30 = 120 + I_3 \quad \boxed{I_3 = -90A}$

" " " F $\quad 120 = 40 + I_5 \quad \boxed{I_5 = 80A}$

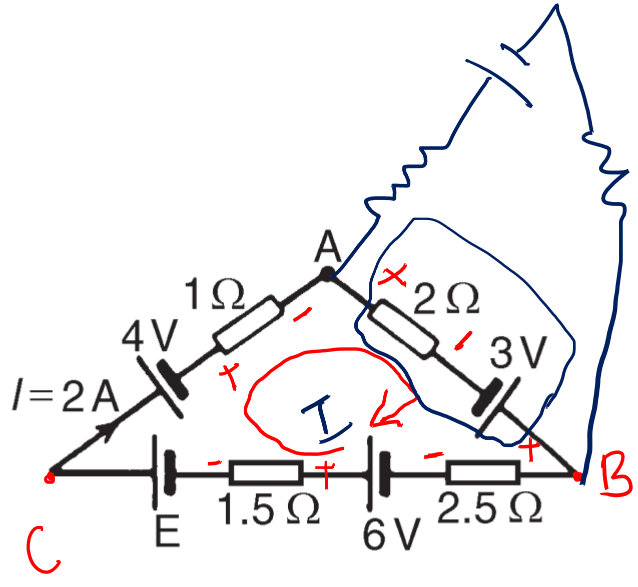
" " " C $\quad 20 + 15 = I_2 \quad \boxed{I_2 = 35A}$

" " " E

$-90 + I_4 = 15$

$\boxed{I_4 = 105A}$

Problems



Determine the value of e.m.f. E in Figure

Applying KVL to the loop ABCA (I)

$$V_{AB}+V_{BC}+V_{CA}=0$$

$$-2I+3-2.5I+6-1.5I+E-4-1I=0$$

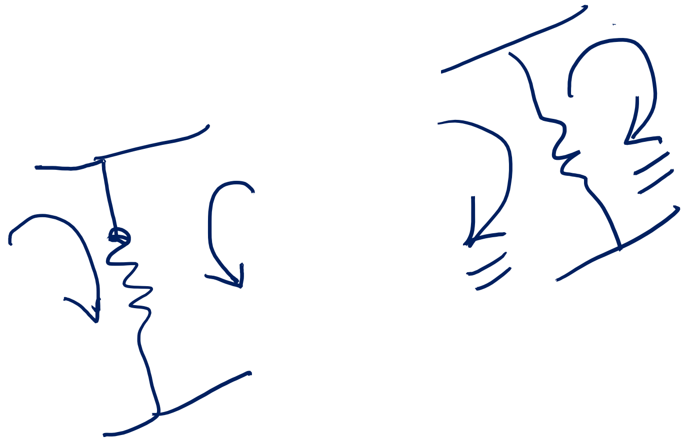
$$-2(2)+3-2.5(2)+6-1.5(2)+E-4-1(2)=0$$

$$-4+3-5+6-3+E-4-2=0$$

$$-18+9+E=0$$

$$-9+E=0$$

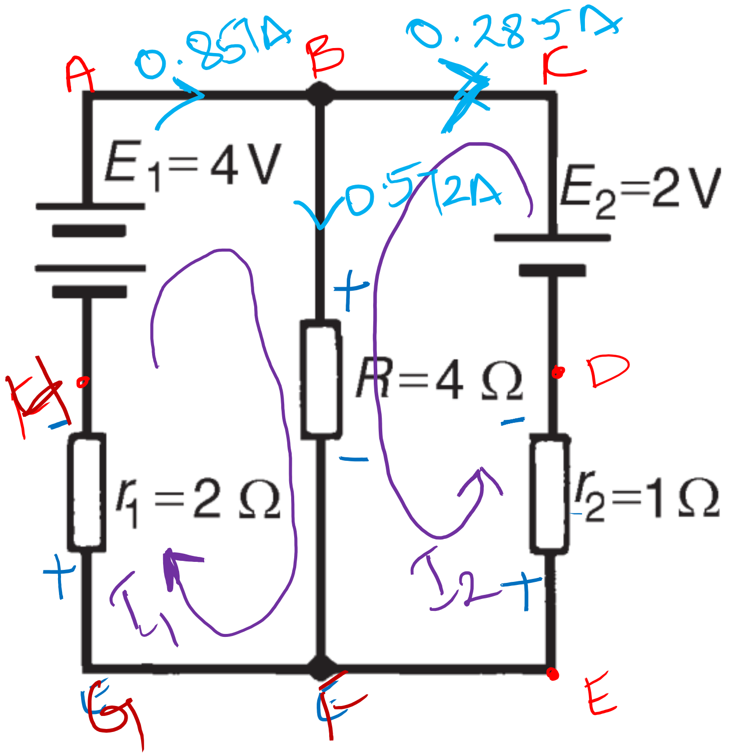
$$\boxed{E=9}$$



Mesh Current Analysis - Problems

Use Kirchhoff's laws to determine the currents flowing in each branch of the network shown in Figure .

Ans: [I_1=0.286A, I_2=0.857A]



Applying KVL to the loop ~~ABEFA~~ ABFGHA (I_1)

$-4(I_1+I_2)-2I_1+4=0$ (KVL)

$-4I_1-4I_2-2I_1=-4$

$-6I_1-4I_2=-4$ — (1)

BFEDCB

Applying KVL to the loop ~~BCDEFB~~ (I_2)

$-4(I_1+I_2)-1(I_2)+2=0$

$-4I_1-4I_2-I_2=-2$

$-4I_1-5I_2=-2$ — (2)

Nodal Voltage Analysis

① ⇒ $-6I_1 - 4I_2 = -4$

2 ⇒ $-4I_1 - 5I_2 = -2$

Using substitution method solving for I_1 & I_2

From ① I_1 : $-6I_1 = -4 + 4I_2$

$$I_1 = \frac{-4}{-6} + \frac{4}{-6} I_2 \quad —③$$

Sub eqn ③ in ②

$$-4\left[\frac{-2}{-3} + \frac{2}{-3} I_2\right] - 5I_2 = -2$$

$$-4\left[\frac{2}{3} - \frac{2}{3} I_2\right] - 5I_2 = -2$$

$$\boxed{I_2 = -0.285A}$$

Sub I_2 eq ①

$$-6I_1 - 4(-0.285) = -4$$

$$\boxed{I_1 = 0.857A}$$

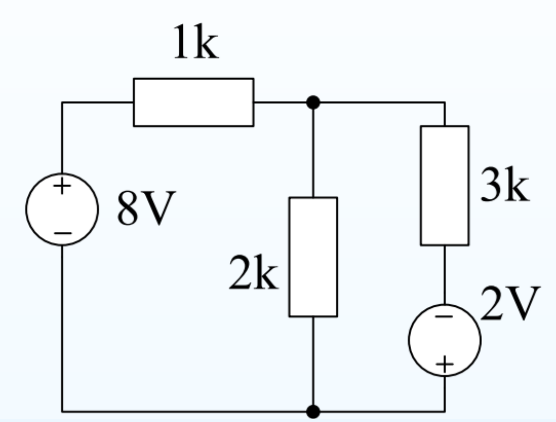
$$I_1 + I_2 = 0.857 - 0.285$$

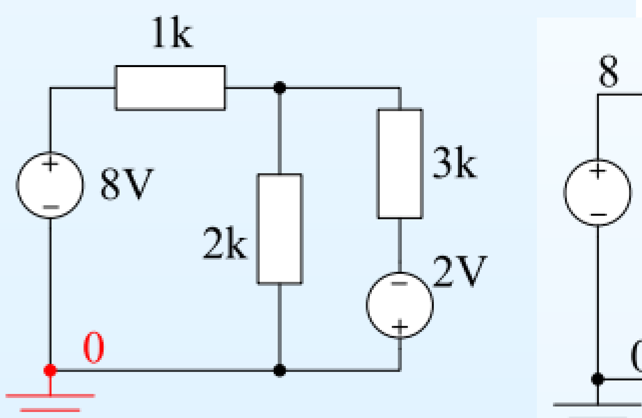
$$\boxed{I_1 + I_2 = 0.572A}$$

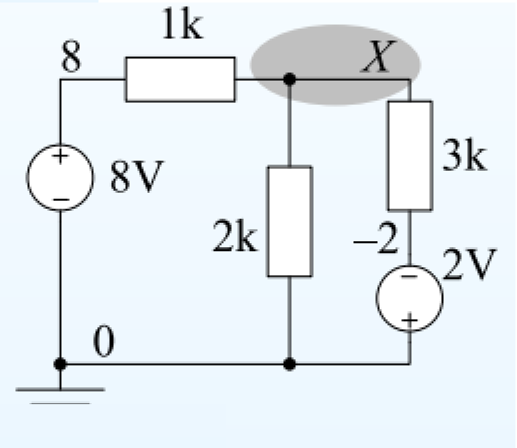
Nodal Analysis

The aim of nodal analysis is to determine the voltage at each node relative to the reference node (or ground).

1. Assign a reference node (ground).
2. Assign node voltage names to the remaining nodes.
3. Solve the easy nodes first, the ones with a voltage source connected to the reference node.
4. Write Kirchhoff's Current Law for each node. Do Ohm's Law in your head.
5. Solve the resulting system of equations for all node voltages.
6. Solve for any currents you want to know using Ohm's Law. For a circuit with N nodes and S voltage sources you will have N-S-1 simultaneous equation to solve.





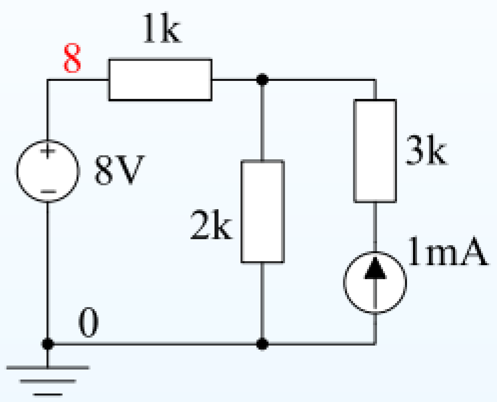


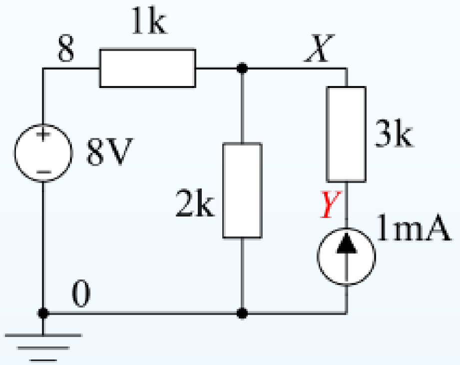
We only have one variable:

$$\frac{X-8}{1\,\mathrm{k}} + \frac{X-0}{2\,\mathrm{k}} + \frac{X-(-2)}{3\,\mathrm{k}} = 0 \quad \Rightarrow \quad (6X-48)+3X+(2X+4)=0$$

$$11X = 44 \quad \Rightarrow \quad X = 4$$

Nodal Analysis





$$\frac{X-8}{1} + \frac{X}{2} + \frac{X-Y}{3} = 0$$

$$\frac{Y-X}{3} + (-1) = 0$$

Solve the equations: $X = 6,\ Y = 9$

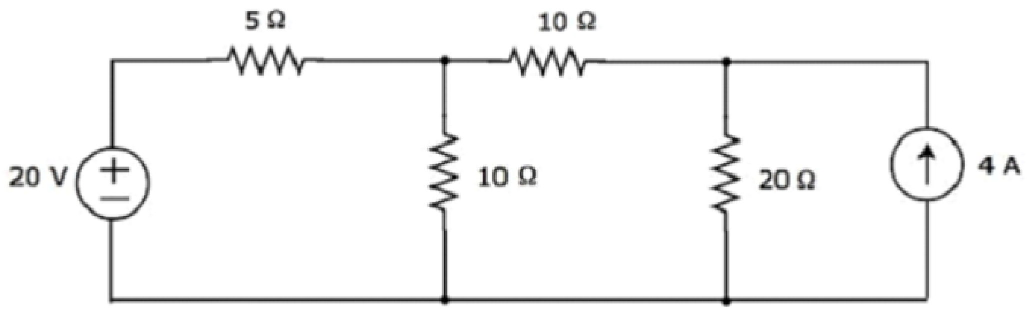
Nodal Analysis

The aim of nodal analysis is to determine the voltage at each node relative to the reference node (or ground).

1. Assign a reference node (ground).
2. Assign node voltage names to the remaining nodes.
3. Solve the easy nodes first, the ones with a voltage source connected to the reference node.
4. Write Kirchhoff's Current Law for each node. Do Ohm's Law in your head.
5. Solve the resulting system of equations for all node voltages.
6. Solve for any currents you want to know using Ohm's Law. For a circuit with N nodes and S voltage sources you will have N-S-1 simultaneous equation to solve.

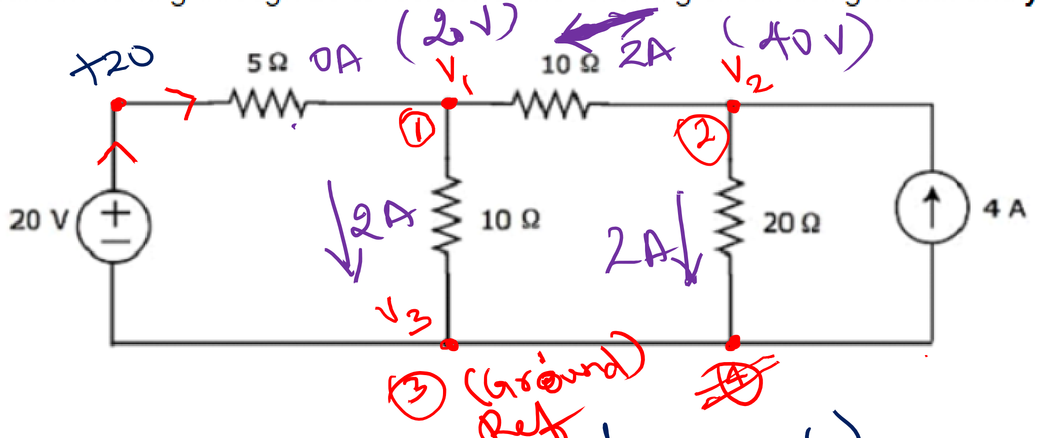
Nodal Analysis

Find the current flowing through 20 Ω resistor of the following circuit using **Nodal analysis**.



Nodal Analysis

Find the current flowing through 20 Ω resistor of the following circuit using **Nodal analysis**.



*Apply KCL to the node ① (V_1)

$$\frac{V_1-20}{5}+\frac{V_1-V_2}{10}+\frac{V_1-\cancel{V_3}^{0}}{10}=0$$

$$\frac{2V_1-40+V_1-V_2+V_1}{10}=0$$

$$4V_1-V_2=40 \quad —①$$

* Apply KCL to the node ② (V_2)

$$\frac{V_2-V_1}{10}+\frac{V_2-V_3}{20}-4=0$$

$$\frac{V_2-V_1}{10}+\frac{V_2}{20}=4$$

$$\frac{2V_2-2V_1+V_2}{20}=4$$

$$2V_2-2V_1+V_2=80$$

$$-2V_1+3V_2=80 \quad —②$$

*Solving for V_1 & V_2

from ② $3V_2=80+2V_1$

$$V_2=\frac{80}{3}+\frac{2}{3}V_1 \quad —③$$

Sub ③ in ①

$$4V_1-\left[\frac{80}{3}+\frac{2V_1}{3}\right]=40$$

$$4V_1-\frac{80}{3}-\frac{2V_1}{3}=40$$

on solving for V_1,

$$\boxed{V_1=20\,V} \quad —④$$

sub ④ in ③

$$V_2=\frac{80}{3}+\frac{2\times 20}{3}$$

$$=\frac{80}{3}+\frac{40}{3}$$

$$=\frac{120}{3}$$

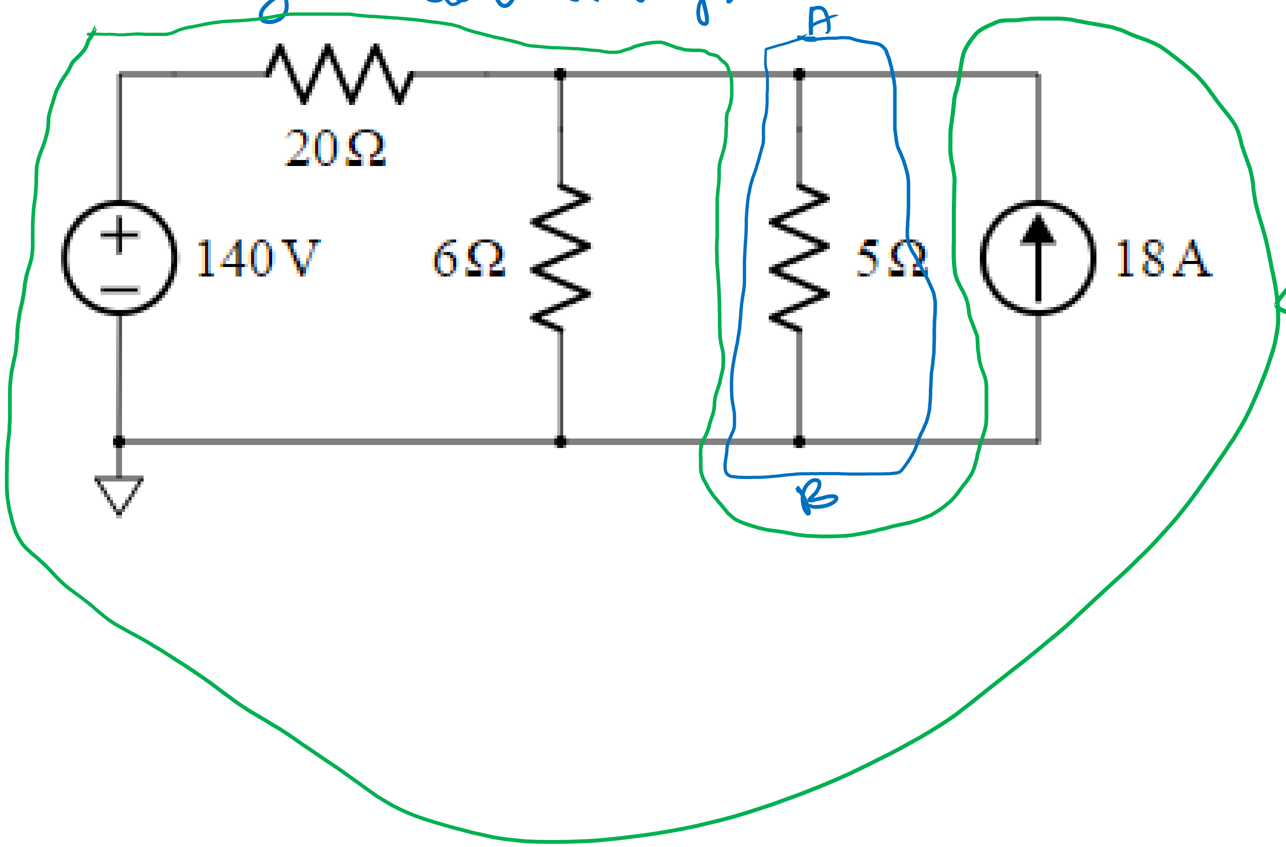
$$\boxed{V_2=40\,V}$$

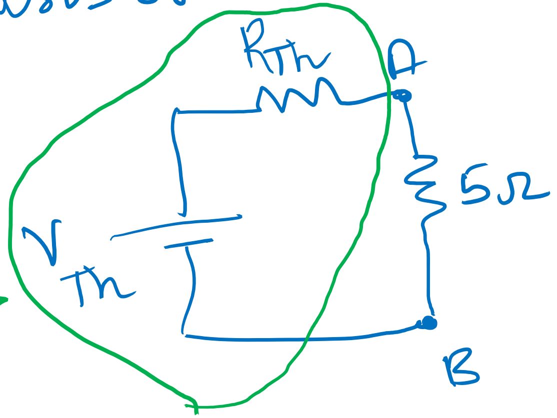
*Current flowing through 20Ω

$$I_{20\Omega}=\frac{V_2-V_3}{20}=\frac{40}{20}=2A$$

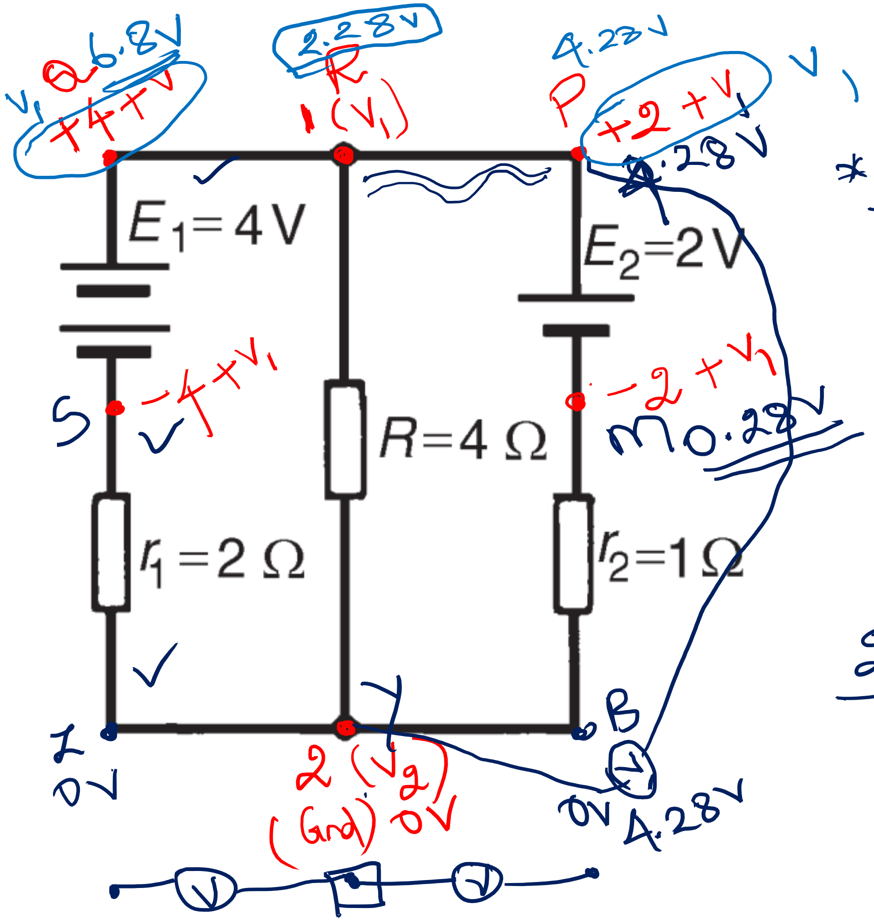
Nodal Analysis

Find the current flowing through 5Ω resistor using Nodal analysis





Nodal Analysis



* Applying KCL to the node (V1)

$$\frac{(V_1-4)-V_2}{2} + \frac{V_1-V_2}{4} + \frac{(V_1-2)-V_2}{1} = 0$$

$$\frac{V_1-4}{2} + \frac{V_1}{4} + \frac{V_1-2}{1} = 0$$

$$\frac{2V_1-8+V_1+4V_1-8}{4} = 0$$

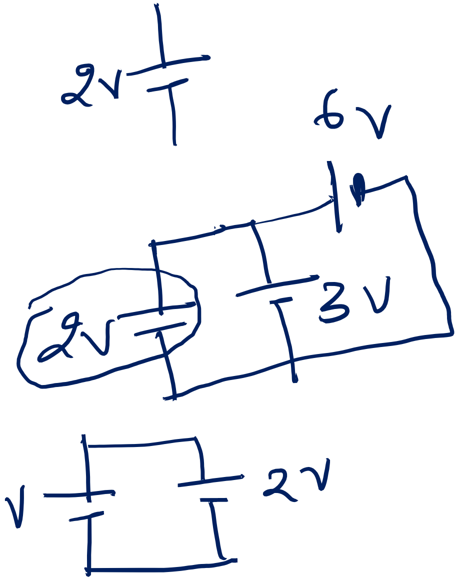
$$7V_1 - 16 = 0$$

$$V_1 = \frac{16}{7} = 2.28V$$

$V_{QZ} = 4+2(-0.857)$
$= 4-1.714$
$= 2.286$

$V_{RY} = V_1 = 2.28$

$V_{PB} =$
$2+1(0.28)$
$2.28V$



* current through r_1

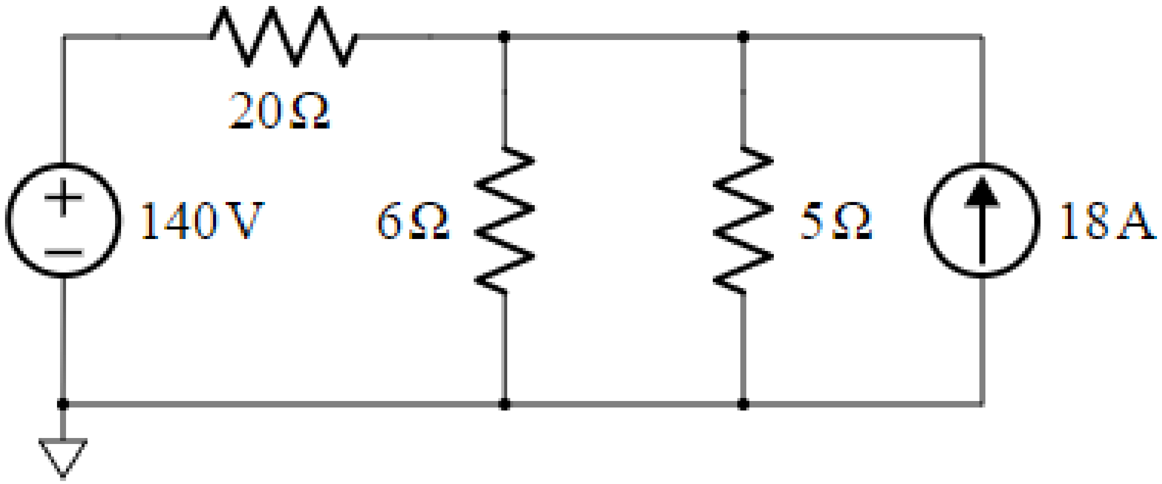
$$I_{r_1} = \frac{(V_1-4)-V_2}{2} = \frac{2.28-4}{2} = -0.857A$$

* current through r_2

$$I_{r_2} = \frac{(V_1-2)-V_2}{1} = 2.28-2 = 0.28A$$

$$I_{4\Omega} = \frac{V_1}{4} = \frac{2.28}{4} = 0.57A$$

Nodal Analysis



$$+\frac{(140-v_b)}{20}-\frac{v_b}{6}-\frac{v_b}{5}+18=0$$

$$+\frac{140}{20}-\frac{v_b}{20}-\frac{v_b}{6}-\frac{v_b}{5}=-18$$

$$-\frac{v_b}{20}-\frac{v_b}{6}-\frac{v_b}{5}=-18-7$$

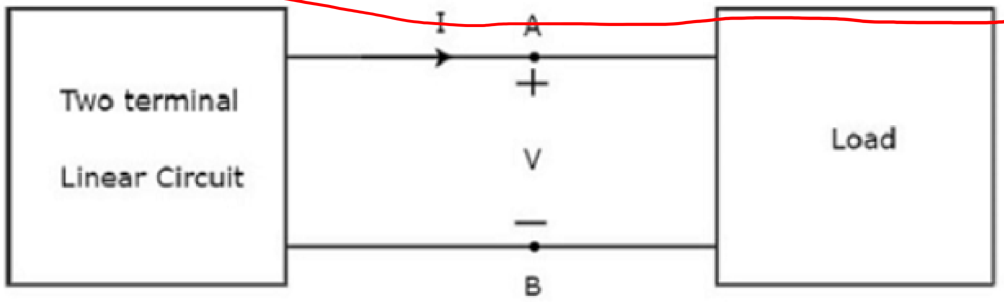
$$\left(-\frac{3}{60}-\frac{10}{60}-\frac{12}{60}\right)\cdot v_b=-25$$

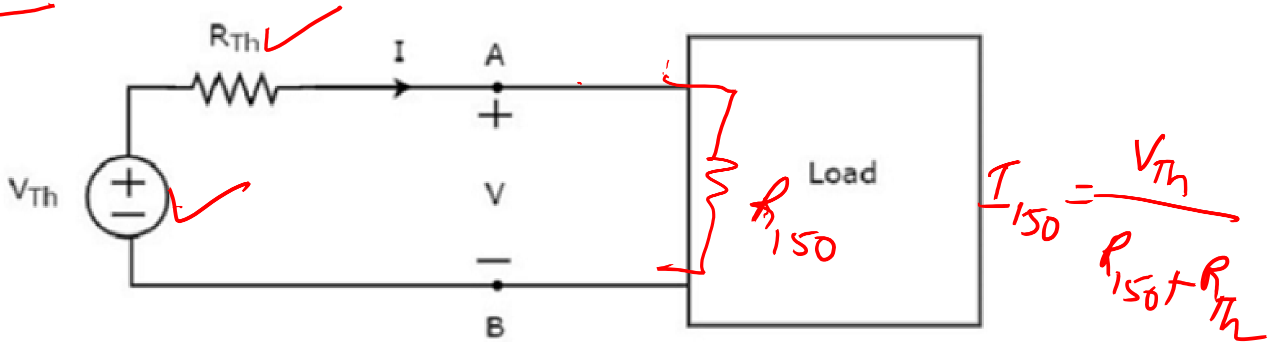
$$v_b=-25\cdot\left(-\frac{60}{25}\right)$$

$$v_b=60\,\mathrm{V}$$

Thevenin's Transfer Theorem

Thevenin's theorem states that any two terminal linear network or circuit can be represented with an equivalent network or circuit, which consists of a voltage source in series with a resistor.

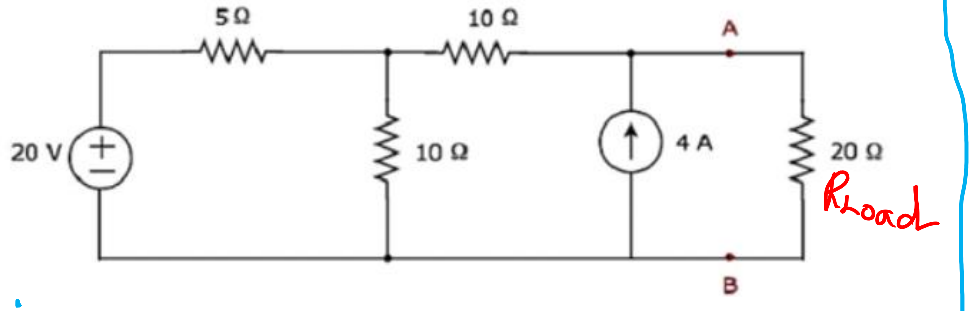




- Steps in order to find the Thevenin's equivalent circuit, when only the **sources of independent type** are present.
- **Step 1** − Consider the circuit diagram by opening the terminals with respect to which the Thevenin's equivalent circuit is to be found.
- **Step 2** − Find Thevenin's voltage $\mathbf{V_{Th}}$ across the open terminals of the above circuit.
- **Step 3** − Find Thevenin's resistance $\mathbf{R_{Th}}$ across the open terminals of the above circuit by eliminating the independent sources present in it.
- **Step 4** − Draw the **Thevenin's equivalent circuit** by connecting a Thevenin's voltage V_{Th} in series with a Thevenin's resistance R_{Th}. Now, we can find the response in an element that lies to the right side of Thevenin's equivalent circuit.

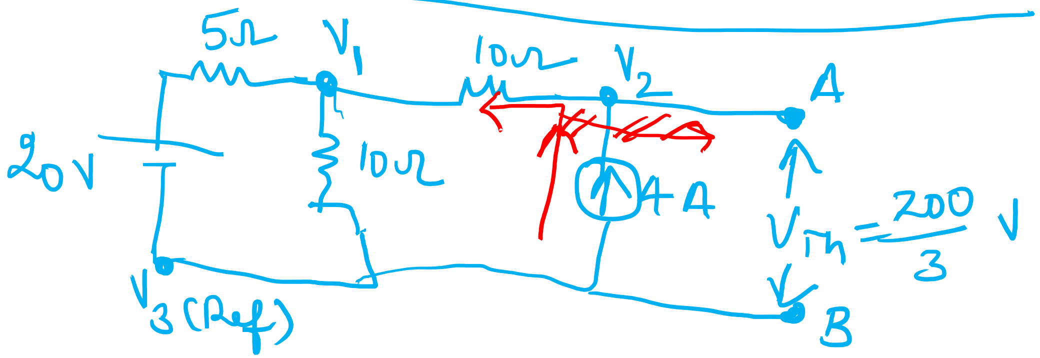
Thevenin's Transfer Theorem

Find the current flowing through 20 Ω resistor by first finding a **Thevenin's equivalent circuit** to the left of terminals A and B.



Solution

* To Find Thevenin Voltage (V_{Th})



Applying KCL to the node (V_1)

$$\frac{V_1-20}{5}+\frac{V_1-V_2}{10}+\frac{V_1}{10}=0$$

$$\frac{2V_1-40+V_1-V_2+V_1}{10}=0$$

$$4V_1-V_2=40 \quad \text{—(1)}$$

Applying KCL to node (V_2)

$$\frac{V_2-V_1}{10}=4$$

$$-V_1+V_2=40 \quad \text{—(2)}$$

from (2)

$$V_2=40+V_1 \quad \text{—(3)}$$

sub (3) in (1)

$$4V_1-40-V_1=40$$

$$3V_1=80$$

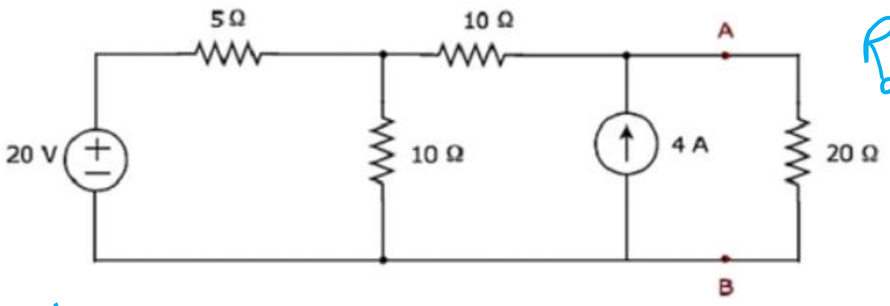
$$V_1=80/3 \text{ V}$$

$$\boxed{\cancel{V_1=16\text{ V}}}$$

$$V_2=40+\frac{80}{3}=\frac{200}{3}$$

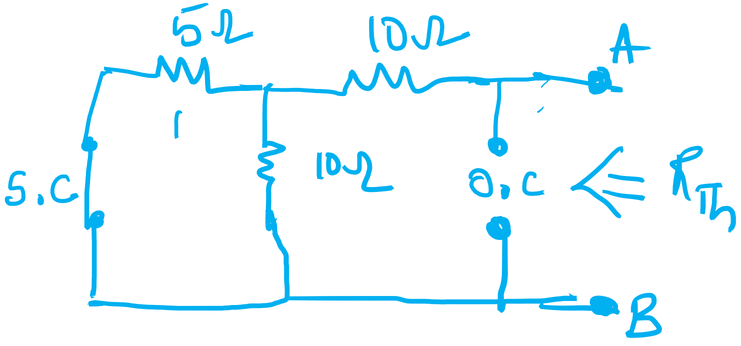
Thevenin's Transfer Theorem

Find the current flowing through 20 Ω resistor by first finding a **Thevenin's equivalent circuit** to the left of terminals A and B.



To Find R_{Th}

* O.C any current Sources
* S.C any Voltage Sources
* Find R_{Th} as look back Resistance



$$R_{ab} = R_{Th} = 10\Omega + 5\Omega \| 10\Omega$$

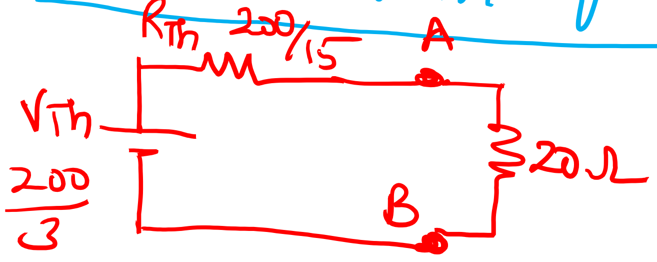
$$= 10 + \frac{5\times10}{5+10}$$

$$= 10 + \frac{50}{15}$$

$$= \frac{150+50}{15}$$

$$= \frac{200}{15}\,\Omega$$

* To Draw thevenin equ. cct



current through 20Ω resistor,

$$I_{20\Omega} = \frac{V_{Th}}{R_{Th}+R_L}$$

$$= \frac{200/3}{\frac{200}{15}+20}$$

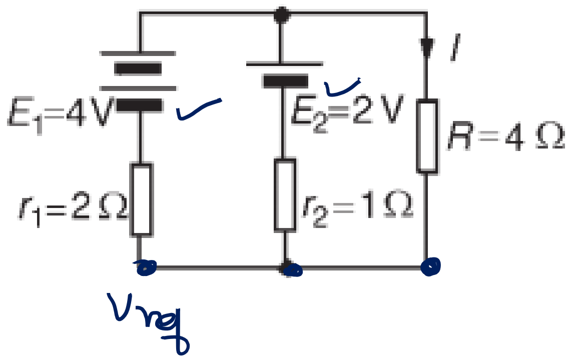
$$= \frac{200/3}{\frac{200+300}{15}}$$

$$= \frac{200}{\cancel{3}} \times \frac{\cancel{15}\ 5}{500}$$

$$\boxed{I_{20\Omega} = 2A}$$

Thevenin's Transfer Theorem

Find the current flowing in the 4ohm resistor : ANS: 0.571A



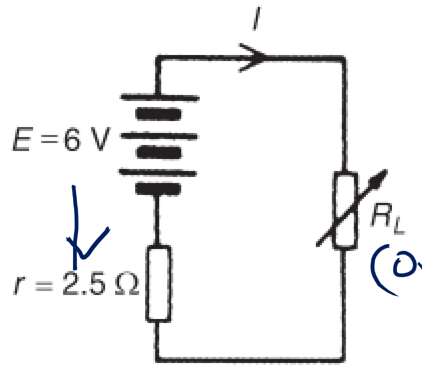
Maximum Power Transfer Theorem

'The power transferred from a supply source to a load is at its maximum when the resistance of the load is equal to the internal resistance of the source.'

3.5mm

M.P B.T.S

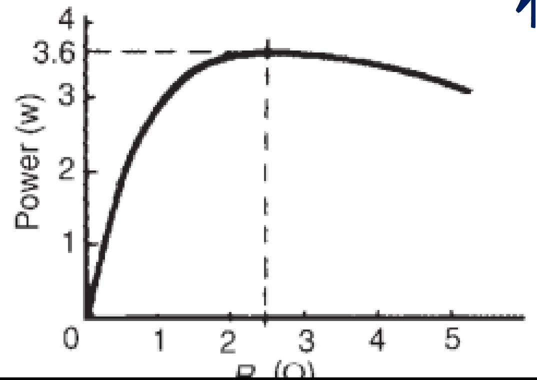
3Ω 3Ω



(0Ω to 5Ω)

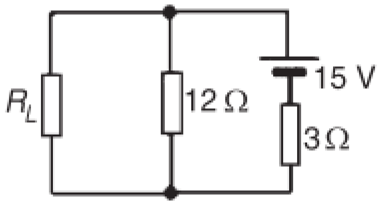
$R_L(\Omega)$	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
$I = \dfrac{E}{r+R_L}$	2.4	2.0	1.714	1.5	1.333	1.2	1.091	1.0	0.923	0.857	0.8
$P = I^2R_L(W)$	0	2.00	2.94	3.38	3.56	3.60	3.57	3.50	3.41	3.31	3.20

$I = \dfrac{6}{2.5 + R_L}$



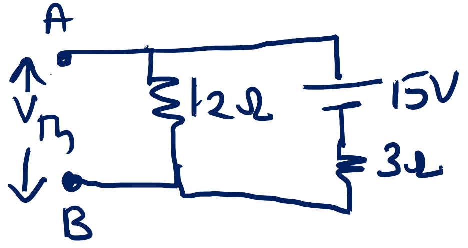
Maximum Power Transfer Theorem

Find the value of R_L such that maximum power is transferred to it using thevenin theorem. **ANS: R_L=2.4 ohm**



Solution

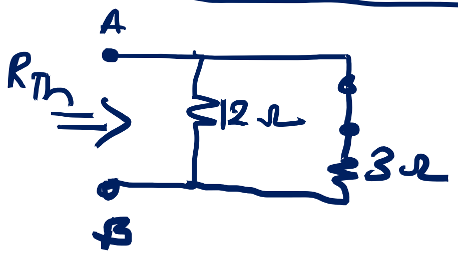
To Find the thevenin ~~theorem~~ Voltage(V_{Th})



By Voltage division Rule

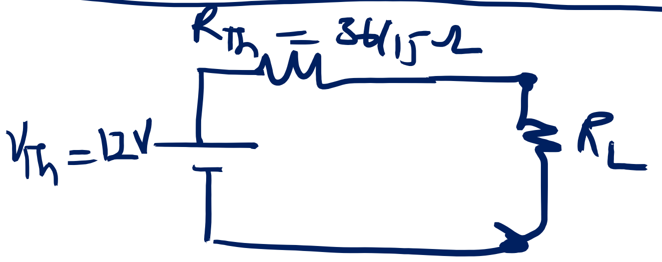
$$V_{12\Omega} = V_{Th} = \frac{15\times12}{12+3} = 12V$$

To Find the Thevenin Resistance R_{Th}



$$R_{Th} = \frac{12\times3}{12+3} = \frac{36}{15}$$

To draw the Thevenin Equ. ckt



for max. power

$$R_L = R_{Th} = \frac{36}{15} = 2.4\Omega$$

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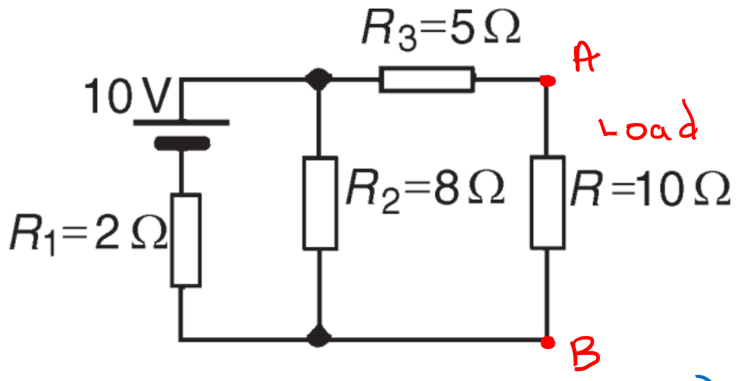
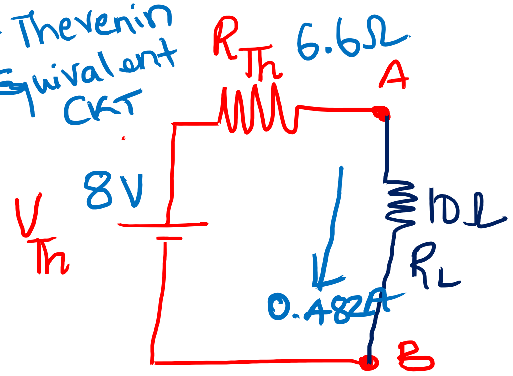
Thevenin's Transfer Theorem

Use Thévenin's theorem to find the current flowing in the 10 Ω resistor for the circuit



③ * Thevenin Equivalent CKT



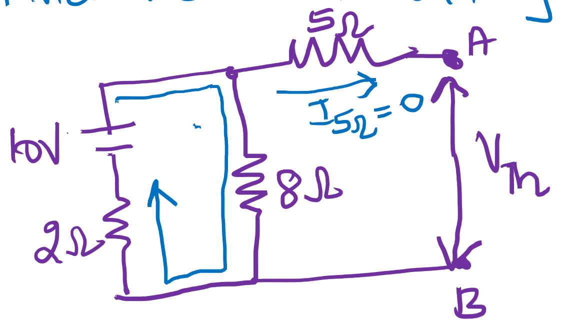
④ Current in 10Ω Load,

$$I_{10\Omega} = \frac{8}{6.6+10} \quad \text{(ohms law)}$$

$$= \frac{8}{16.6} = \underline{0.482 A}$$

①

*Find Thevenin Voltage (V_{Th})

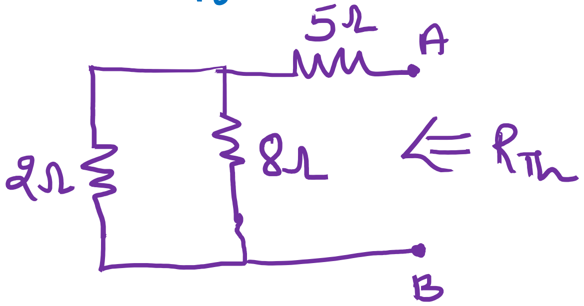


By ohms law, $I_{8\Omega} = \frac{10}{2+8} = 1A$

Now, $V_{Th} = V_{8\Omega} = I_{8\Omega} \times R_{8\Omega} = 8 \times 1$
$= 8V$

* To Find R_{Th}

② → O.C any Current Source
→ S.C any Voltage Source
→ R_{eff} from load end = R_{Th}



So, R_{Th} = 5Ω (Series) 2Ω || 8Ω

$$= 5 + \frac{2\times 8}{2+8} = 5 + \frac{16}{10}$$

$$= 6.6\,\Omega$$

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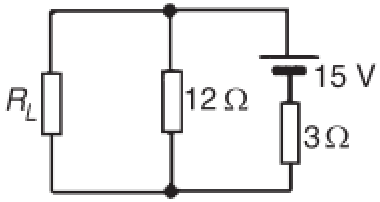
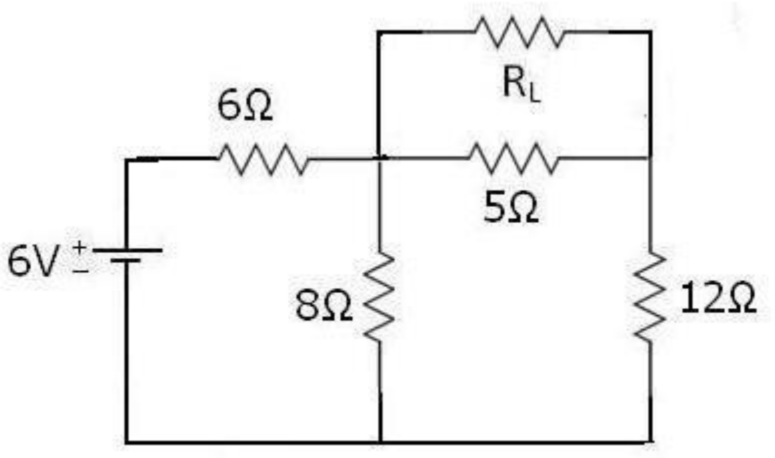
Maximum Power Transfer Theorem

Find the value of R_L such that maximum power is transferred to it using thevenin theorem. **ANS: R_L=2.4 ohm**



Maximum Power Transfer Theorem

Find the value of R_L for the given network below that the power is maximum? And also find the Max Power through load-resistance R_L by using maximum power transfer theorem?



ANS: R_L=3.77 ohm