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Department of EEE
Emitting Elite Energy

BEEE203:Elements of Electrical Egineering
MODULE 1: DC CIRCUITS

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Electrical & Electronics Engineering

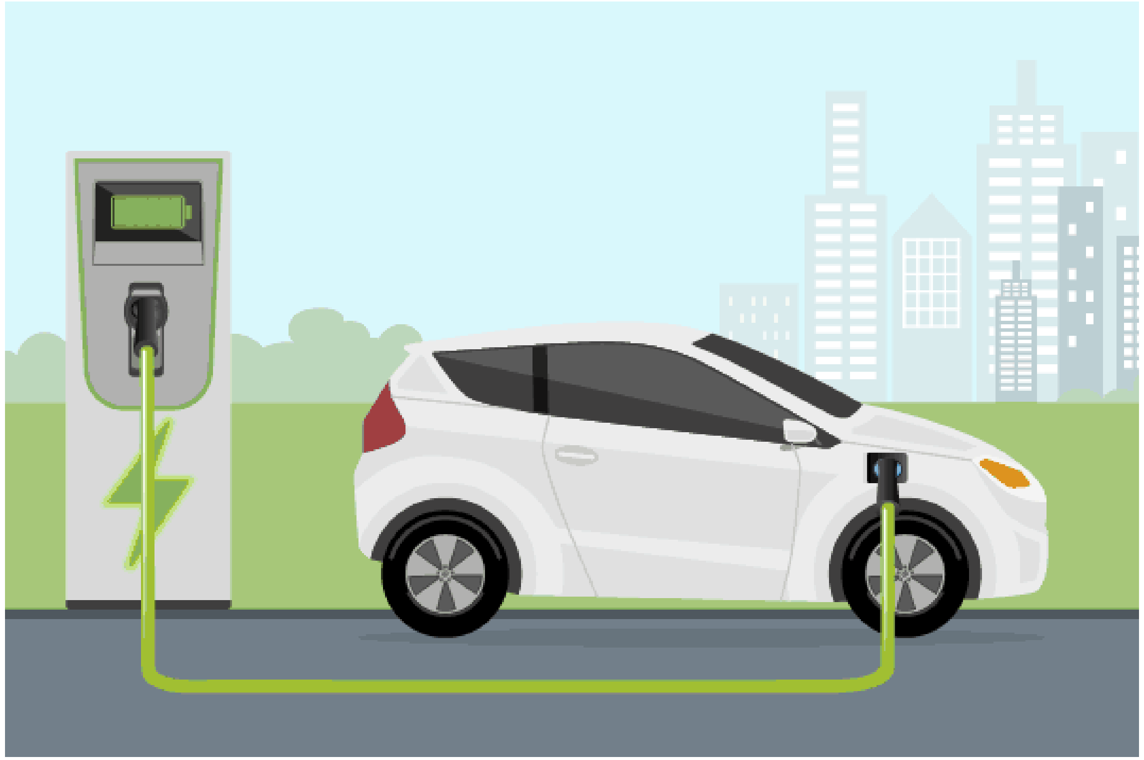
- **Every walk of life is dependant on Electricity.**

Invention of Electric Bulb

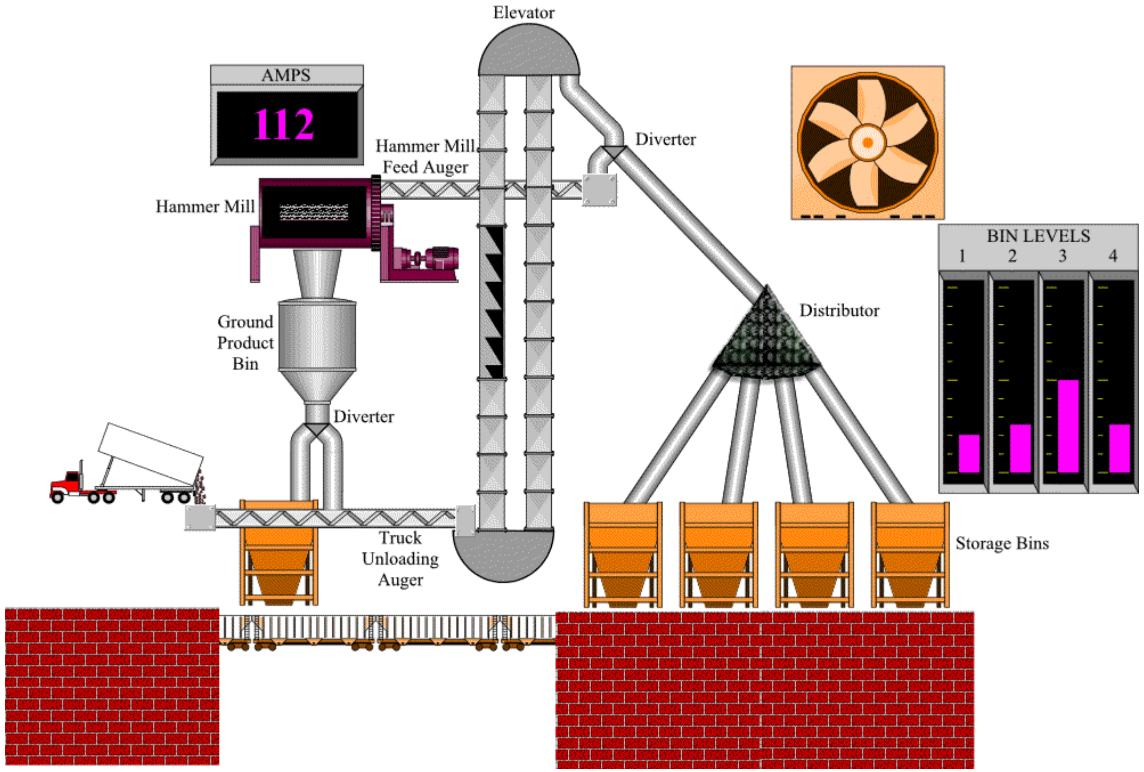
Electronic Gadgets like Smart phone

Agriculture Sector

Transport Sector



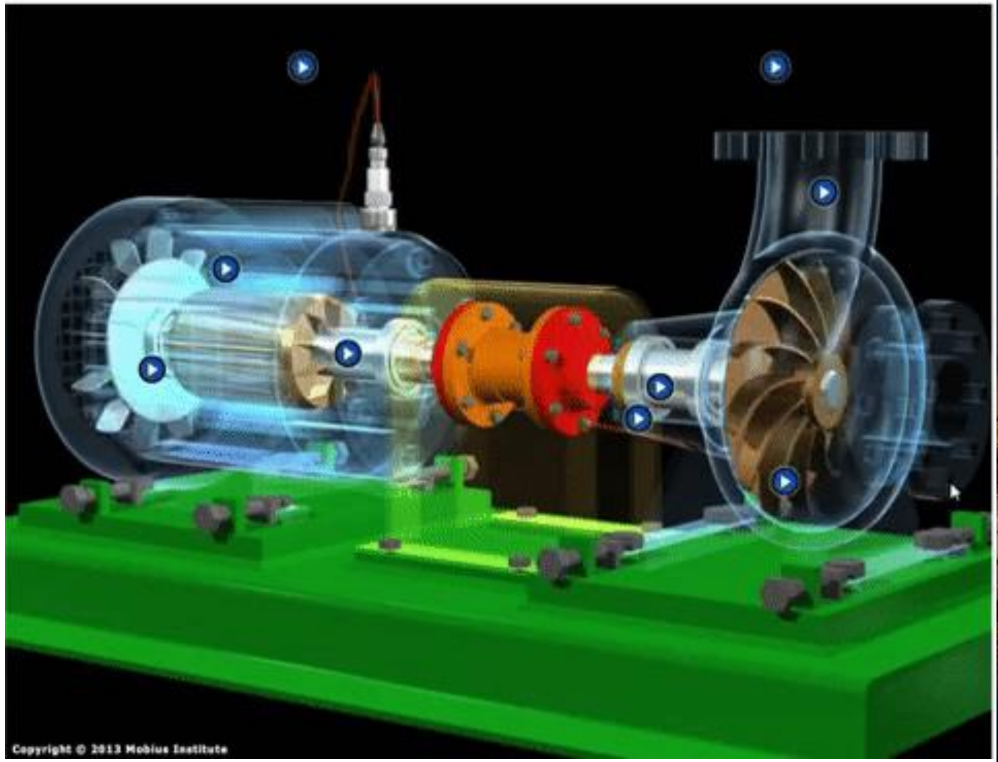
Industry Sector



Electrical & Electronics Engineering

Over the past century, Electrical Industry contributes to the:

- Welfare
- Progress
- Technological advancement



Power Industry

Famous Electrical Engineers

Mr. Narayanamurthy, Founder, Infosys

Mr. Nandan Nilekani, Chairman, UIDAI

Mr. Jeff Bezos, Amazon

Mr.Rowan Attkinson (Mr.Bean), Actor

Mr.Azim Premji, Chairman, Wipro

Mr.Satya Nandella, CEO, Microsoft

COURSE DETAILS
Course Credit Description:

Course Code	Course	Teaching Hours /Week	Exam Duration in Hours	EXT SEE MARKS	I.A CIE MARKS	Total Marks	Credits
18ELE23	Basic Electrical Engineering	4	3	60	40	100	3

Prerequisites:

- Engineering Physic
- Basic Electronics
- Engineering Mathematics-I
- Fundamentals of Electricity

Syllabus

Module -1 :

D C circuits: Ohm’s Law and Kirchhoff’s Laws, analysis of series, parallel and series- parallel circuits excited by independent voltage sources. Power and Energy.

AC fundamentals: Generation of sinusoidal voltage, frequency of generated voltage, definition and numerical values of average value, root mean square value, form factor and peak factor of sinusoidally varying voltage and current, phasor representation of alternating quantities. [L4]

Course Delivery:

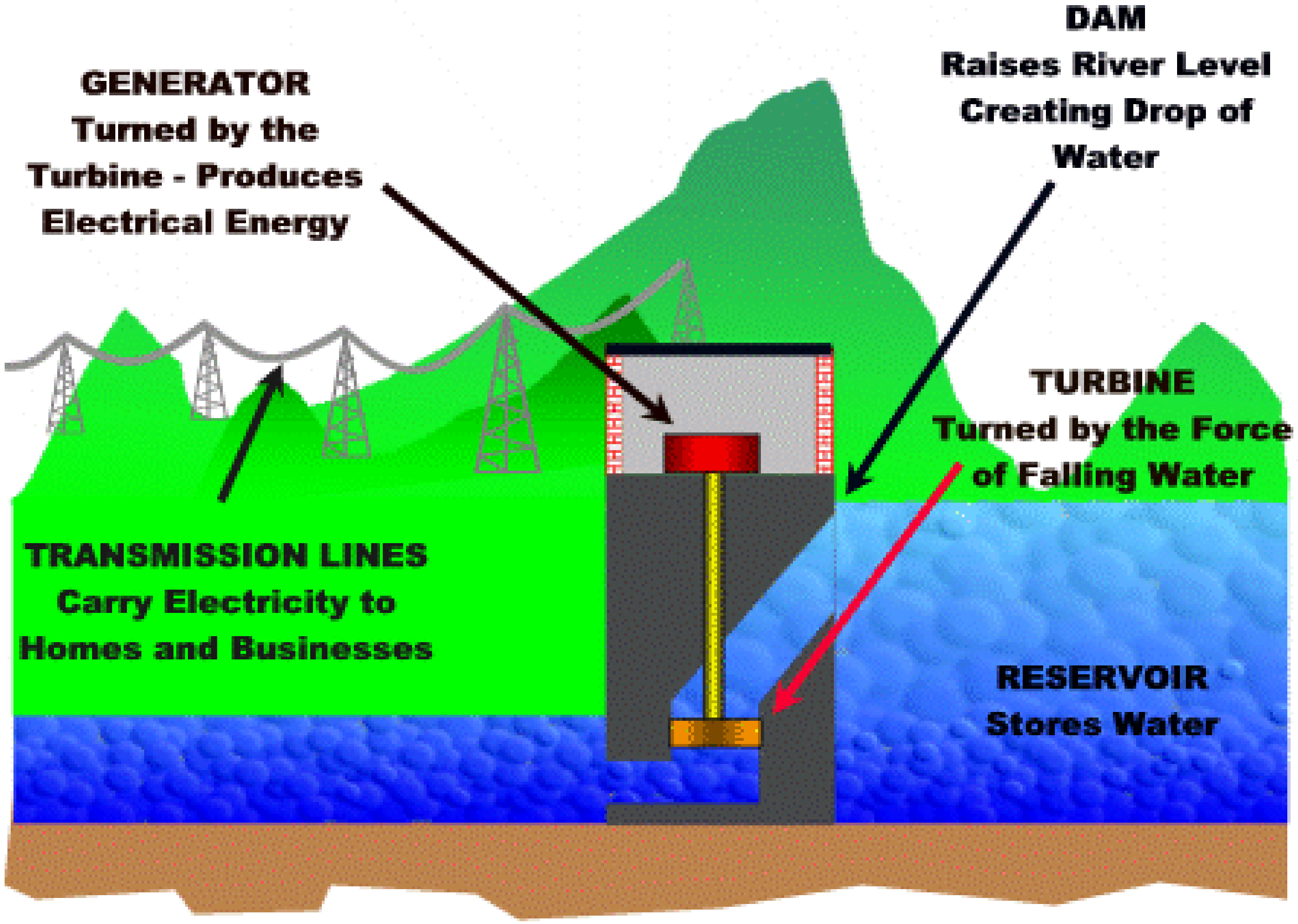
Duration	Week 1 to Week 3
Module 1: **DC CIRCUITS** **AC FUNDAMENTALS**	**1 A) D C circuits**: Ohm's Law and Kirchhoff's Laws, analysis of series, parallel and series-parallel circuits excited by independent voltage sources. Power and Energy. **1 B) AC fundamentals:** Generation of sinusoidal voltage, frequency of generated voltage, definition and numerical values of average value, root mean square value, form factor and peak factor of sinusoidally varying voltage and current, phasor representation of alternating quantities. **(L4)**

COURSE OUTCOME

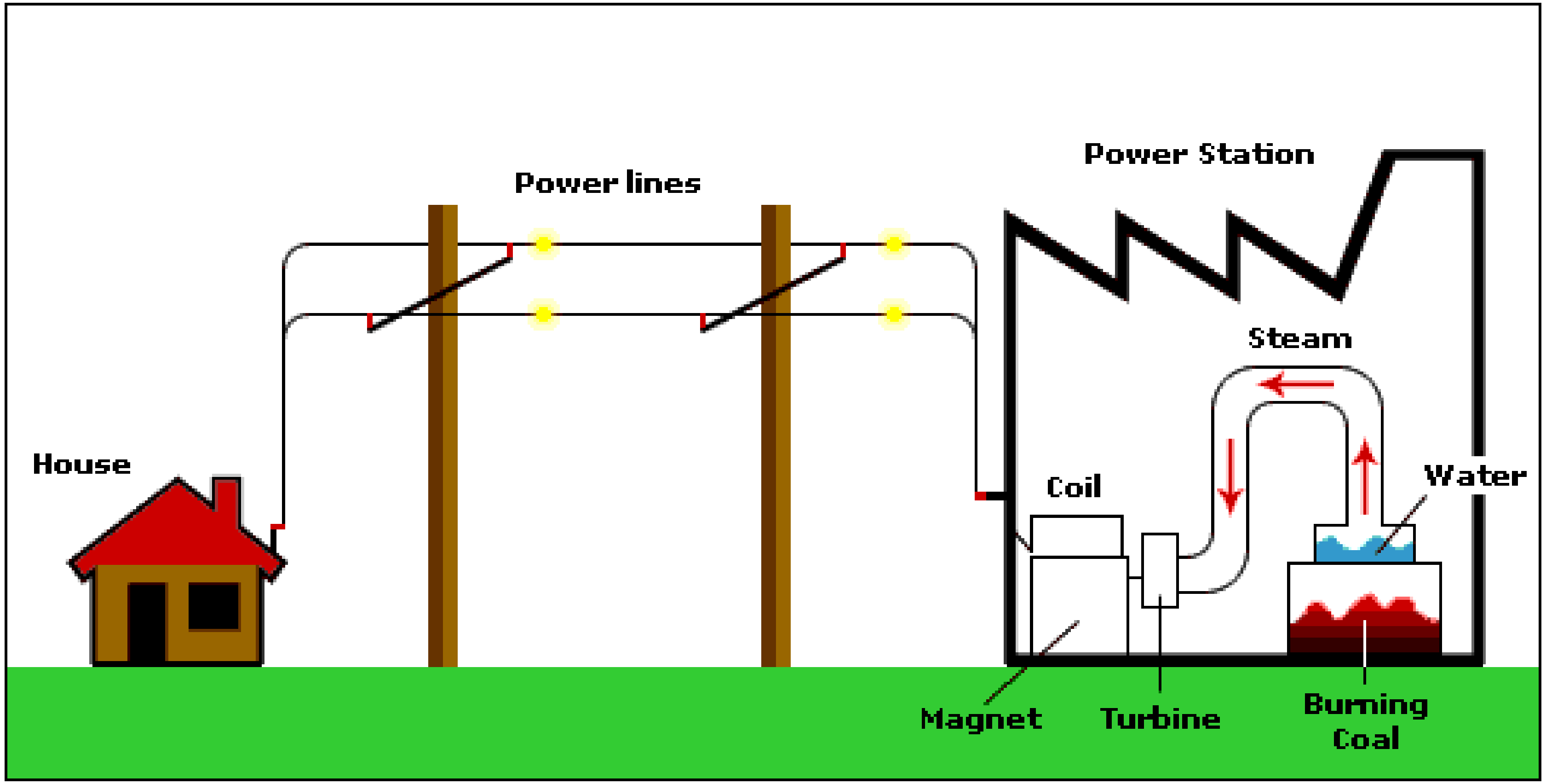
CO-1: Analyze the DC Circuits and to interpret the concepts of AC fundamentals.

1.1 Introduction
Fundamental Electrical Parameters

Hydropower


DAM
Raises River Level
Creating Drop of
Water
GENERATOR
Turned by the
Turbine - Produces
Electrical Energy
TURBINE
Turned by the Force
of Falling Water
TRANSMISSION LINES
Carry Electricity to
Homes and Businesses
RESERVOIR
Stores Water

Electric generator

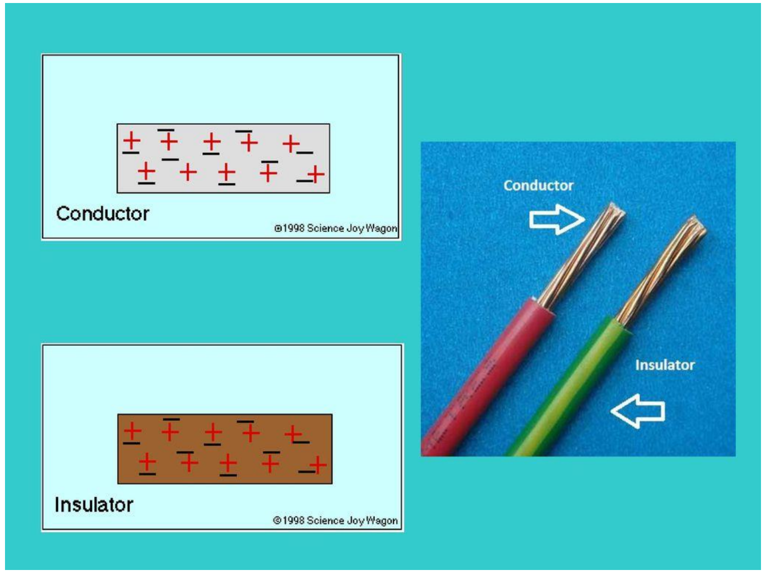


Fundamental Electrical Parameters

POWER **VOLTAGE** **CURRENT** **RESISTANCE**

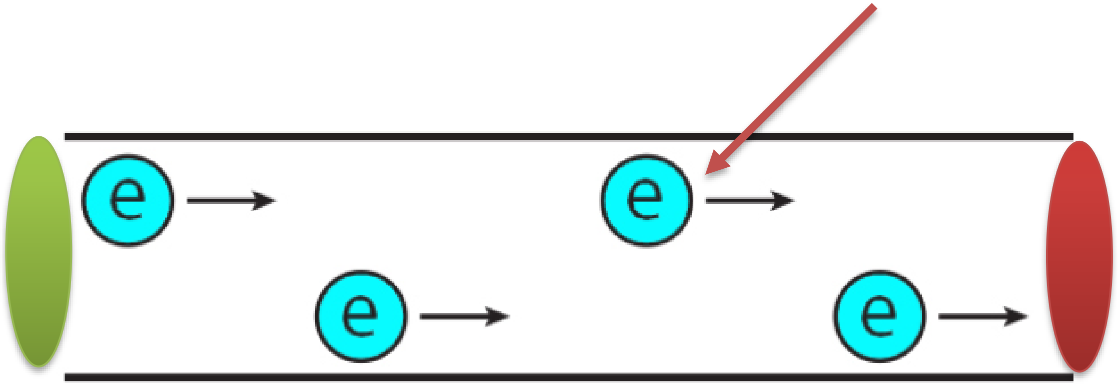
Current- flow of electrons – Amps(A)

Electric current is defined as a stream of charged particles—**<u>such as electrons or ions</u>**—moving through an electrical **conductor or space**



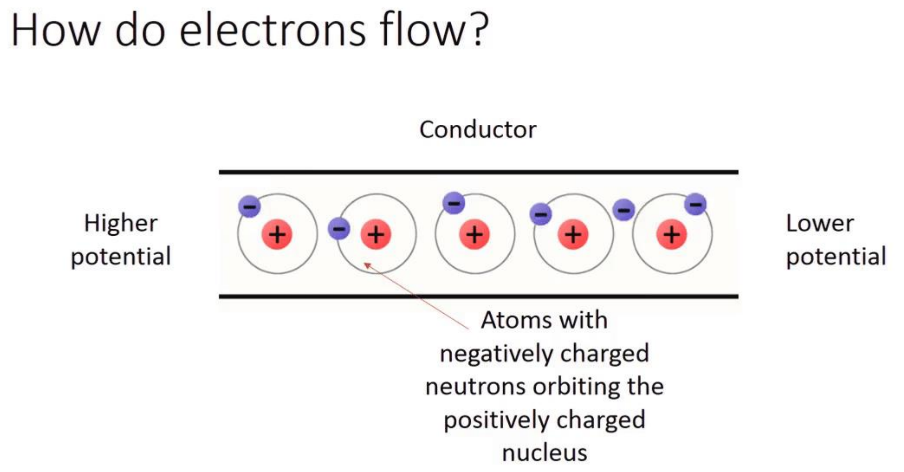
In the conductor

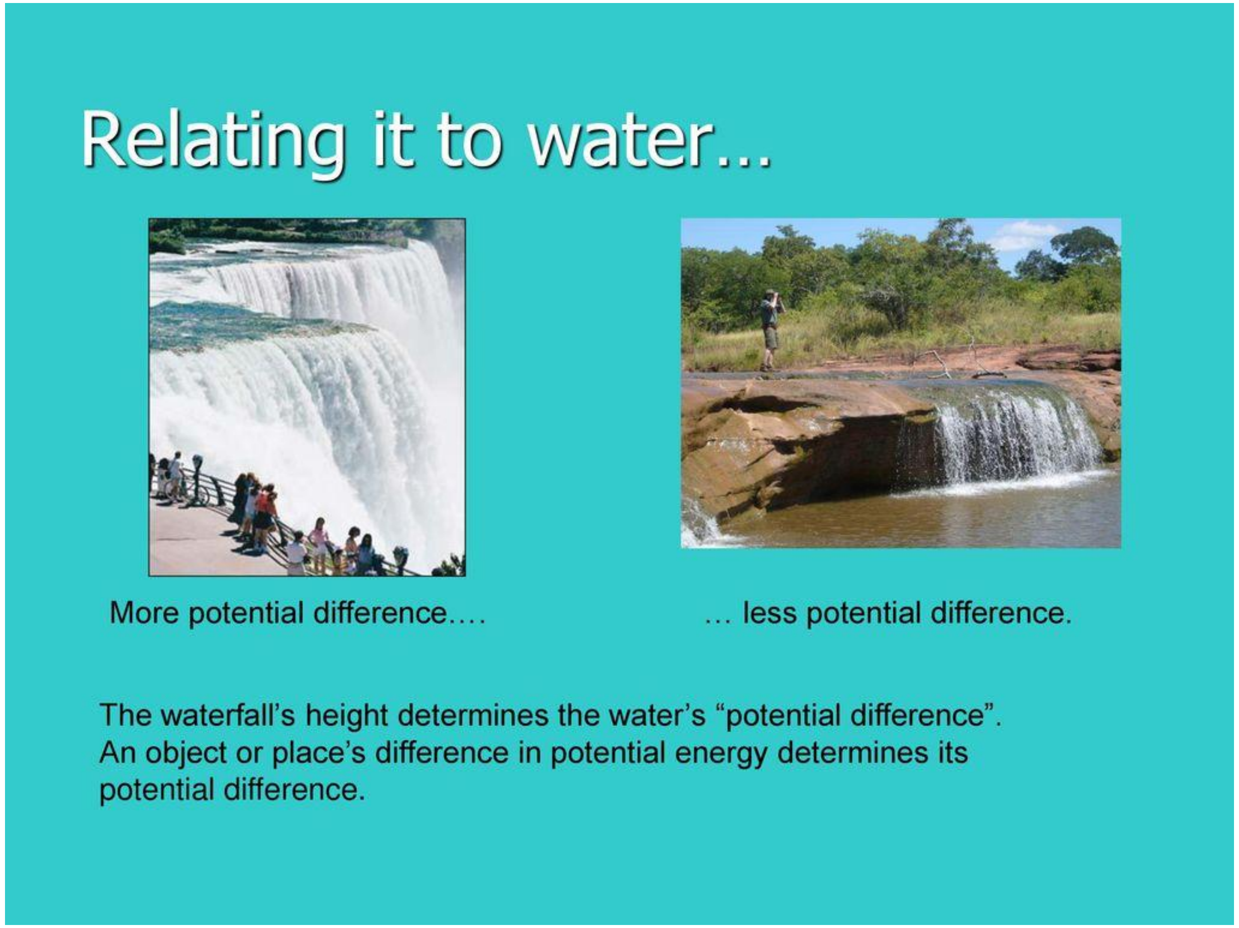
flow of current is due to **electrons**



Current is measured using **Ammeter** and is always connected in **Series**

When an electrical potential difference is applied between **two points** in a conductive medium, an electric current starts flowing from **higher potential** to **lower potential.**





Inference:

If two points in a circuit are at the same potential, then the current cannot flow. **The magnitude of a current depends on voltage or potential difference between two points**. Hence, we can say the current is the **effect of voltage.**

CURRENT TYPES

AC CURRENT

An **alternating current** changes its a direction at a periodic interval.

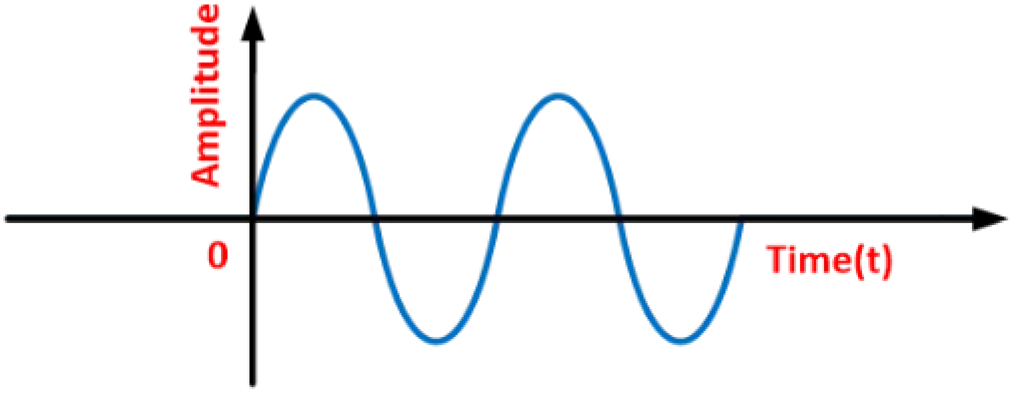
DC CURRENT

The flow of electric charge in only one direction is known as **direct current** (DC)

Current Types

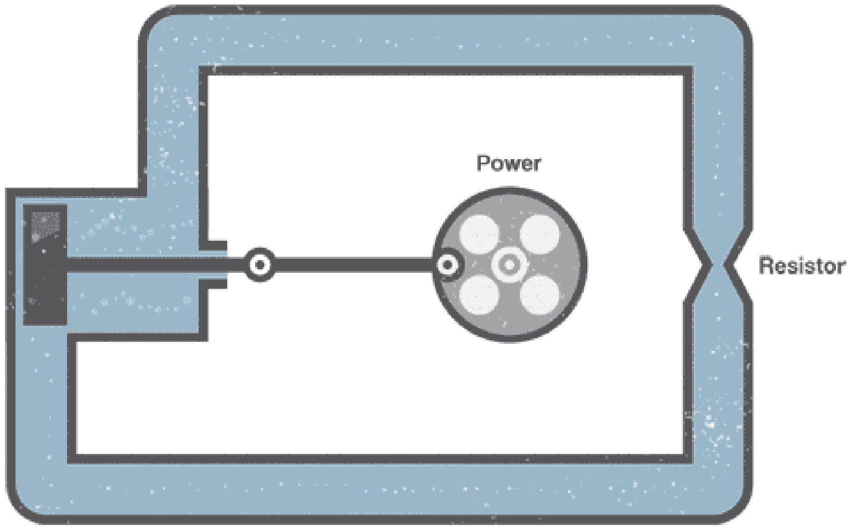
Alternating Current

An **alternator** can generate an alternating current. The alternator is a special type of electrical generator designed to generate alternating current.



Alternating Current (AC)

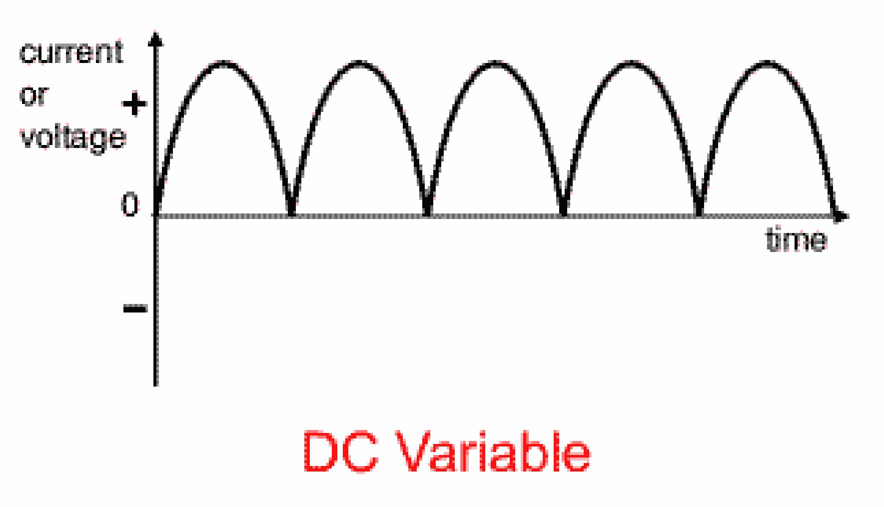
Alternating Current: The Water Analogy

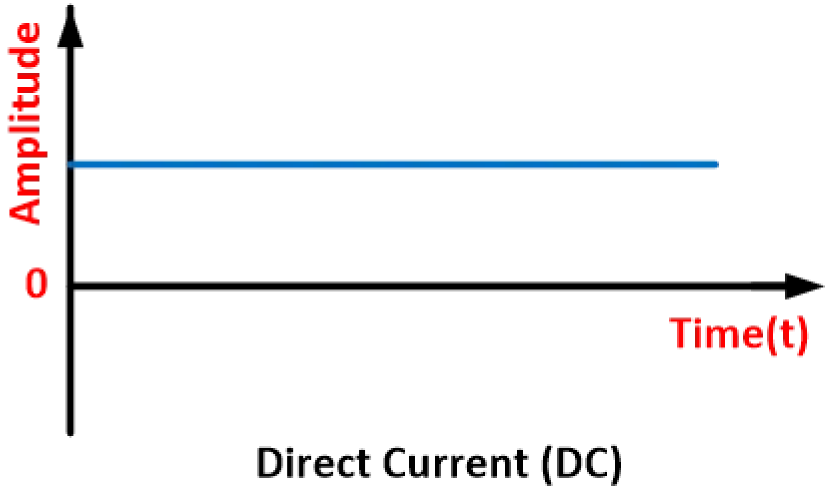


The type of current that keeps on changing directions during its flow. It periodically reverses direction that is why it is termed as alternating current.

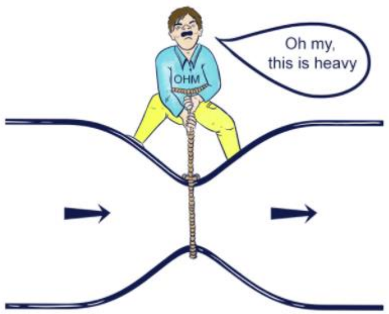
DC CURRENT

As DC flows only in one direction, hence it is also referred to as **<u>unidirectional current</u>**

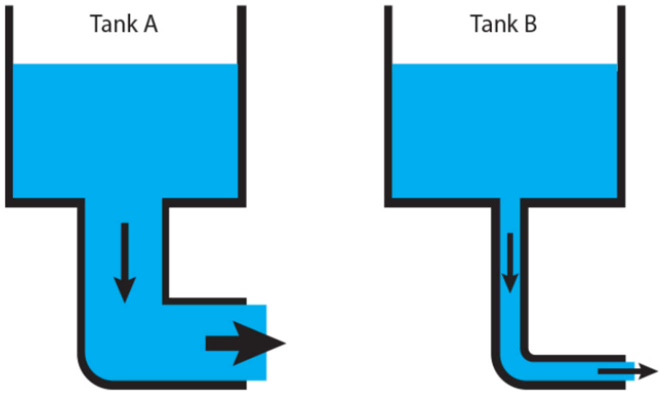


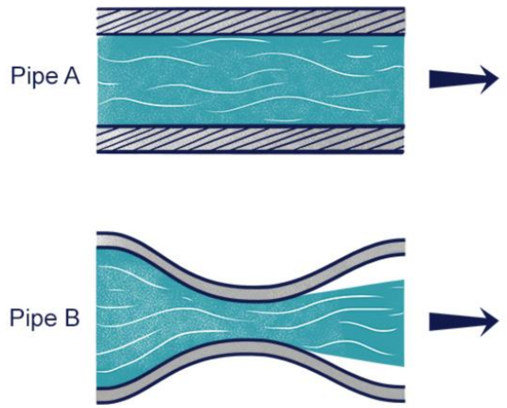


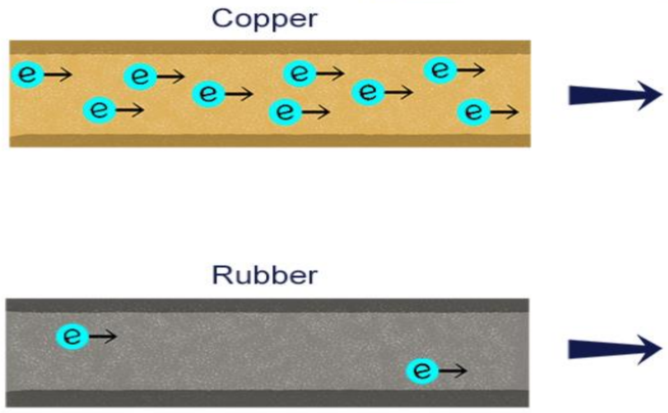
Basic Definition- Resistance



Resistance – opposition offered – measured in Ohm (Ω)







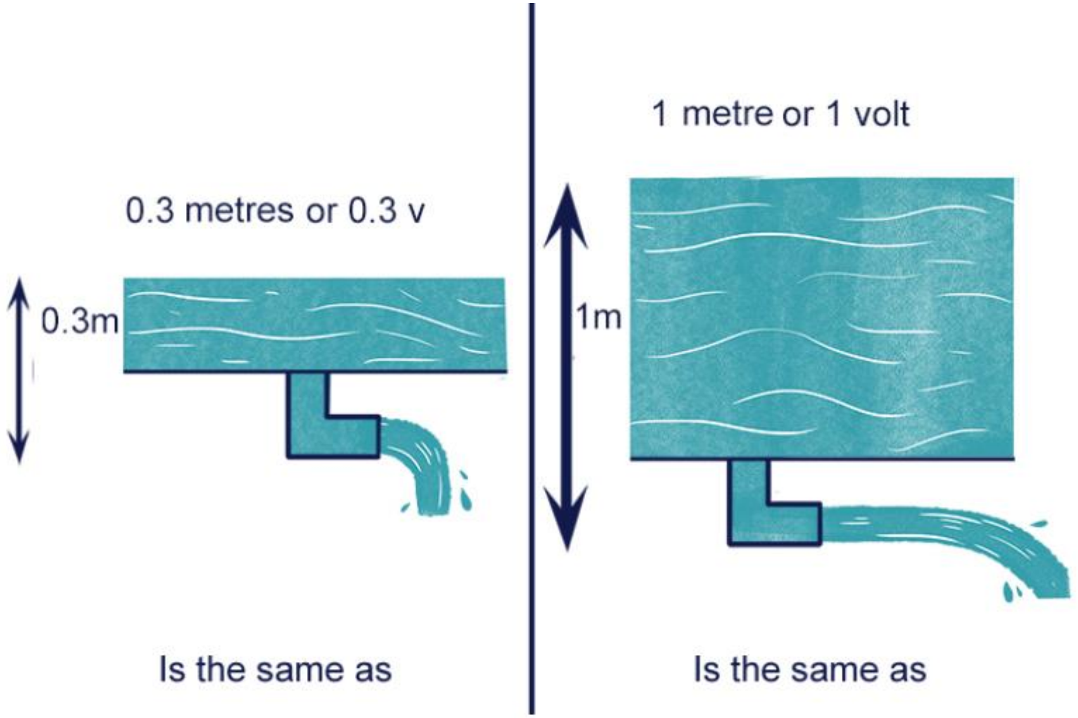
There is less resistance in Tank A and it will empty a lot faster than Tank B.

There is less resistance in Pipe A and therefore flow will be a lot faster through it than Pipe B.

If the material is rubber it has a very high resistance.
If the material is copper it has a very low resistance.

Basic Definition- Voltage

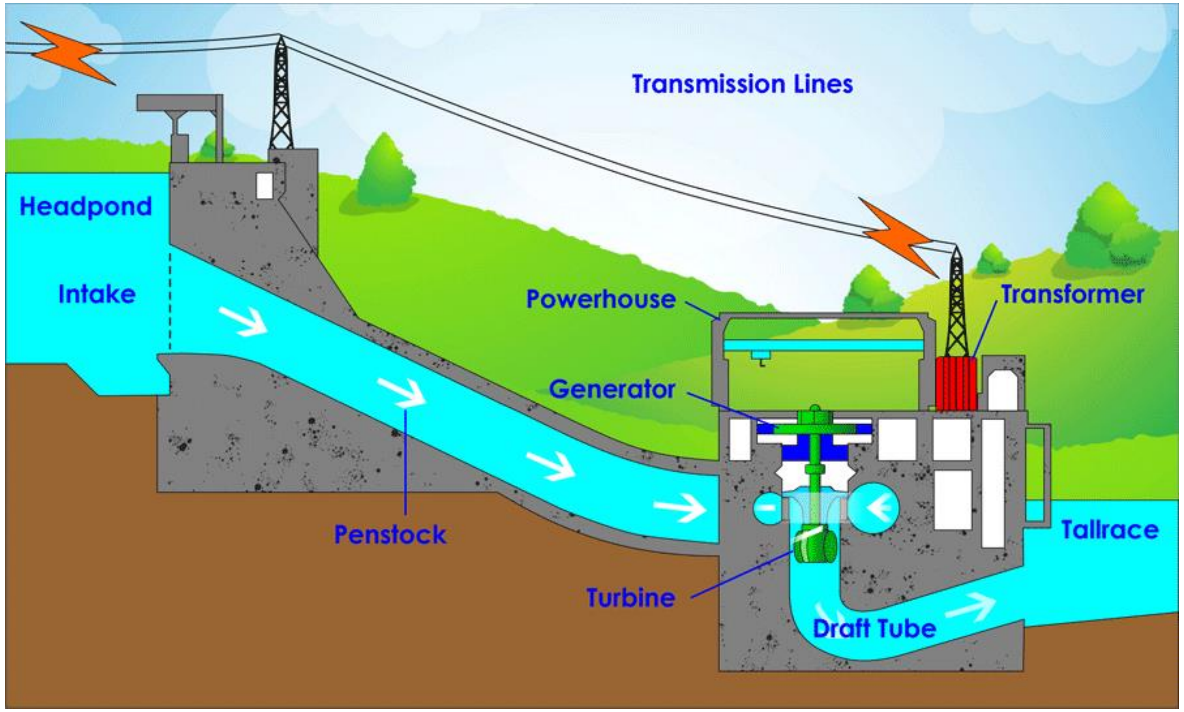
Voltage- potential difference between two points –Volts- V



Voltage is measured using **Voltmeter** and is always connected in **Parallel**

Power

The rate at which energy is converted from the electrical energy of the moving charges to some other form of energy like **mechanical energy, heat, magnetic fields or energy stored in electric fields**, is known as **electric power.**



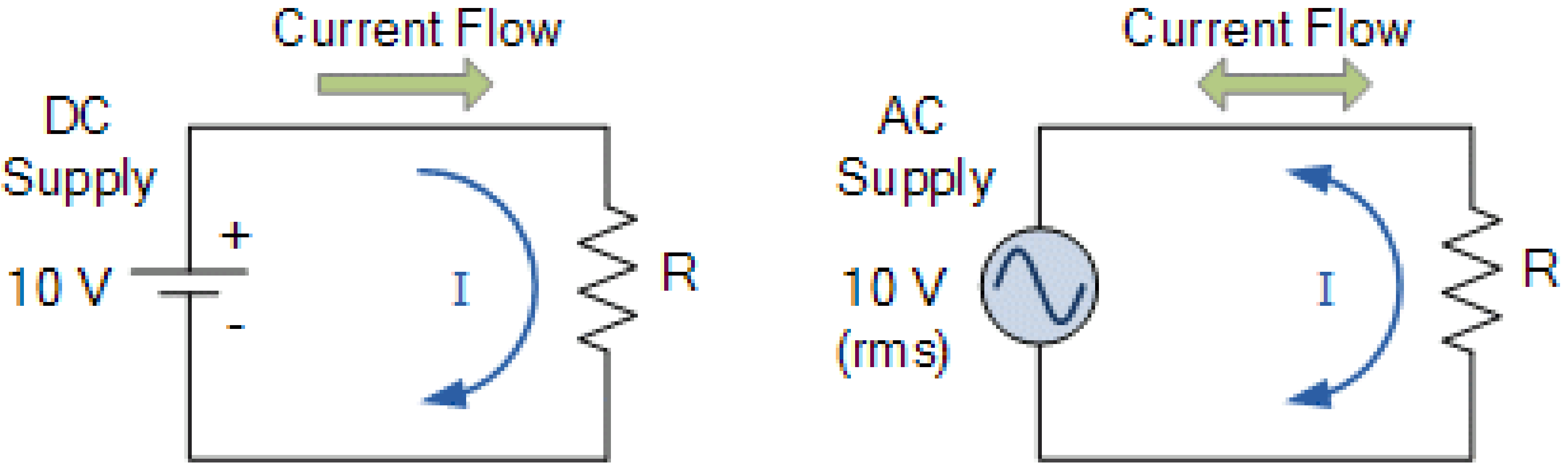
What is an Electrical Circuit?

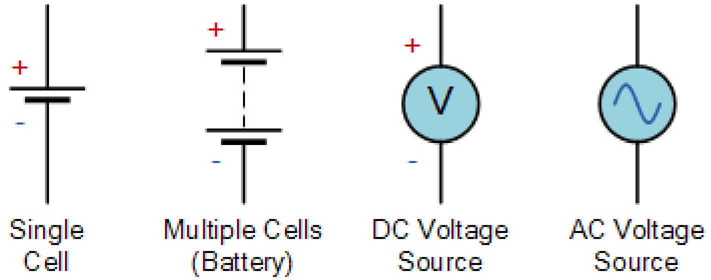
An **electrical circuit** is a combination of two or more electrical components that are interconnected by conducting paths. The electrical components may be active components, or Passive components, or some combination of the two.

Voltage Source
Current Source
Generators

- **Resistors**
- **Inductors**
- **Capacitors**
- **Transformers**

DC Circuit V/S AC Circuit





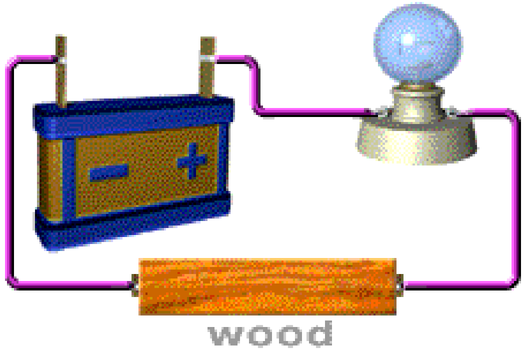
Characteristics	Alternating Current – AC	Direct Current – DC
Definition	The electric current that flows back and forth periodically.	The electric current that flows in only forward direction
Symbol	AC ∿	DC ⎓
Direction of current	It is bidirectional i.e. it can flow in both forward and reverse direction.	It is unidirectional and it flows in only one direction i.e. forward
Voltage and current	The current and voltage varies continuously.	The current and voltage is constant.
Polarity	There is no polarity in AC because it fluctuates.	There is fixed polarity in DC marked by Positive (+) and Negative (-) signs
Swapping Terminals or Polarity	Swapping the source terminal will not affect the circuit	Swapping the source terminal may damage the circuit.
Frequency	The frequency of the alternating current is usually 50 or 60 Hz	The frequency of the direct current is 0.

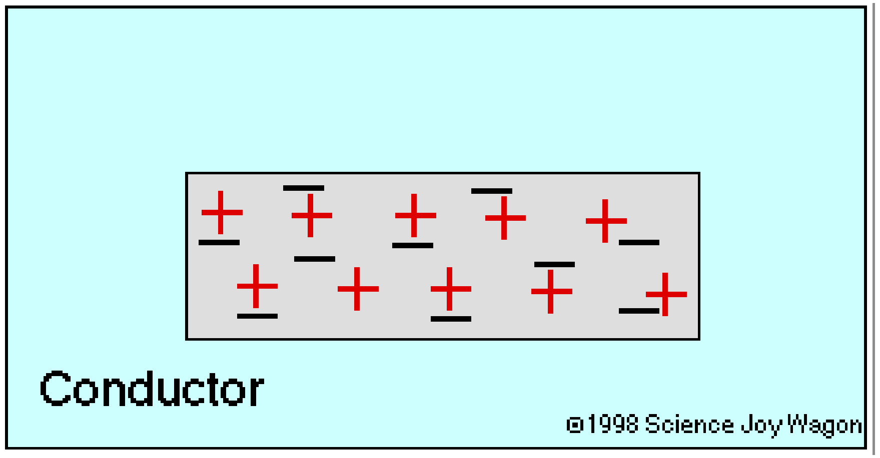
1.2 Ohms Law

What is Ohm’s Law?

Ohm demonstrated that there are no "perfect" **electrical conductors** through a series of experiments in 1825.

Every conductor he tested offered some level of resistance. These experiments led to **Ohm's law**.

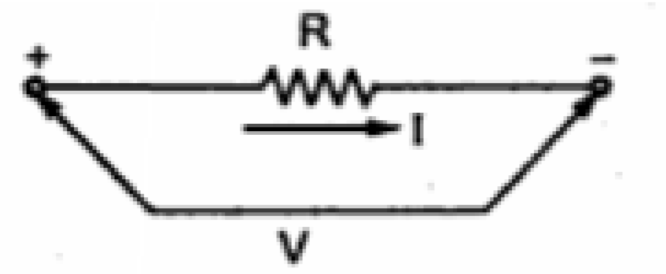




What is Ohm's Law?

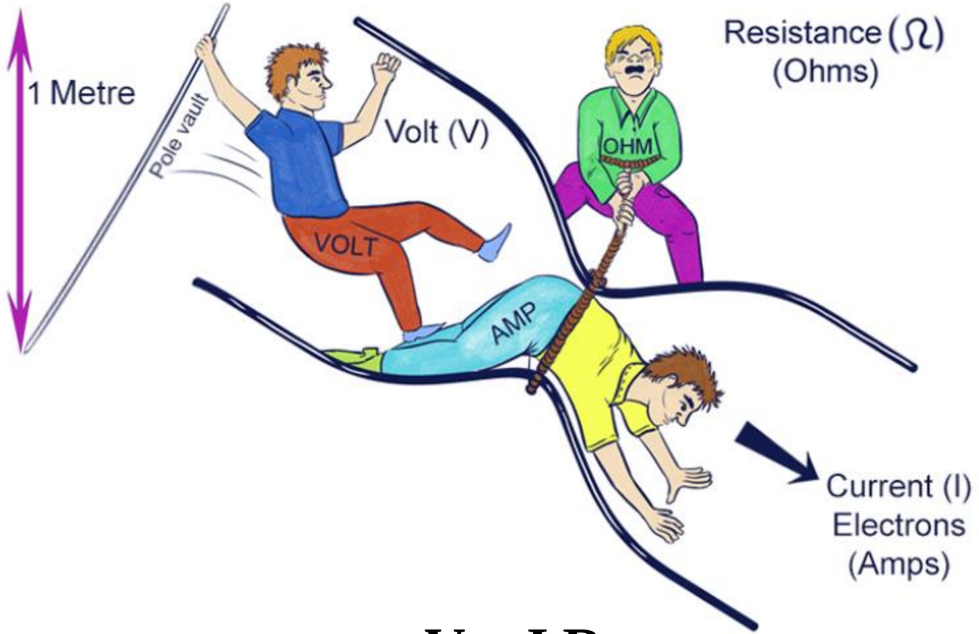
Ohm's law deals with the relationship between

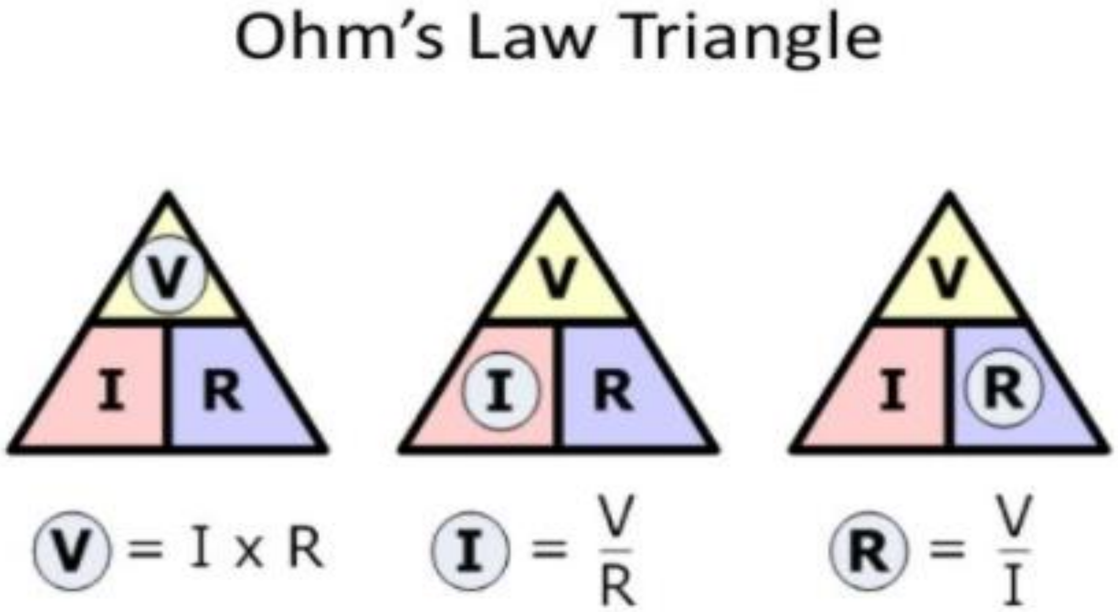
- Current
- Voltage
- Resistance.



Ohm's Law: *The* ***current*** *flowing through the electric circuit is* ***directly proportional*** *to the potential difference across the circuit and* ***inversely proportional*** *to the* ***resistance*** *of the circuit, provided the temperature remains constant.*

Relation between Voltage, Current and Resistance – Ohms Law

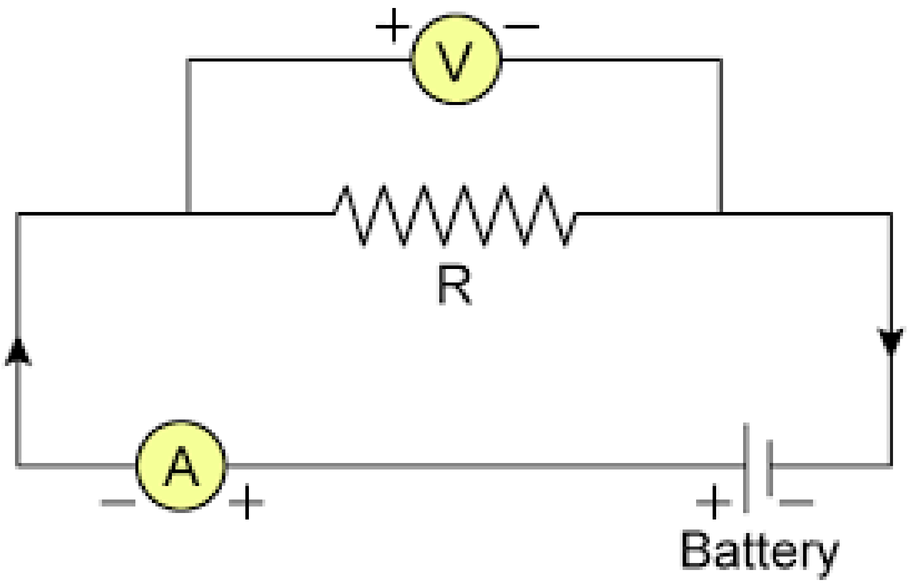




V= I R

Definition: At Constant Temperature , I flowing through the circuit is directly proportional to the potential difference across the ends of the conductor

Where **I is the current** flowing in amperes, the V is the voltage applied and R is the resistance of the conductor, as shown In the Fig.



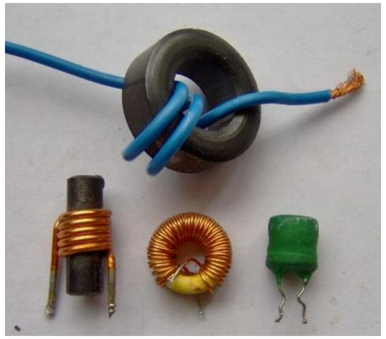
Ohm's Law is, $I = \dfrac{V}{R}$ amperes

$V = I\,R$ volts

$\dfrac{V}{I}$ = constant = R ohms

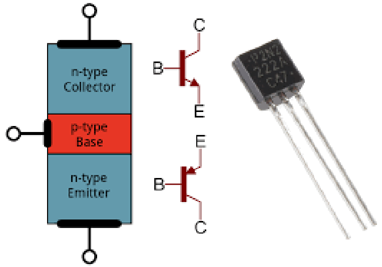
Limitation of Ohms Law

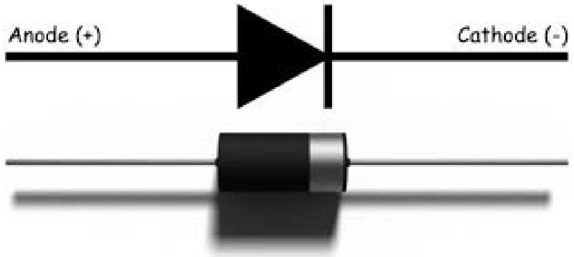
1. Not applicable for non linear devices voltage and current wont be constant with respect to time.
   Eg: Capacitor **Inductor**



2. Not applicable for unilateral electrical elements as they allow current to flow through one direction only. They do not have voltage-current relation for both directions of current.

   Eg : Diode, transistor

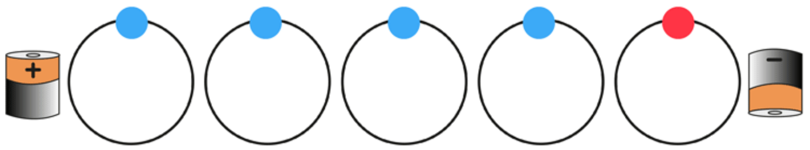


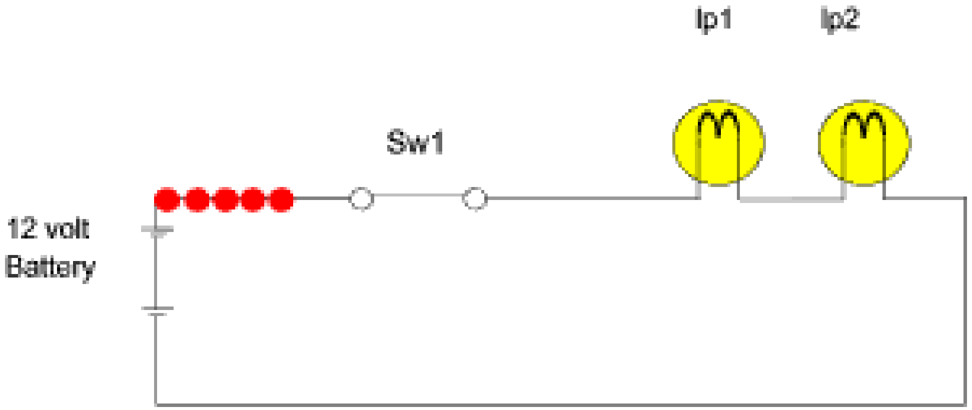


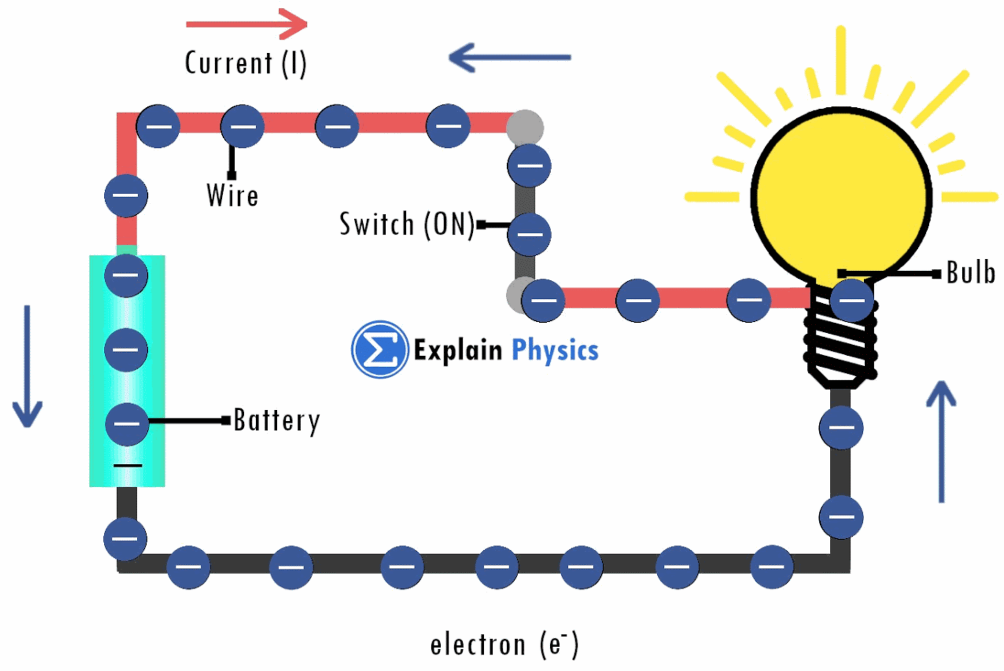
3. Not applicable to temperature dependent devices.

Note : Flow of electrons is from - to +

But we consider conventional electron flow i.e + to -







FAQ

What can Ohm’s Law be used for?

Ohm’s law is used to validate the static values of circuit components such as current levels, voltage supplies, and voltage drops.

Is Ohm’s Law Universal?

No. Ohm’s law is not a universal law. This is because ohm’s law is only applicable to ohmic conductors such as iron and copper but is not applicable to non-ohmic conductors such as semiconductors.

Why is Ohm’s law not applicable to semiconductors?

Ohm’s law doesn’t apply to semiconducting devices because they are nonlinear devices. This means that the ratio of voltage to current doesn’t remain constant for variations in voltage.

When does Ohm’s law fail?

Ohm’s law fails to explain the behaviour of semiconductors and unilateral devices such as diodes. Ohm’s law may not give the desired results if the physical conditions such as temperature or pressure are not kept constant.

Ohm's Law Solved Problems

Example 1: If the resistance of an electric iron is 50 Ω and a current of 3.2 A flows through the resistance. Find the voltage between two points.

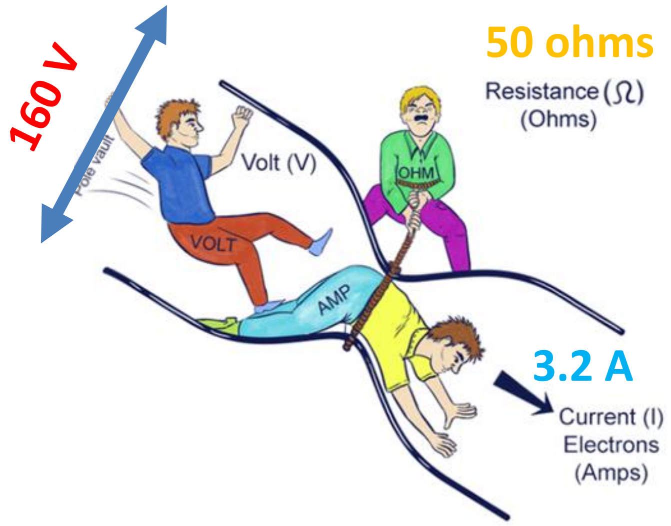
Solution:

Therefore, we use the following formula to calculate the value of V:

V = I × R

Substituting the values in the equation, we get

V = 3.2 A × 50 = **<u>160 V</u>**



Ohm’s Law Solved Problems

Example 2: An EMF source of 8.0 V is connected to a purely resistive electrical appliance (a light bulb). An electric current of 2.0 A flows through it. Consider the conducting wires to be resistance-free. Calculate the resistance offered by the electrical appliance.

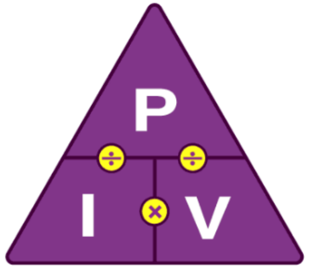
Solution:

$R = V \div I$

$R = 8\ V \div 2\ A = \underline{\mathbf{4\ \Omega}}$

Calculating Electrical Power Using Ohm's Law

The unit of power is the **watt**. The electrical power can be calculated using the Ohm's law and by substituting the values of voltage, current and resistance.



Formula to find power

When the values for voltage and current are given,

$$P = VI$$

When the values for voltage and resistance are given,

$$P = V^2 \div R$$

When the values for current and resistance are given,

$$P = I^2 R$$

When the values of current and voltage are given, the formula for finding power is,

$$P = VI$$

When the values of power and voltage is given, the formula for finding current is,

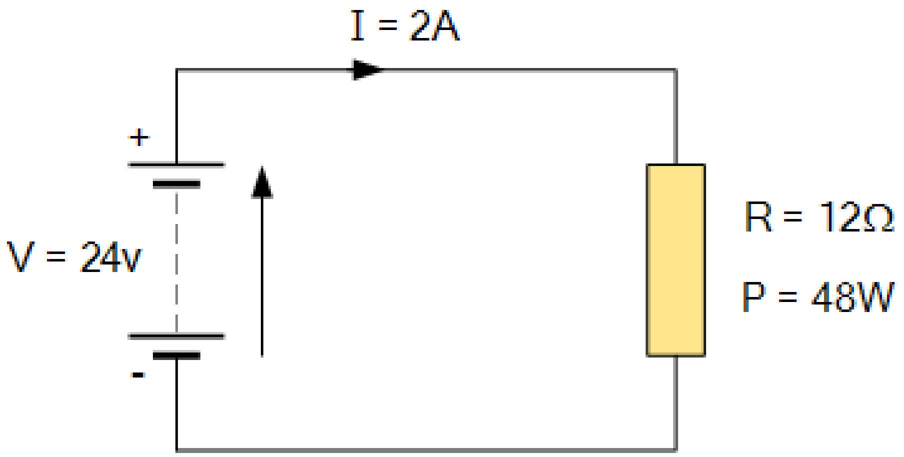
$$I = P/V$$

When the values of power and current is given, the formula for finding voltage is,

$$V = P/I$$

Ohms Law Example No3

For the circuit shown below find the Voltage (V), the Current (I), the Resistance (R) and the Power (P).



Solution:

Voltage [V = I x R] = 2 x 12Ω = 24V

Current [I = V ÷ R] = 24 ÷ 12Ω = 2A

Resistance [R = V ÷ I] = 24 ÷ 2 = 12 Ω

Power [P = V x I] = 24 x 2 = 48W

$P=I^2*R=48W$

$P=V^2/R=48W$

Ohm's Law Matrix Table

Known values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	....	....	$V = I \times R$	$P = I^2 \times R$
Voltage & Current	$R = \frac{V}{I}$	....	....	$P = V \times I$
Power & Current	$R = \frac{P}{I^2}$	....	$V = \frac{P}{I}$	....
Voltage & Resistance	....	$I = \frac{V}{R}$	....	$P = \frac{V^2}{R}$
Power & Resistance	....	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{Z \times R}$	....
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	....	....

ASSIGNMENT

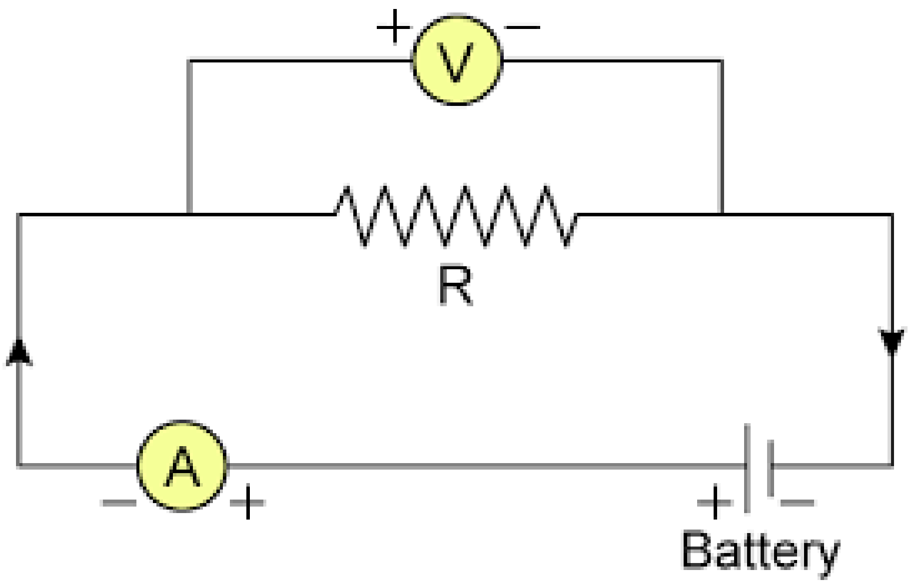
With relevant expressions and diagram, Expalin Ohms Law. What are the limitations of Ohms law.

Solution: Write the following details

1. Definition
2. Circuit and Equations
3. Ohm Law Triangle
4. Limitations

ASSIGNMENT

Ohms law circuit diagram



1. A voltage of 6V is applied to a resistance of 30Ω. Find current ?

2. A voltage of 60V is applied and a current of 6A is flowing in the circuit Find Resistance?

3. Find the voltage when a 12A of current is flowing through the circuit having 12 Ω resistance

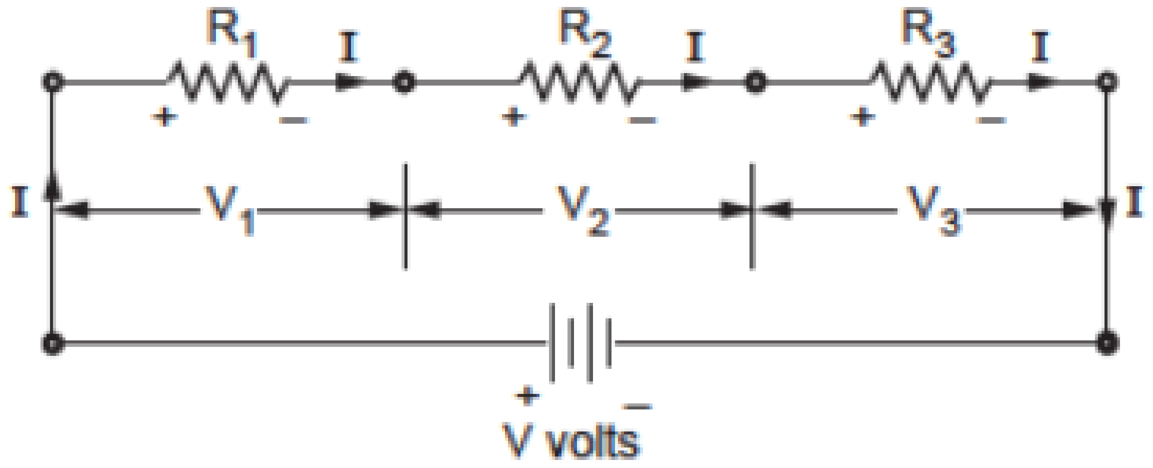
Electrical Parameter	Measuring Unit	Symbol	Description
Voltage	Volt	V or E	Unit of Electrical Potential $V = I \times R$
Current	Ampere	I or i	Unit of Electrical Current $I = V \div R$
Resistance	Ohm	R or Ω	Unit of DC Resistance $R = V \div I$
Conductance	Siemen	G or ℧	Reciprocal of Resistance $G = 1 \div R$
Capacitance	Farad	C	Unit of Capacitance $C = Q \div V$
Charge	Coulomb	Q	Unit of Electrical Charge $Q = C \times V$

Units

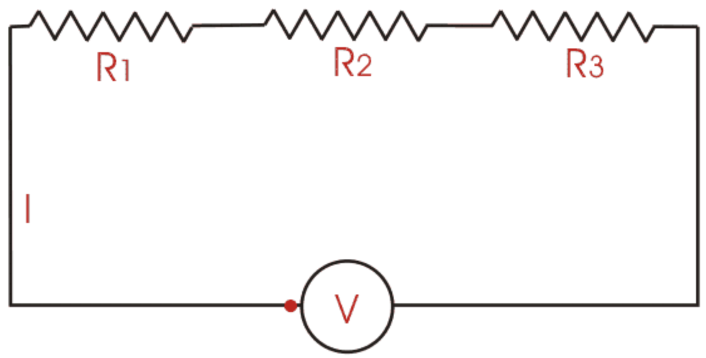
Electrical Parameter	Measuring Unit	Symbol	Description
Inductance	Henry	L or H	Unit of Inductance $V_L = -L(di/dt)$
Power	Watts	W	Unit of Power $P = V \times I$ or $I^2 \times R$
Impedance	Ohm	Z	Unit of AC Resistance $Z^2 = R^2 + X^2$
Frequency	Hertz	Hz	Unit of Frequency $f = 1 \div T$

1.3 Analysis of Series circuit excited by independent voltage sources

Resistance Connected in Series



- One end of the resistance is connected to other end
- Cascade connection
- End to end connection

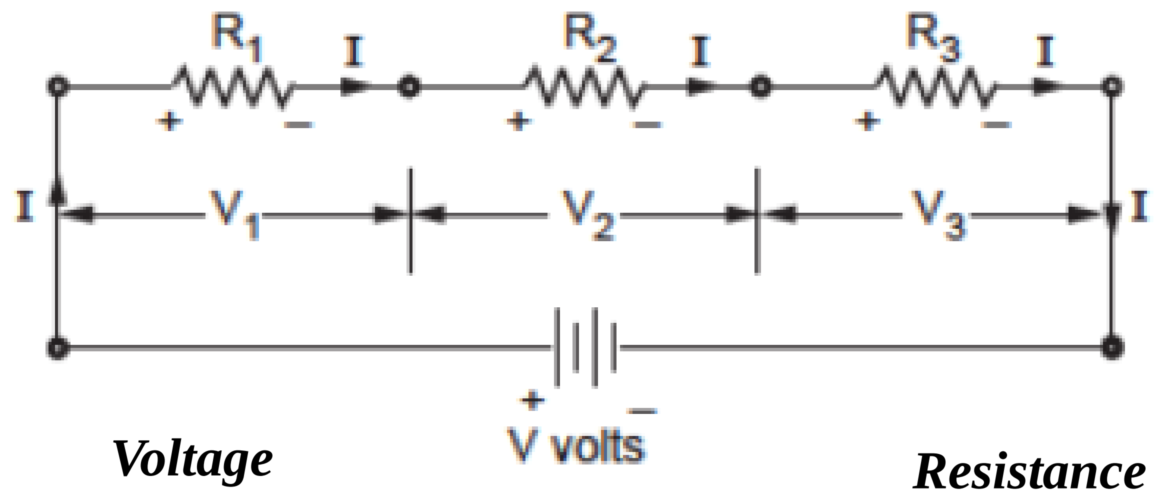


Resistance Connected in Series

Step 1:*Consider a DC Circuit where* ***current I*** *will pass through the resistance* ***R_1, R_2 and R_3.***

Step 2:*Applying Ohm's law, it can be found that voltage drops across the resistances will be* ***$V_1 = IR_1$****,* ***$V_2 = IR_2$*** *and* ***$V_3 = IR_3$.***

Step 3:*Now, if total voltage applied across the combination of* ***resistances in series****, is V.*



Voltage

V_1, V_2 and V_3

Resistance

R_1, R_2 and R_3

$V = V_1 + V_2 + V_3$ → 1

$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = I R_3$

Step 4:Substituting in Eq. 1

$$V = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3)$$

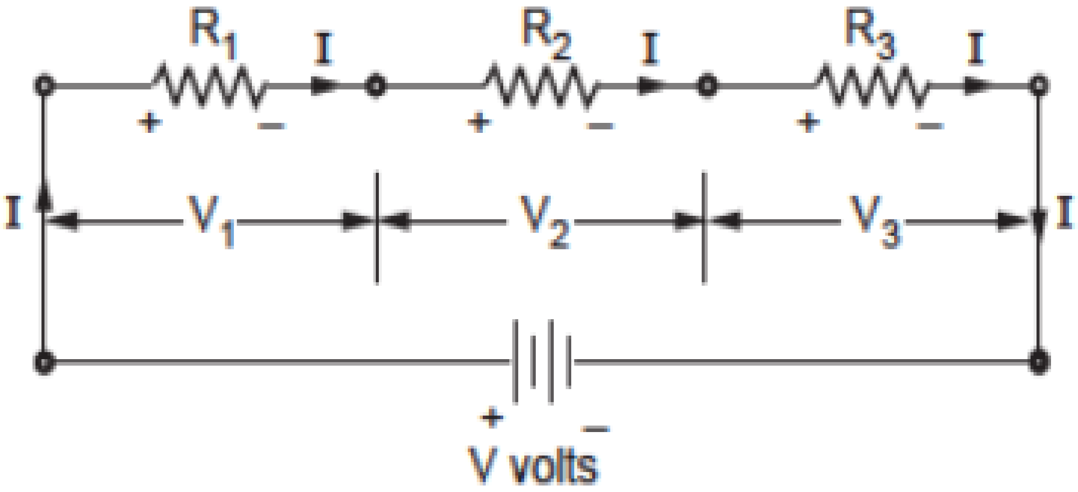
$$V = I\,R_{eq}$$

$$\boxed{R_{equivalent} = R_1 + R_2 + R_3 + \ldots}$$

Resistance Connected in Series

Inference:

1. When a number of electrical components are connected in series, the same current flows through all the components of the circuit.
2. The applied voltage across a series circuit is equal to the sum total of voltage drops across each component.
3. The voltage drop across individual components is directly proportional to its resistance value



Example on Series Circuits

1. Three Resistance of 3kΩ, 10kΩ, 5kΩ are connected in series , if the voltage of 9V is applied to the circuit find the current in the circuit

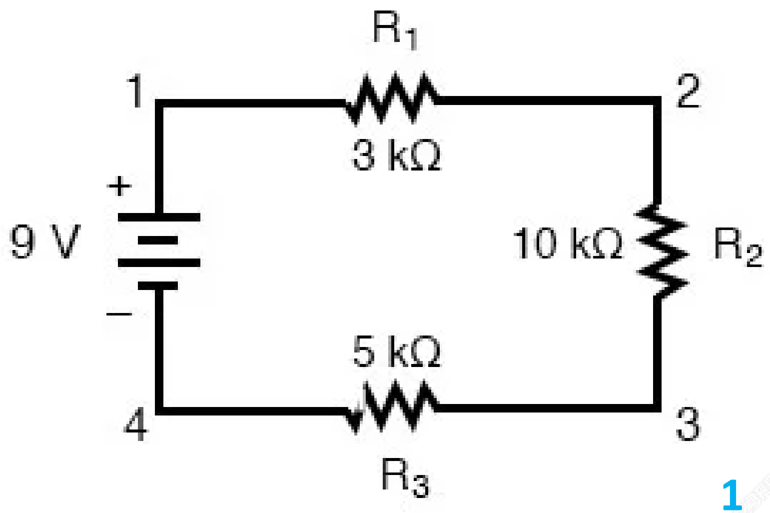
Solution:

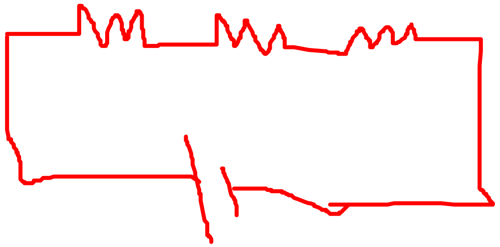
$$R_{equivalent} = R_1 + R_2 + R_3 + \ldots$$

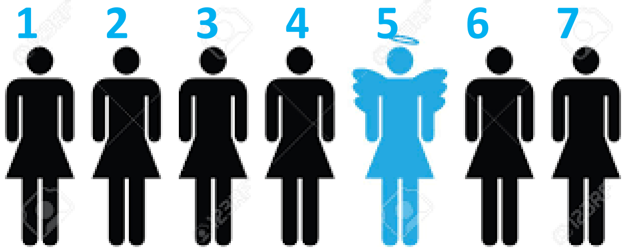
$$= \mathbf{18K\Omega}$$

$$V = I\,R_{eq}$$

I = 9/ 18K = **<u>0.0005A</u>**







1.4 Analysis of Parallel circuit excited by independent voltage sources

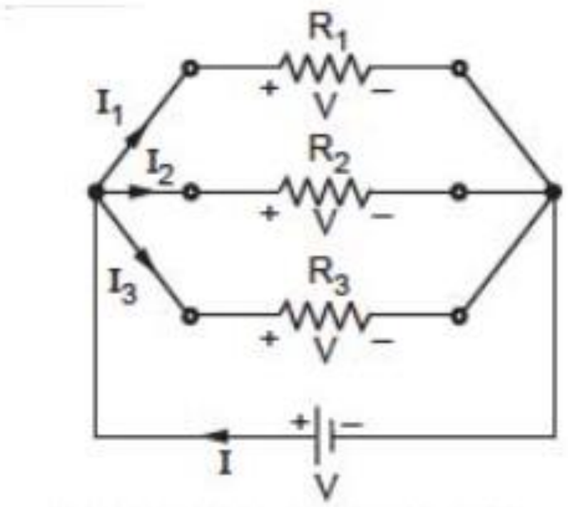
Resistance Connected in Parallel

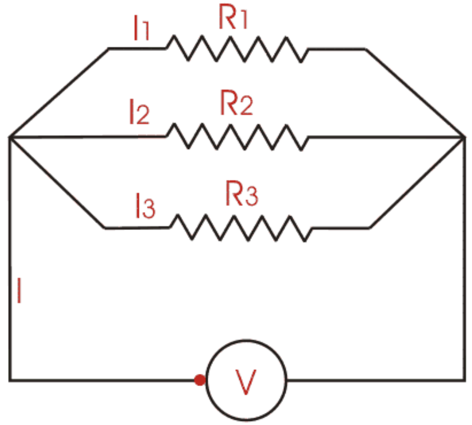
➢ Same ends of the resistance are connected to a junction

Step 1: *Consider a DC Circuit connected in parallel where* ***current I1,I2,I3*** *will flow across resistance* ***R_1, R_2 and R_3.***

Step 2: *Now, if total current flowing is the* ***sum of currents****, is I*

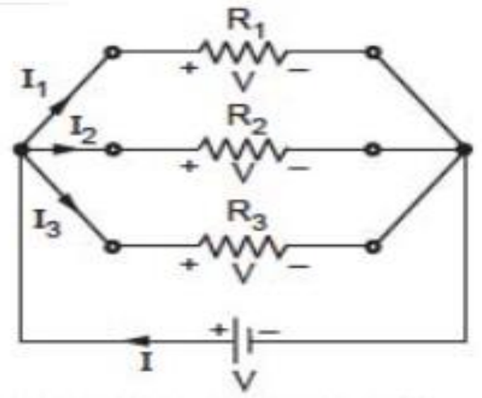
$$I = I_1 + I_2 + I_3 \quad \rightarrow (1)$$





Step 3:*Applying Ohm's law, it can be found that each of the resistances in parallel, is connected across the* ***same voltage source****, the voltage drops across each resistor is the same, and it is same as supply voltage* $V = \mathbf{V_1 = V_2 = V_3}$ 2

$$V = I_1R_1,\ V = I_2R_2,\ V = I_3R_3 \quad 3$$



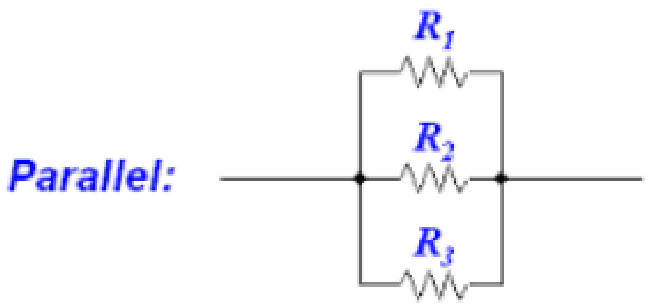
Step 4:*Rewriting the equation in terms of current*

$$I_1 = \frac{V}{R_1},\ I_2 = \frac{V}{R_2},\ I_3 = \frac{V}{R_3} \quad 4$$

$$I = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

Consider eqn 1 $I = I_1 + I_2 + I_3$

Subst eqn 4 in eqn 1 $I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$ 5



Consider eqn 5, $$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad (5)$$

subst…. I=V/R in LHS $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$$

$$= \quad R_{eq} = (1/R_1 + 1/R_2 + 1/R_3)^{-1}$$

$$V = I R_{eq} \quad \text{and} \quad I = \frac{V}{R_{eq}}$$

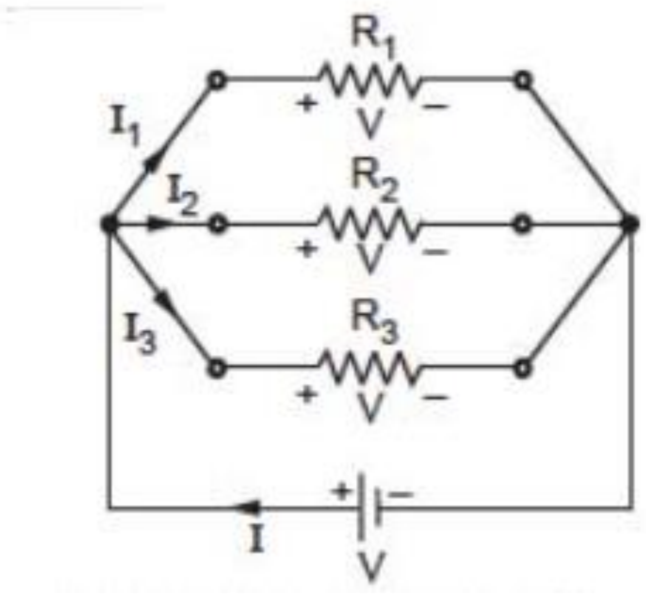
Inference

1.Voltage drops are the same across all the components connected in parallel.

2.Current through individual components connected in parallel is inversely proportional to their resistances.

3.Total circuit current is the arithmetic sum of the currents passing through individual components connected in parallel.

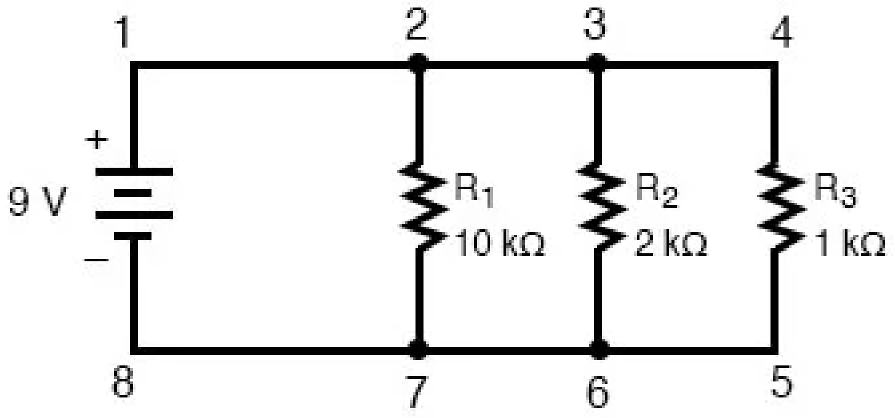
4.The reciprocal of equivalent resistance is equal to the sum of the reciprocals of the resistances of individual components connected in parallel.



Example on Parallel Circuits

1. Three Resistance of 2kΩ, 10kΩ, 1kΩ are connected in parallel , if the voltage of 9V is applied to the circuit, find the current in the circuit

$$R_T = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + etc...\right)}$$

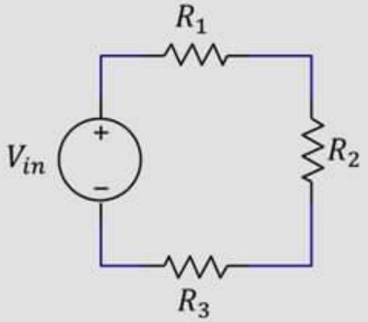
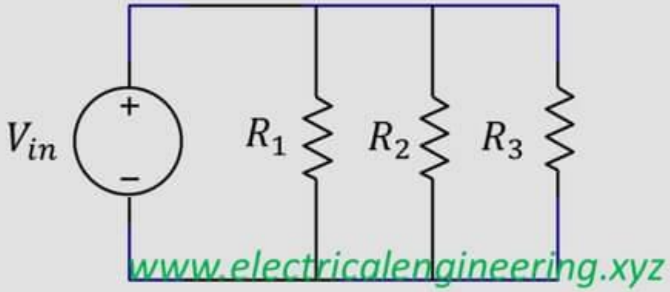


Req = $\frac{1}{Rp}$ = 625

$$V = I\,R_{eq}$$

I = 9/ 625 = 0.0144A

I1=V/R1
I2=V/R2
I3=V/R4
I=I1+I2+I3

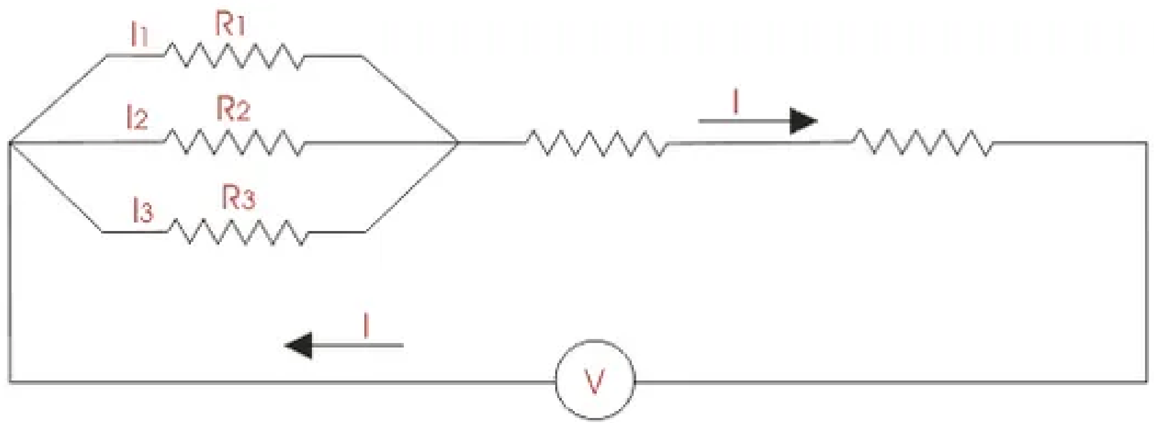
	Series	Parallel
How it looks		
Voltage	$V_{in} = V_1 + V_2 + V_3$	$V_{in} = V_1 = V_2 = V_3$
Current	$I_{series} = I_1 = I_2 = I_3$	$I_{in} = I_1 + I_2 + I_3$
Resistance	$R_{eq} = R_1 + R_2 + R_3$	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Features	If one components burns current becomes inactive	If one component burns current stops only through that branch rest part works fine

1.4 Analysis of Series-Parallel circuit excited by independent voltage sources

So far we have discussed series DC circuits and parallel DC circuits separately, but in practice, the electrical circuit is generally a combination of both series circuits and parallel circuits.

Such combined **series and parallel circuits can be solved by proper application of Ohm's law and the rules for series and parallel circuits to the various parts of the complex circuit.**

Series and Parallel Circuit

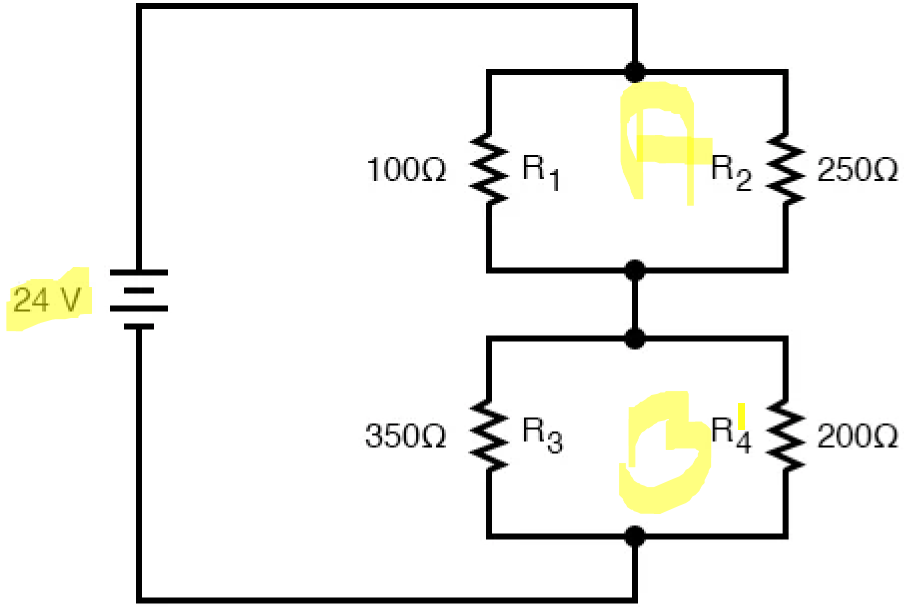


- **Step 1:** Assess which resistors in a circuit are connected together in simple series or simple parallel.
- **Step 2:** Re-draw the circuit, replacing each of those series or parallel resistor combinations identified in step 1 with a single, equivalent-value resistor.

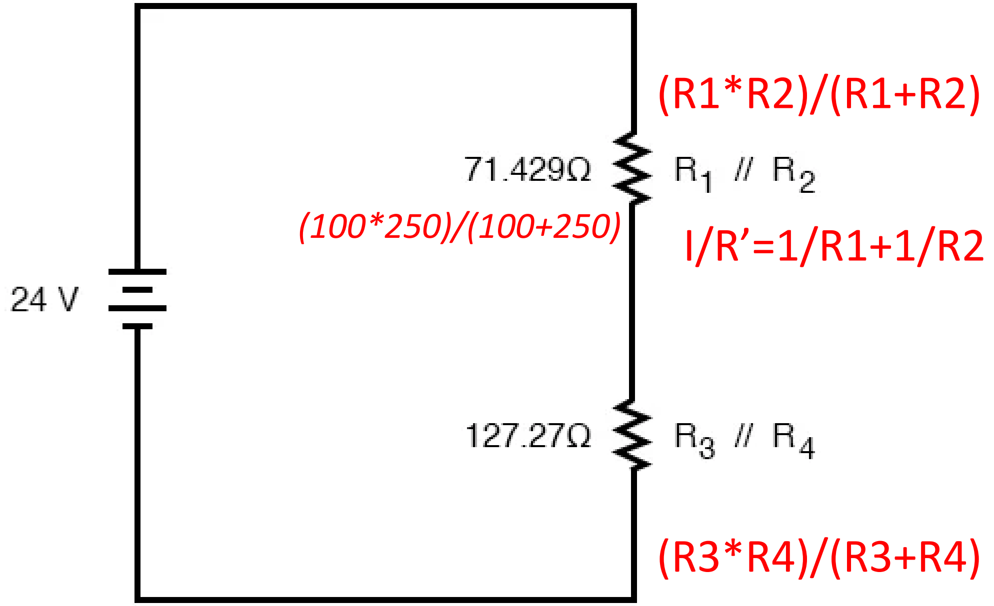
- **Step 3:** Repeat steps 1 and 2 until the entire circuit is reduced to one equivalent resistor.
- **Step 4:** Calculate total current from total voltage and total resistance (I=E/R).
- **Step 6:** From known resistances and total voltage / total current values from step 4, use Ohm's Law to calculate unknown values (voltage or current) (E=IR or I=E/R).

Example on Series-Parallel Circuits

A series-parallel combination circuit

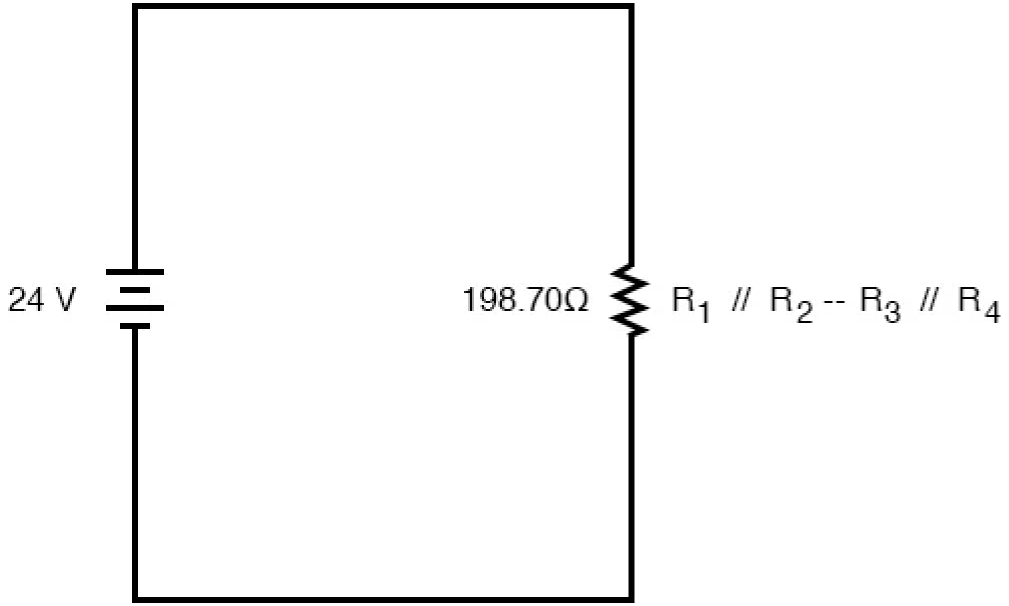


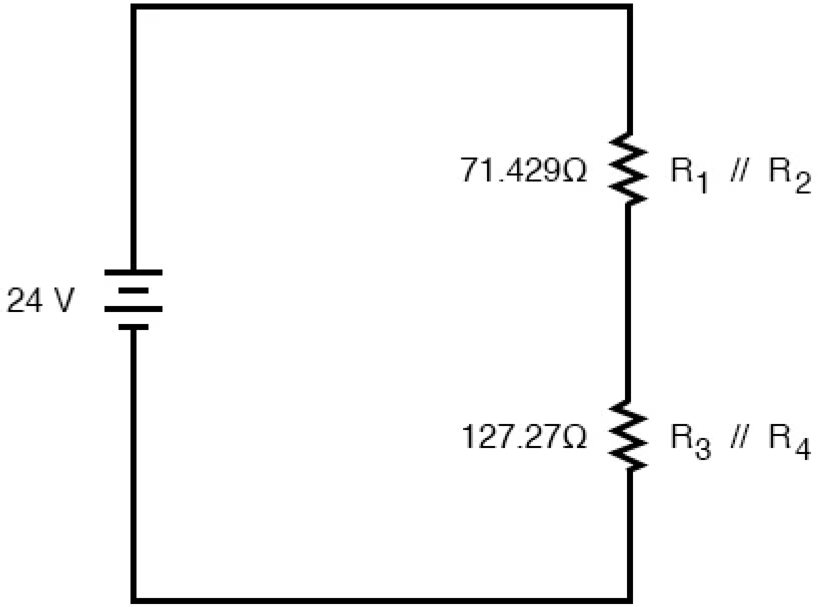
	R_1	R_2	R_3	R_4	Total	
E					24	Volts
I						Amps
R	100	250	350	200		Ohms



	R_1	R_2	R_3	R_4	$R_1 // R_2$	$R_3 // R_4$	Total	
E							24	Volts
I								Amps
R	100	250	350	200	**71.429**	**127.27**		Ohms

198.70 Ω.

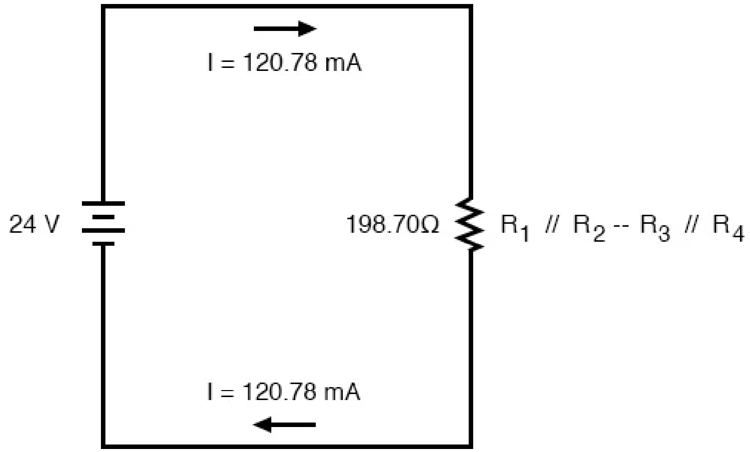




	R_1	R_2	R_3	R_4	$R_1 // R_2$	$R_3 // R_4$	$R_1 // R_2$ -- $R_3 // R_4$ Total	
E							24	Volts
I								Amps
R	100	250	350	200	71.429	127.27	**198.70**	Ohms

Now, total circuit current can be determined by applying Ohm's Law (I=E/R) to the "Total" column in the table:

	R_1	R_2	R_3	R_4	$R_1 // R_2$	$R_3 // R_4$	$R_1 // R_2$ -- $R_3 // R_4$ Total	
E							24	Volts
I							**120.78m**	Amps
R	100	250	350	200	71.429	127.27	198.70	Ohms



VTU QP PROBLEMS

1. For the given circuit Determine I1, E, I2 and I. If Voltage across 9Ω Resistance is 27V . (8 Marks)

- Voltage across 9**Ω** is 27 V. Using ohms Law , I1 is calculated as

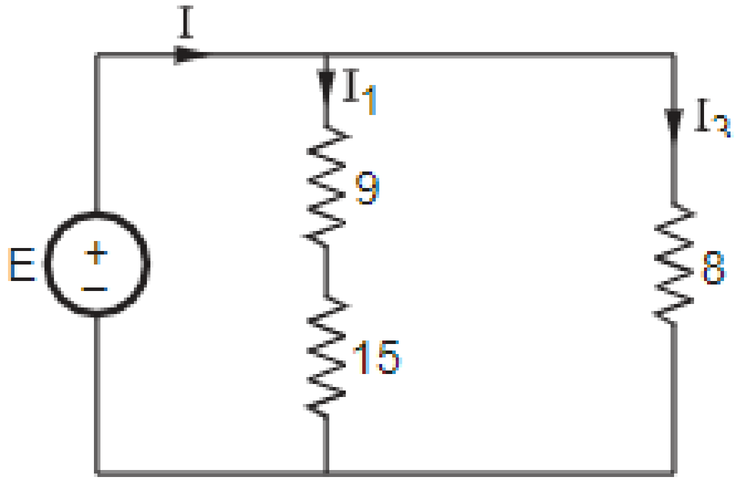
$$I_1 = \frac{V_R}{R} \qquad I_1 = \frac{V_R}{R} = \frac{27}{9} = 3\ \mathbf{A}$$

- E is the voltage across 9 and 15 ohms

$$E = I_1 \times (9+15) \qquad E = I_1 \times (9+15) = \mathbf{72\ V}$$

- Since two branch are parallel the voltage drop is same across 8 ohm

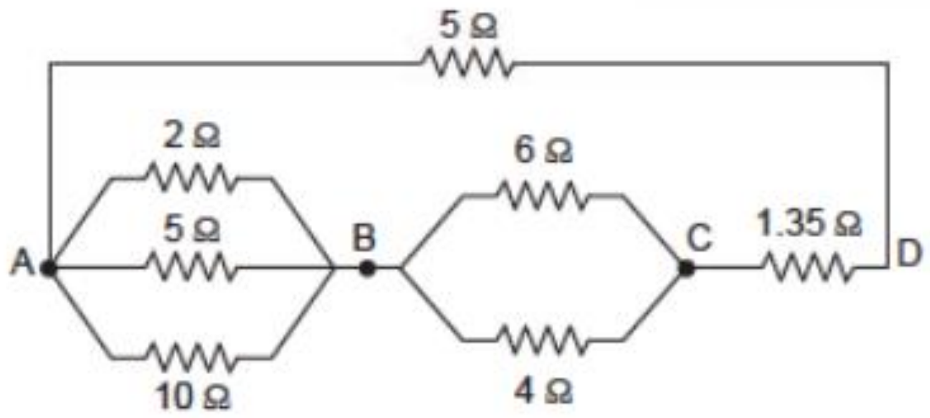
$$I_2 = \frac{E}{8} = \qquad I_2 = \frac{E}{8} = \frac{72}{8} = \mathbf{9\ A}$$



To find total current I

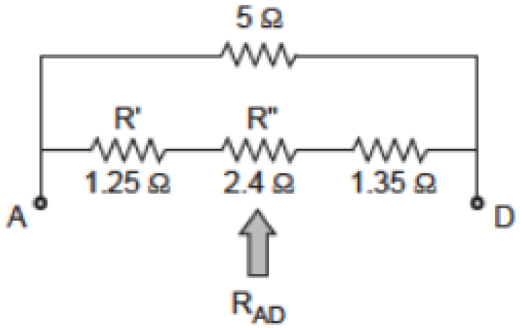
$$I = I_1 + I_2 = \quad I = I_1 + I_2 = 3 + 9 = 12 \text{ A}$$

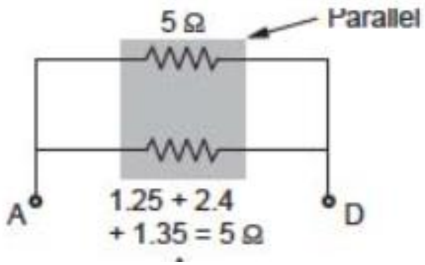
2. Find the resistance of the circuit shown (R_{AD}) – VTU QP

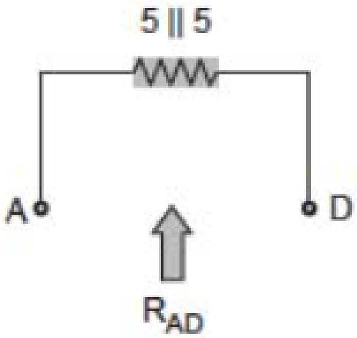


R_{AB} $\quad \frac{1}{R'} = \frac{1}{2}+\frac{1}{5}+\frac{1}{10}$ i.e. $R' = 1.25\ \Omega$

R_{BC} $\quad R'' = \frac{6\times 4}{6+4} = 2.4\ \Omega$



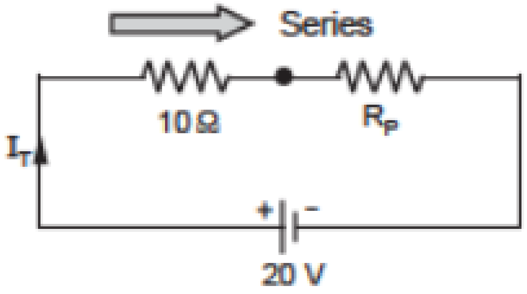




$$R_{AD} = \frac{5\times 5}{5+5} = 2.5\ \Omega$$

3. A resistance of 10 ohm is connected in series with the two resistance of each of 15 ohm arranged in parallel, what resistance must be shunted across this parallel combination so that the total current taken will be 1.5A from a 20V supply fed.

$$\frac{1}{R_P} = \frac{1}{R} + \frac{1}{15} + \frac{1}{15} = \frac{1}{R} + \frac{2}{15} \qquad R_P = \frac{15R}{15+2R}$$



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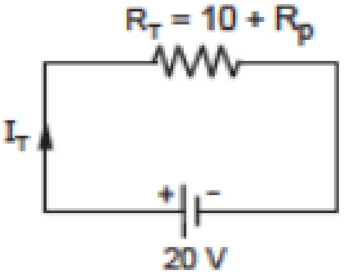

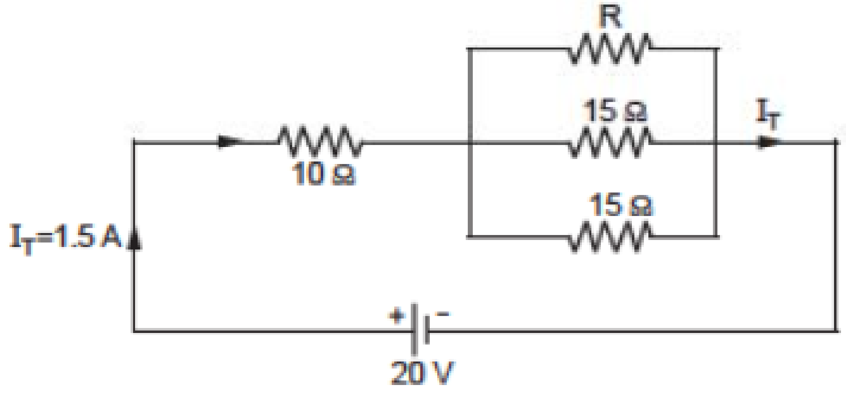

$$R_T = 10 + R_P = 10 + \frac{15R}{15+2R} = \frac{150+20R+15R}{15+2R}$$

$$R_T = \frac{150+35R}{15+2R}$$

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$$I_T = 1.5\ A$$

$$R_T = \frac{V}{I_T} = \frac{20}{1.5} = 13.33\ \Omega$$

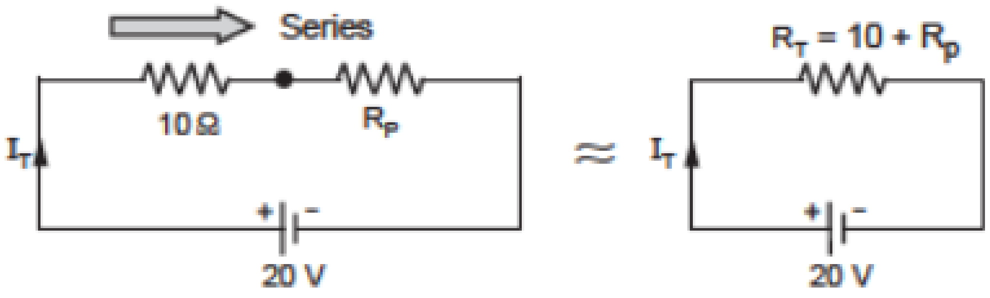
$$R_T = \frac{150+35R}{15+2R}$$

$$\frac{150+35R}{15+2R} = 13.33$$

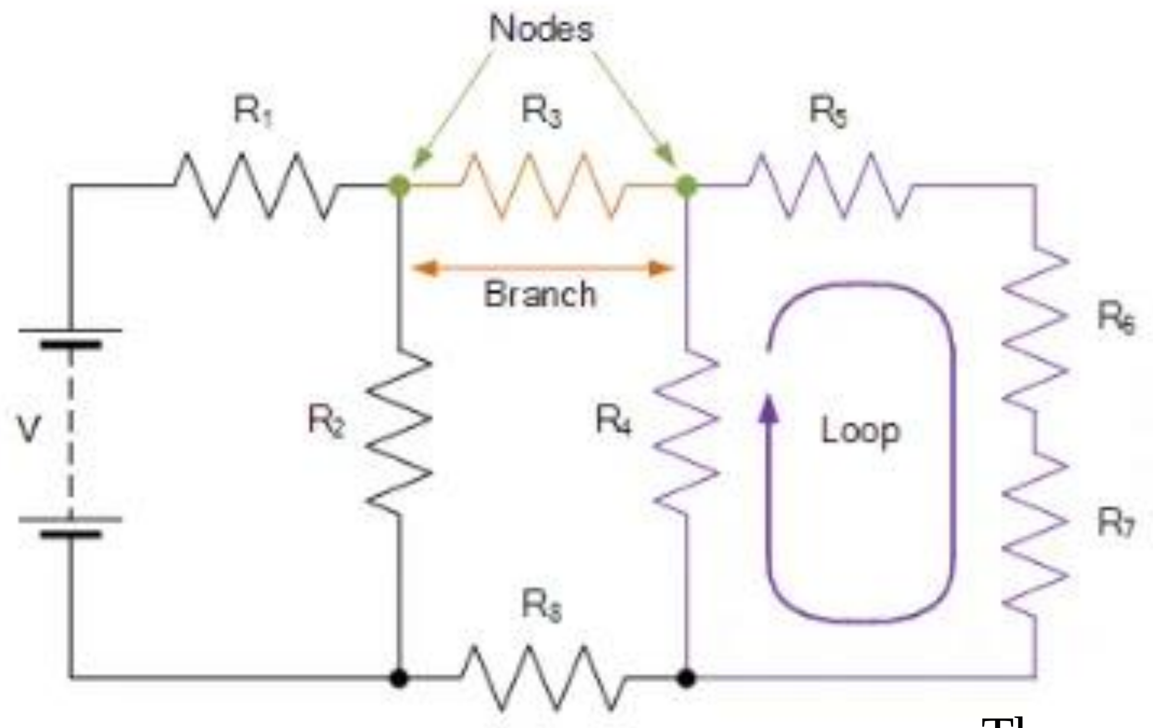
$$150+35R = 199.95+26.66R$$

$$8.34R = 49.95$$

$$\boxed{R = 6\ \Omega}$$



Kirchoff Law



There are some simple relationships between currents and voltages of different branches of an electrical circuit.

These relationships are determined by some basic laws that are known as **Kirchhoff laws** or more specifically **Kirchhoff Current and Voltage laws**.

Kirchhoff's Laws

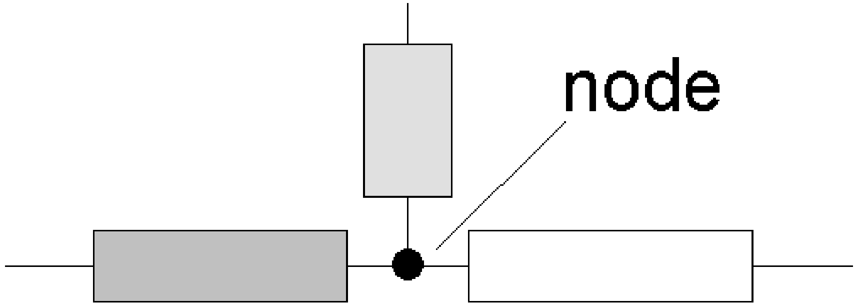
- **<u>Kirchhoff's Current Law (KCL)</u>:**
  - The algebraic sum of all the currents entering any node in a circuit equals zero. (An expression of the conservation of charge.)
- **<u>Kirchhoff's Voltage Law (KVL)</u>:**
  - The algebraic sum of all the voltages around any loop in a circuit equals zero. (As a result of conservation of energy.)

Construction of a Circuit Model

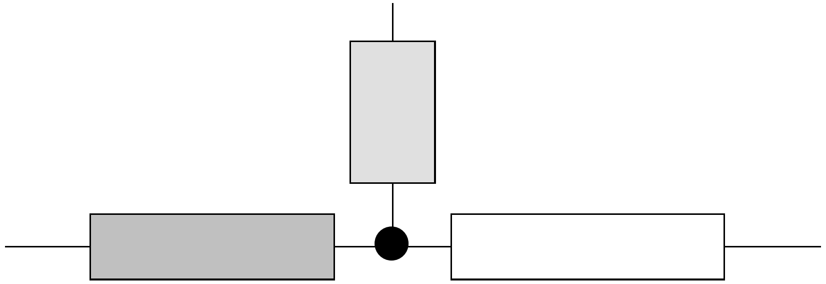
- The electrical behavior of each physical component is of primary interest.
- We need to account for undesired as well as desired electrical effects.
- Simplifying assumptions should be made wherever reasonable.

Terminology: Nodes and Branches

Node: A point where two or more circuit elements are connected

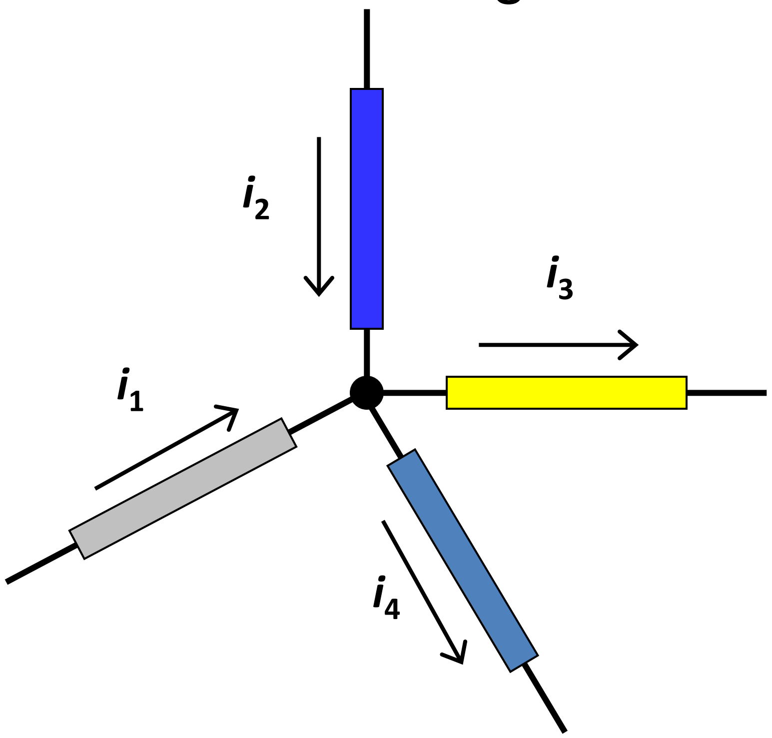


Branch: A path that connects two nodes



Using Kirchhoff's Current Law (KCL)

Consider a node connecting several branches:



- Use **reference directions** to determine whether currents are "entering" or "leaving" the node – with no concern about actual current directions

Alternative Formulations of Kirchhoff's Current Law

(Charge stored **in node** is zero.)

Formulation 1:

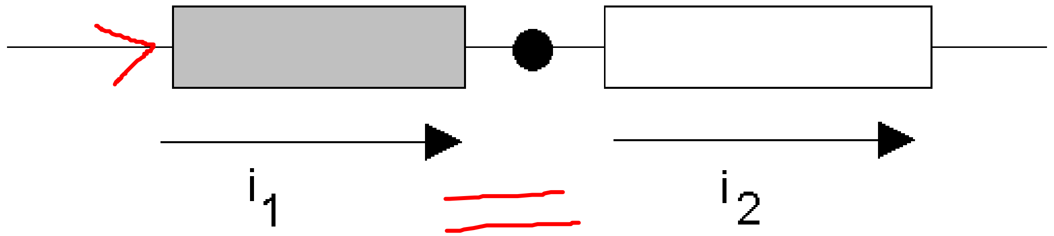
Sum of currents entering node = sum of currents leaving node

Formulation 2:

Algebraic sum of currents at a node =0

A Major Implication of KCL

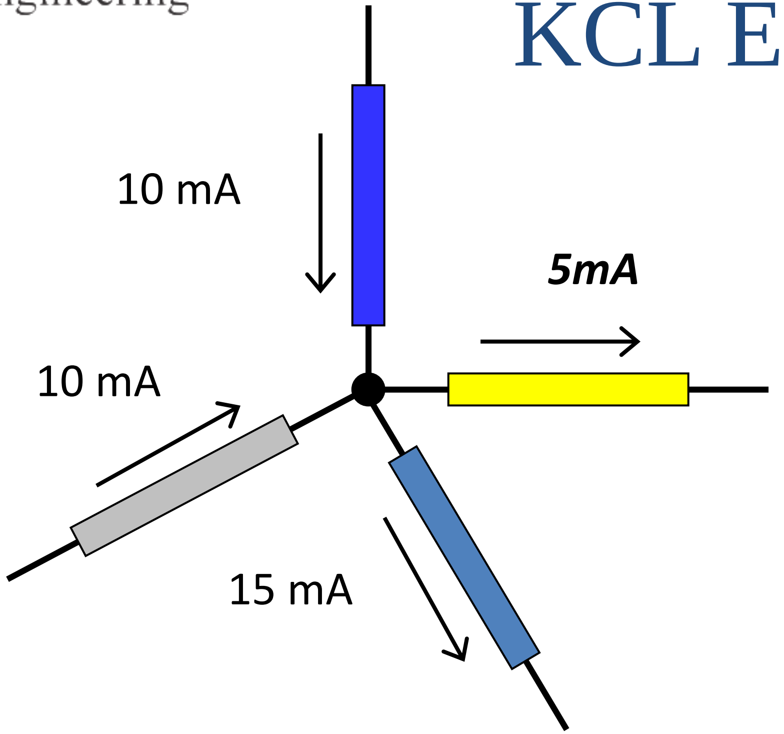
- KCL tells us that **all of the elements in a single branch carry the same current.**
- We say these elements are connected ***in series***.



Current entering node = Current leaving node

$$i_1 = i_2$$

KCL Example



Currents entering the node: 10mA+10mA=20mA

Currents leaving the node:15mA+5mA=20mA

Using Kirchhoff's Voltage Law (KVL)

Consider a branch which forms part of a loop:

- Use **reference polarities** to determine whether a voltage is dropped – with no concern about actual voltage polarities

Formulations of Kirchhoff's Voltage Law

(Conservation of energy)

Formulation 1:

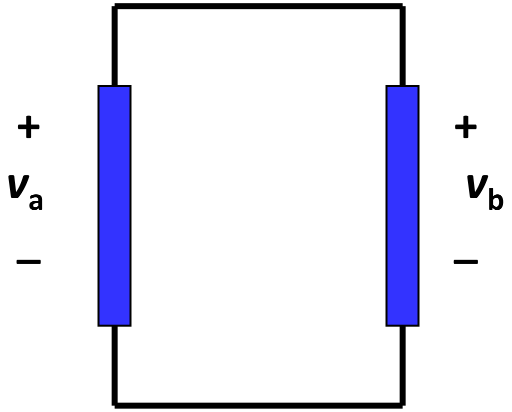
Sum of voltage drops around loop
= sum of voltage rises around loop

Formulation 2:

Algebraic sum of voltage drops around loop = 0

A Major Implication of KVL

- KVL tells us that **any set of elements that are connected at both ends carry the same voltage**.
- We say these elements are connected **in parallel**.



For Va: (- to +) ; rise=+ve

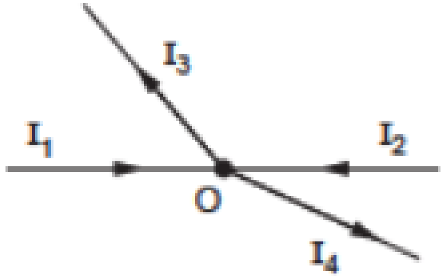
For Vb: (+ to -) ; drop= - ve

Applying KVL in the clockwise direction, starting at the top:

$$v_a - v_b = 0 \rightarrow v_b = v_a$$

Kirchhoff's Current Law

- The Total Current entering the node is equal to the total current leaving node
- The sum of current at the junction is equal to Zero



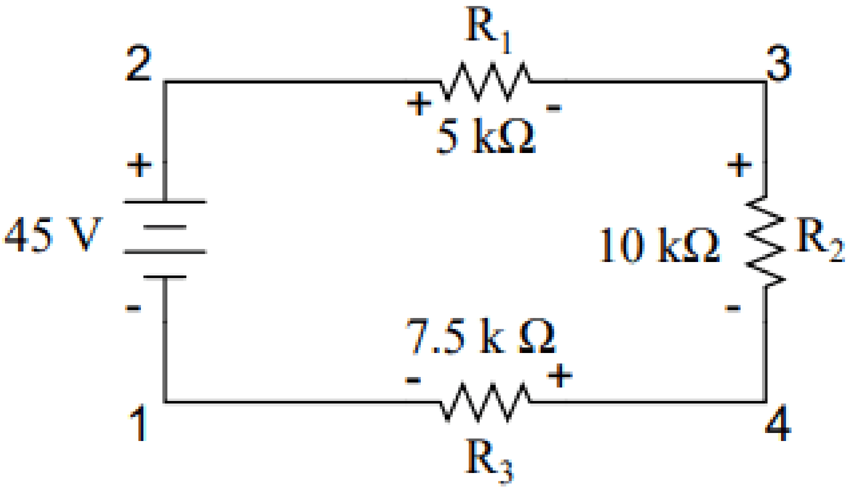
- Applying KCL $\sum I$ at point o is = 0
- Sum of Current entering and leaving the node = 0

$$I_1 + I_2 = I_3 + I_4$$

$$I_1 + I_2 - I_3 - I_4 = 0$$

Kirchhoff's Voltage Law

- The algebraic sum of all the branch voltage in a closed loop is zero.
- Sum of potential rise must be equal to



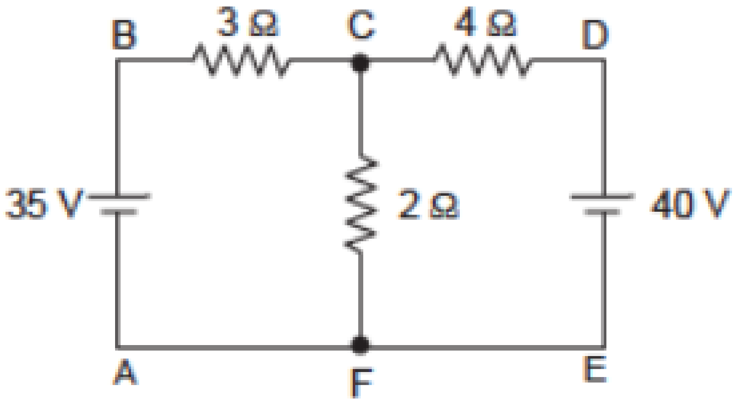
Sign Convention and steps to apply KVL

- - to + potential rise considered as +ve
- + to – Potential drop considered as -ve

Steps to solve KVL

- Marks the polarities for source voltages
- Mark the assumed dimension of current using KCL.
- Mark all the direction of voltage drop (resistor)
- Apply KVL to all the loops and obtain equation
- Solve by simultaneous equation method to find unknown and find other unknowns

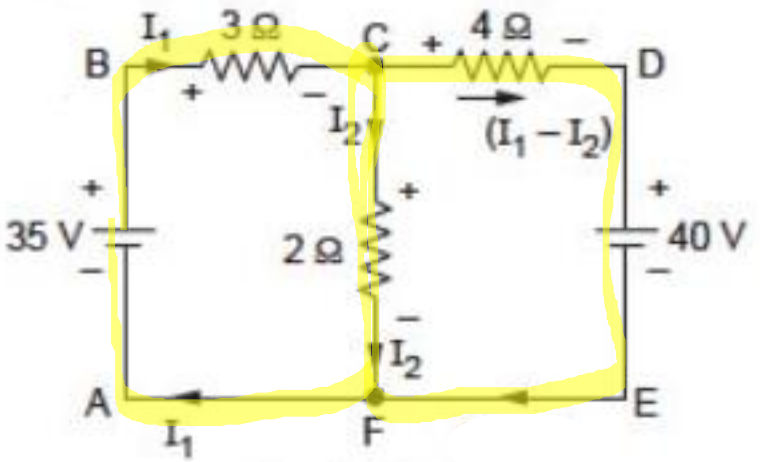
P 1.4 . Calculate the Current in 2Ω resistor. VTU QP



- Step 1: Mark the direction of Current
- Step 2: Mark Polarities for Voltage Drop
- Step 3: Apply KVL to the Loop ABCFA

$$35 - 3I_1 - 2I_2 = 0$$

$$3I_1 + 2I_2 = 35 \quad \rightarrow \quad \textbf{1}$$



- Step 4: Apply KVL to the Loop CDEFC

$$-4(I_1 - I_2) - 40 + 2I_2 = 0$$

$$-4I_1 + 6I_2 = 40 \quad \rightarrow \quad \textbf{2}$$

- Solving 1 and 2 Simultaneously

$$3I_1 + 2I_2 = 35 \rightarrow (1) \rightarrow \text{Multiply by 4}$$

$$-4I_1 + 6I_2 = 40 \rightarrow (2) \rightarrow \text{Multiply by 3}$$

$$\cancel{12}\, I_1 + 8\, I_2 = 140 \rightarrow \boxed{1}$$

$$-\cancel{12}\, I_1 + 18\, I_2 = 120 \rightarrow \boxed{2}$$

$$26 I_2 = 260$$

$$I_2 = 260/26$$

$$I_2 = 10\ A$$

$$3\, I_1 + 2\,(10) = 35$$

$$3\, I_1 + 20 = 35$$

$$3\, I_1 = 35 - 20$$

$$3\, I_1 = 15$$

$$I_1 = 15/3$$

$$I_1 = 5A$$

P 1.6 . For the circuit shown obtain the voltage between X and Y

VTU QP

- ✗ Apply KVL to Loop 1

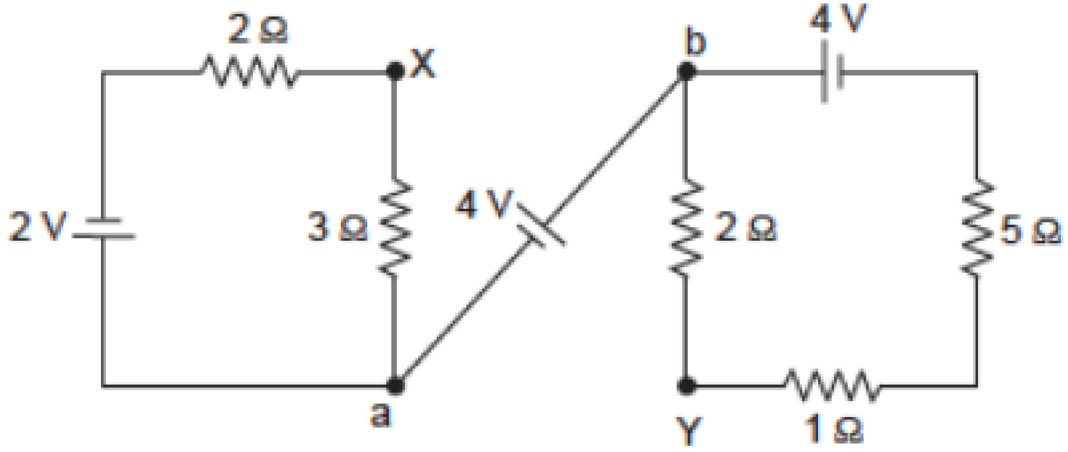
$$+2I_1 + 3I_1 - 2 = 0$$

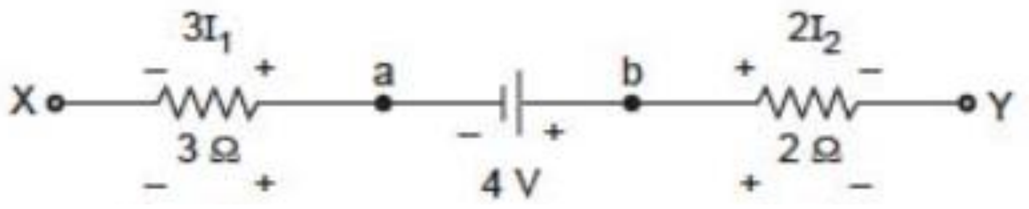
$$I_1 = 0.4 \text{ A}$$

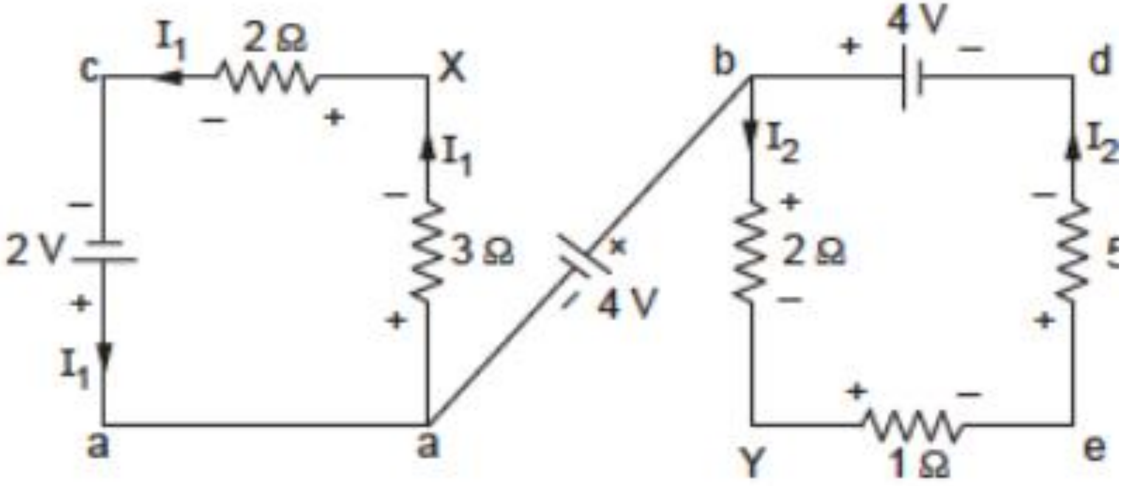
- ✗ Apply KVL to Loop 2

$$-4 + 5I_2 + I_2 + 2I_2 = 0$$

$$I_2 = 0.5 \text{ A.}$$







3×0.4
$= 1.2$ V

2×0.5
$= 1$ V

$$\boxed{V_{XY} = 4 + 1.2 - 1}$$

Vxy=4.2V

P 1.7 . Find the current in the Battery, Current in each branches and pd (Potential difference) across AB for a given network

VTU QP

- Applying KVL to Loop 1

$$-2I_1 - 3I_1 - 4(I_1 + I_2) + 10 = 0$$

$$9I_1 + 4I_2 = 10 \longrightarrow \textbf{1}$$

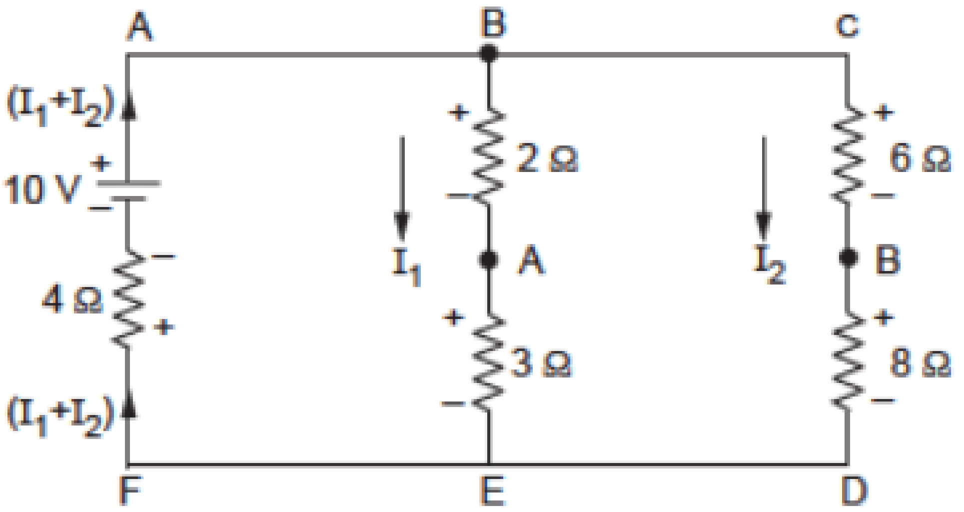
- Applying KVL to Loop 2

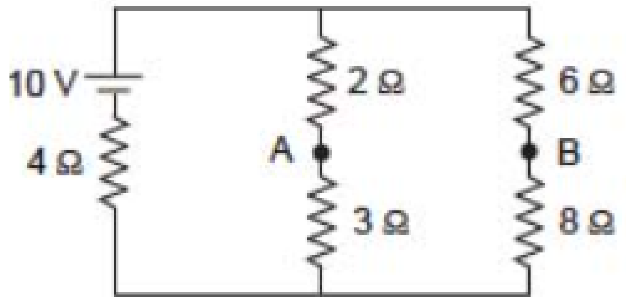
$$-6I_2 - 8I_2 + 3I_1 + 2I_1 = 0$$

$$5I_1 - 14I_2 = 0 \longrightarrow \textbf{2}$$

$I_1 = 0.9589$ A, $\quad I_2 = 0.34246$ A

$I_1 + I_2 = 1.3013$ A

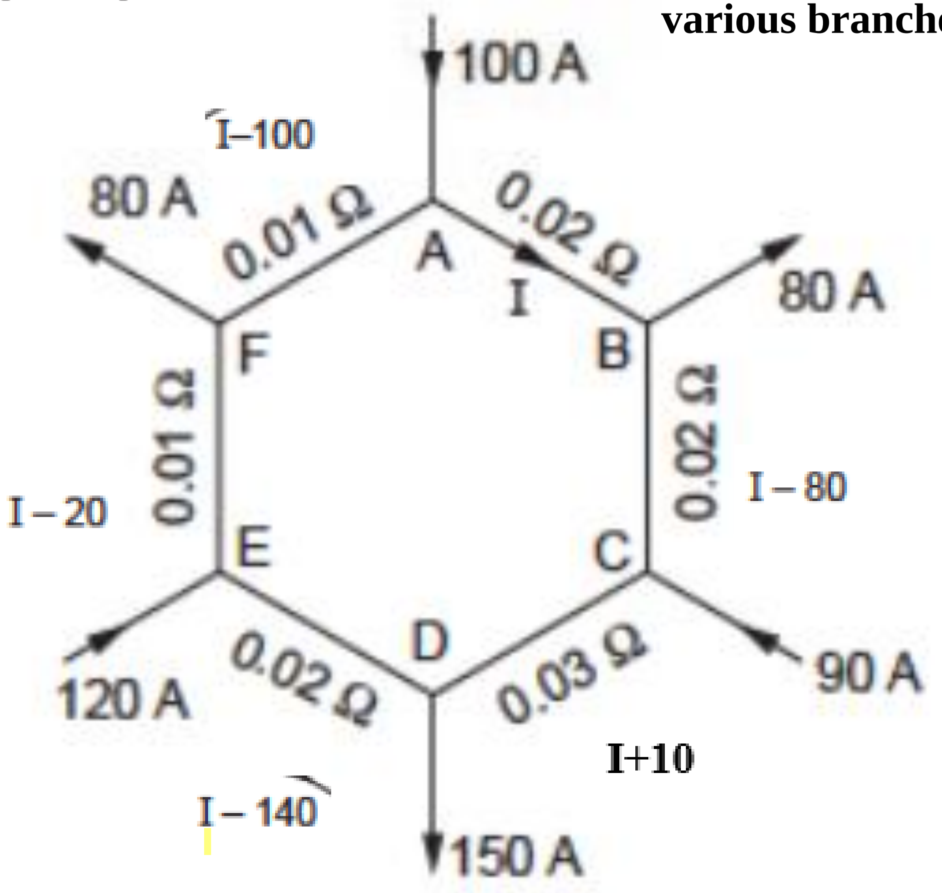


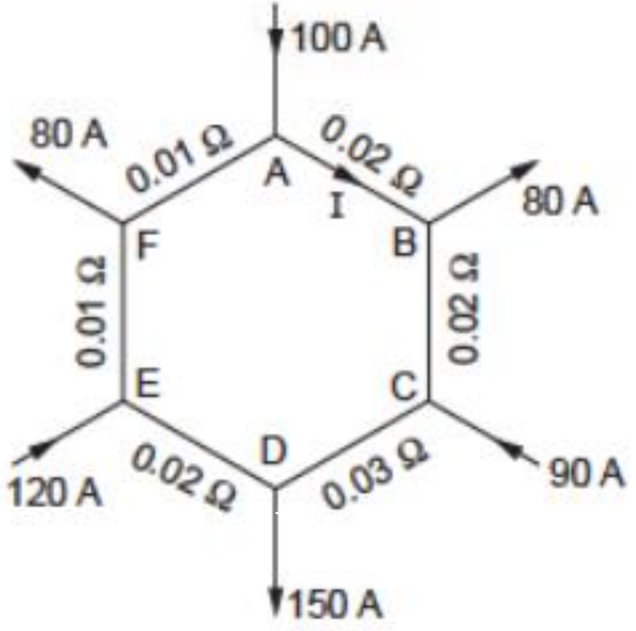


$\boxed{= 2.8767\ V}$ $\qquad$ $\boxed{= 2.7396\ V}$

$$V_{AB} = 2.8767 - 2.7396 \boxed{= 0.13702\ V}$$

P 1.5 . Find the current in the various branches of given network





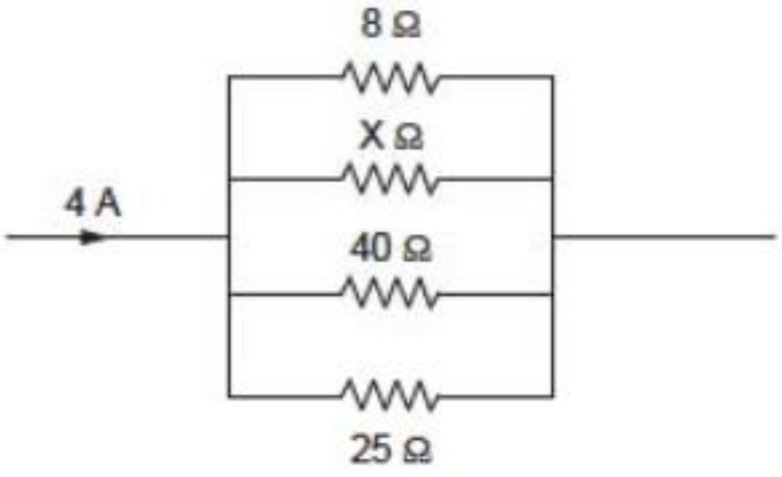
By using KCL

$$I(0.02) + (I - 80)\,0.02 + (I + 10)\,0.03 + (I - 140)\,0.02 + (I - 20)\,0.01 + (I - 100)\,0.01 = 0$$

P 1.8 . In the Parallel Arrangement of resistors shown the current flowing in the 8Ω resistor is 2.5A, Find i) Current in the other resistor ii) resistor X iii) Equivalent Resistance VTU QP

- The drop across 8ohm resistor is

$$\text{across } 8\ \Omega = 8 \times I_{8\,\Omega} = 8 \times 2.5 = 20\ V.$$



- The voltage drop is same across parallel circuit

$$I_{40\,\Omega} = \frac{20}{40} = 0.5\ A,$$

$$I_{25\,\Omega} = \frac{20}{25} = 0.8\ A,$$

$$I_X = I_T - I_{8\,\Omega} - I_{40\,\Omega} - I_{25\,\Omega}\ \text{(KCL)}$$

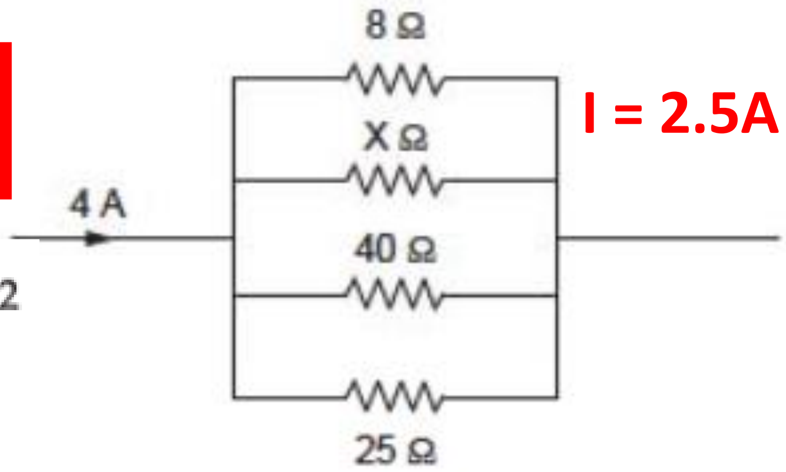
$$\boxed{I_X = 4 - 2.5 - 0.5 - 0.8 = 0.2\ A}$$

$$I_X = \frac{20}{X}$$

$$\boxed{0.2 = \frac{20}{X} = \quad \text{i.e.} \quad X = 100\ \Omega}$$

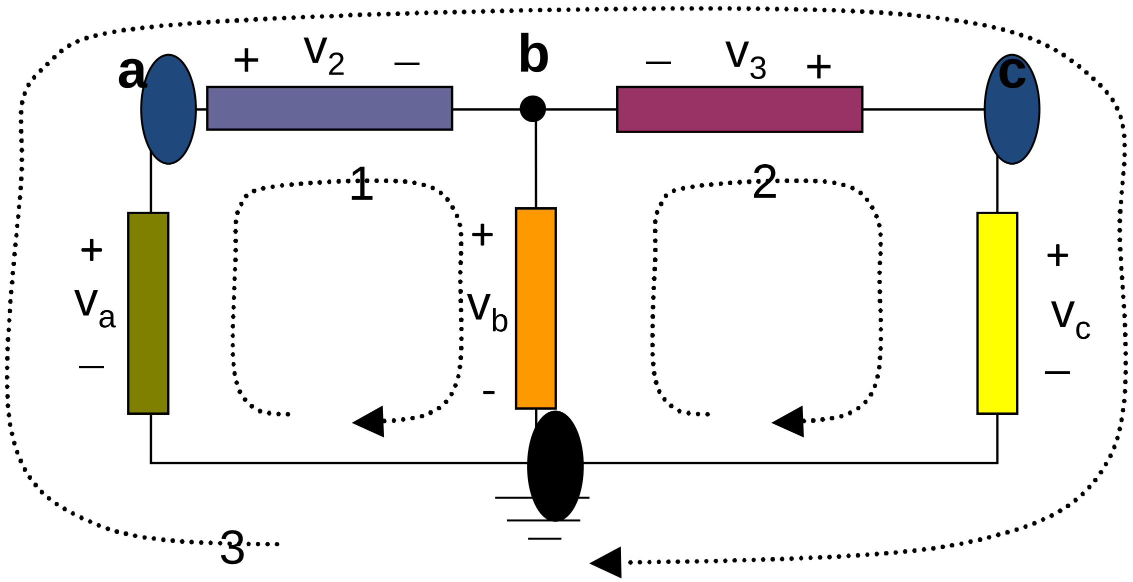
$$\frac{1}{R_{eq}} = \frac{1}{8} + \frac{1}{100} + \frac{1}{40} + \frac{1}{25} = 0.2$$

$$\boxed{R_{eq} = 5\ \Omega}$$



KVL Example

Three closed paths:

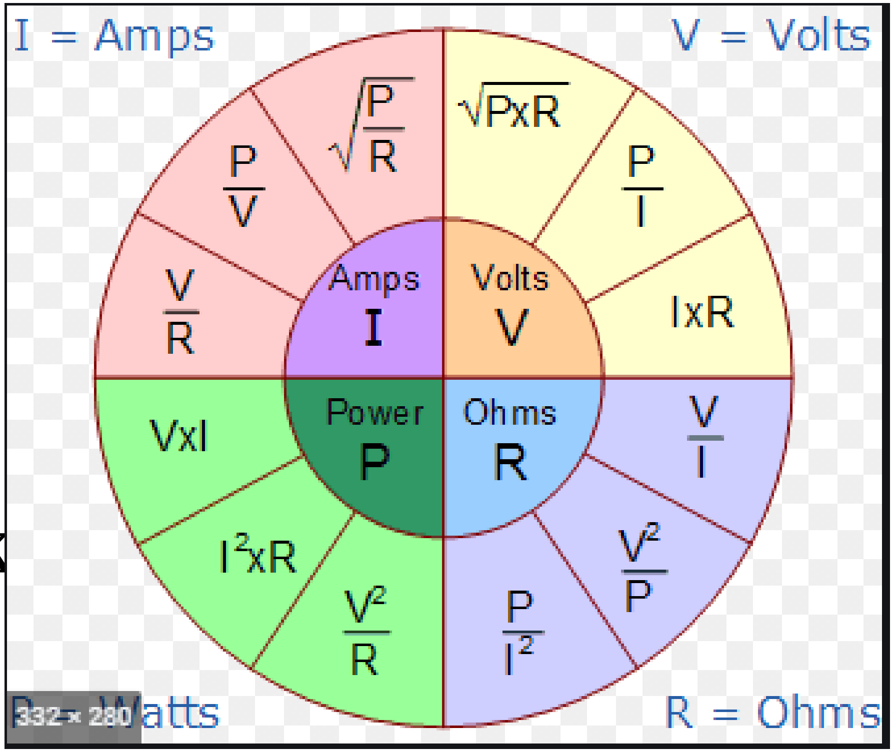


Path 1:

Path 2:

Path 3:

Power and Energy



- P = Electrical Work done = V I
- P in terms of ohms law when Voltage is k

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

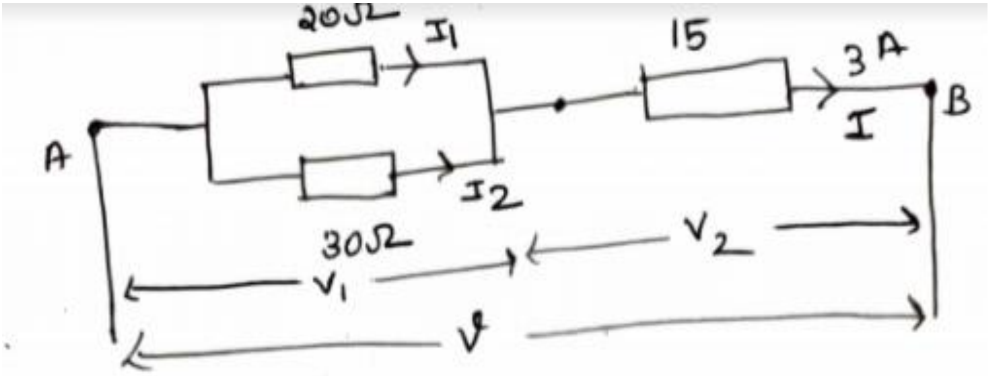
- P in terms of ohms law when Current is known

$$P = I^2 R$$

- Energy – Power * Time – J or W*Sec

P 1.9 . A circuit consist of two parallel resistance having resistance of 20ohm and 30ohm , respectively connected in series with a 15 ohm resistor , through which current is 3A find i) Current in 20ohm and 30 ohm resistor ii) the voltage across whole circuit iii) and total power consumed in all resistors

VTU QP



$R_p = \frac{20 \times 30}{20+30} = 12\Omega$

$R_{eq} = R_p + 15$

$R_{eq} = 12 + 15 = 27\Omega$

$I_1 = \frac{V_1}{20\Omega}$

$= \frac{36}{20}$

$I_1 = 1.8\,A$

$I_2 = \frac{V_2}{30}$

$= \frac{36}{30}$

$I_2 = 1.2\,A$

$P = I^2 R$

$P_{20} = 1.8^2 \times 20 = 64.8\,W$

$P_{30} = 1.2^2 \times 30 = 43.2\,W$

$P_{15} = 3^2 \times 15 = 135\,W$

$V = I\,R_{eq}$

$V = 3 \times 27$

$\boxed{V = 81\,V}$

$V_2 = I \times R_{15}$

$V_2 = 3 \times 15 = 45\,V$

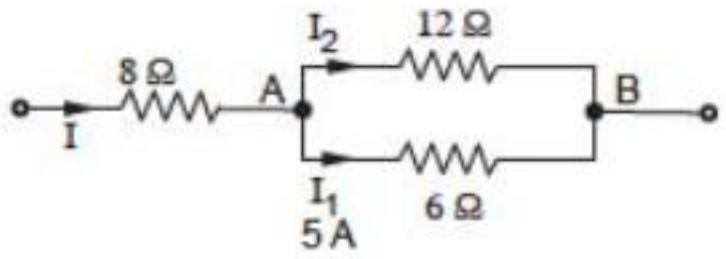
$V_T = V_1 + V_2$

$81 = V_1 + 45$

$V_1 = 36\,V$

P 1.10. A 8 ohm resistor is in series with a parallel combination of two resistors 12 ohm and 6 ohm. If the current in the 6 ohm resistor is 5 A, determine the total power dissipated in the circuit.

VTU QP



$$V_{AB} = I_1 \times 6 = 5 \times 6 = 30 \text{ V}$$

$$I_2 = \frac{V_{AB}}{12} = \frac{30}{12} = 2.5 \text{ A}$$

$$I = I_1 + I_2 = 7.5 \text{ A}$$

$$P_{12} = I_2^2 \times 12 = (2.5)^2 \times 12 = 75 \text{ W},$$

$$P_6 = I_1^2 \times 6 = (5)^2 \times 6 = 150 \text{ W}$$

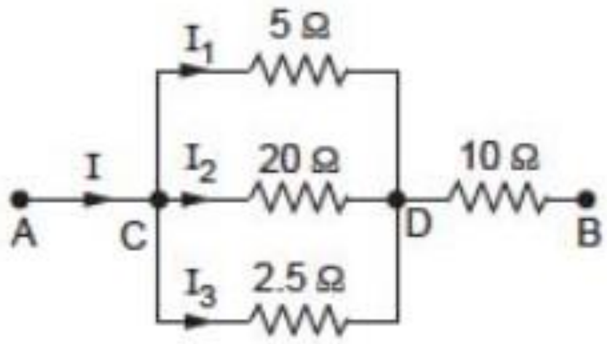
$$P_8 = I^2 \times 8 = (7.5)^2 \times 8 = 450 \text{ W},$$

$$P_T = P_{12} + P_6 + P_8$$

$$\boxed{= 675 \text{ W}.}$$

P 1.11. For the circuit shown, the total power dissipated is 488 W. Calculate the current flowing in each resistance and pd between A and B..

VTU QP



$$\frac{1}{R} = \frac{1}{5}+\frac{1}{20}+\frac{1}{2.5} \qquad R' = 1.5384\ \Omega$$

$$R_{eq} = R' + 10 = 11.5384\ \Omega$$

$$P = I^2 R_{eq} \qquad I^2 = \frac{488}{11.5384} \qquad I = \mathbf{6.5033\ A}$$

$$V_{AB} = I \times R_{eq} = 6.5033 \times 11.5384 = \mathbf{75.038\ V}$$

$$R' = V_{AB} - 10I = 75.038 - 65.033 = 10\ V$$

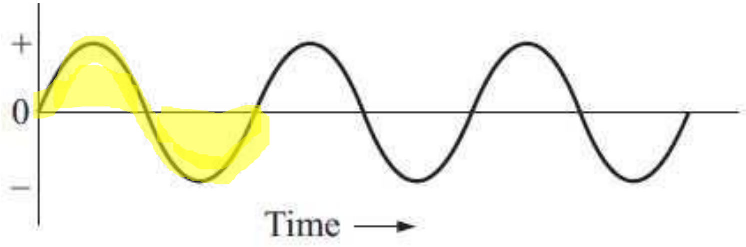
$$I_1 = \frac{10}{5} = \mathbf{2\ A}, \quad I_2 = \frac{10}{20} = \mathbf{0.5\ A}, \quad I_3 = \frac{10}{2.5} = \mathbf{4\ A}$$

AC fundamentals:

- Generation of sinusoidal voltage
- Frequency of generated voltage
- Definition and numerical values of average value, root mean square value, form factor and peak factor of sinusoidally varying voltage and current, phasor representation of alternating quantities.

WHAT IS ALTERNATING CURRENT (A.C.)?

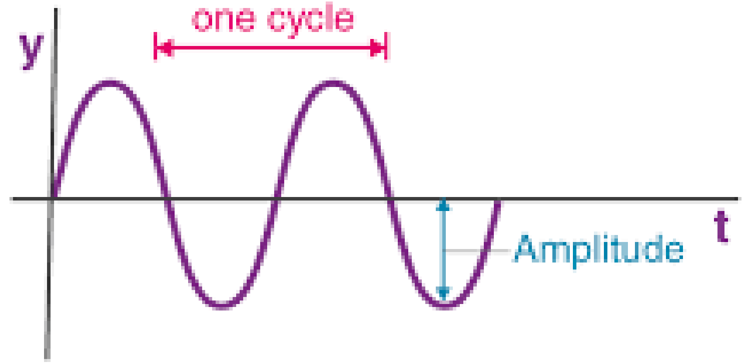
Alternating current is the current which constantly changes in amplitude, and which reverses direction at regular intervals.



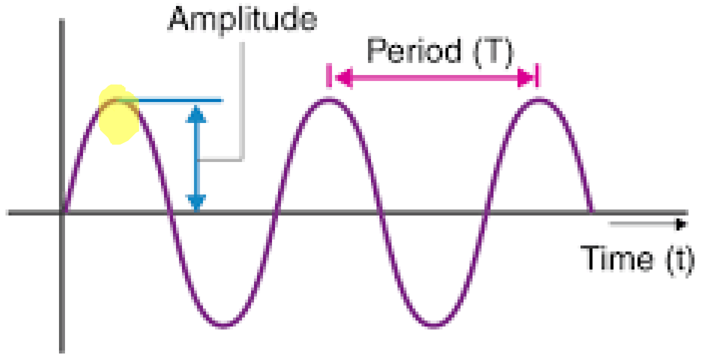
Because the changes are so regular, alternating voltage and current have a number of properties associated with any such waveform. These basic properties include :

Frequency: It is the number of complete cycles that occurred in one second. The frequency of the wave is commonly measured in cycles per second (cycles/sec) and expressed in units of Hertz (Hz). It is represented in mathematical equations by the letter '*f*'.

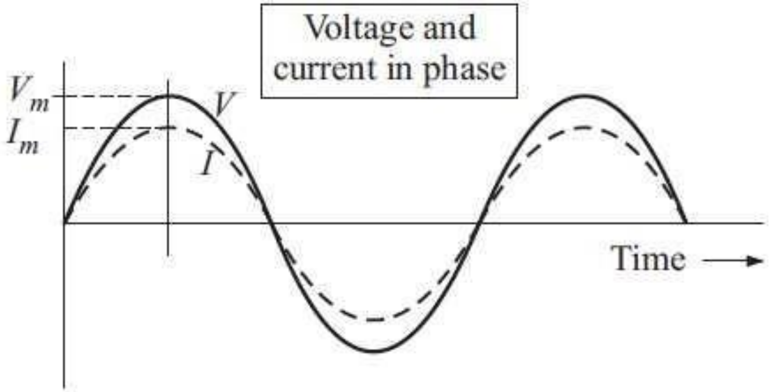
Time Period: It is the duration of time required for the quantity to complete one cycle. And is denoted by T. This is reciprocal of frequency.



Amplitude: Mathematically, the amplitude of a sine wave is the value of that sine wave at its peak. This is the maximum value, positive or negative, that it can attain.



A.C. Fundamentals



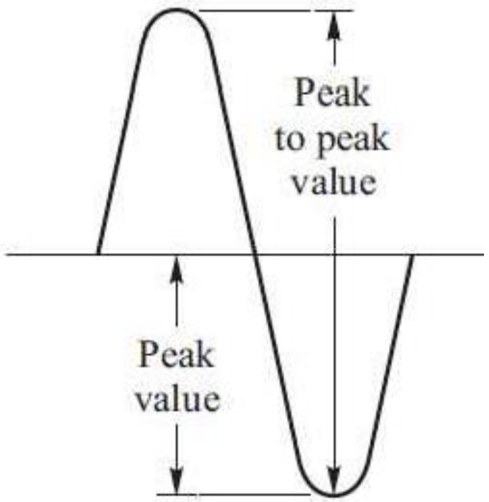
Instantaneous Value: The instantaneous value of an alternating voltage or current is the value of voltage or current at one particular instant.

Average Value: The average value of an alternating current or voltage is the average of all the instantaneous values during one alternation. Since the voltage increases from zero to peak value and decreases back to zero during one alternation, the average value must be some value between those two limits.

Peak Value[Ip]

Peak Value[Ip]

Refer to figure, it is the maximum value of voltage [Vp] or Current [Ip]. The peak value applies to both positive and negative values of the cycle.



Derivation of Average Value of Current [I_{av}]

The average value of A.C. is the average over one complete cycle and is clearly zero, because there are alternately equal positive and negative half cycles.

Alternating current is represented as $I = I_0 \sin \omega t$

$$I_{mean} = \frac{\int_0^{T/2} I_0 \sin \omega t \, dt}{\int_0^{T/2} dt}$$

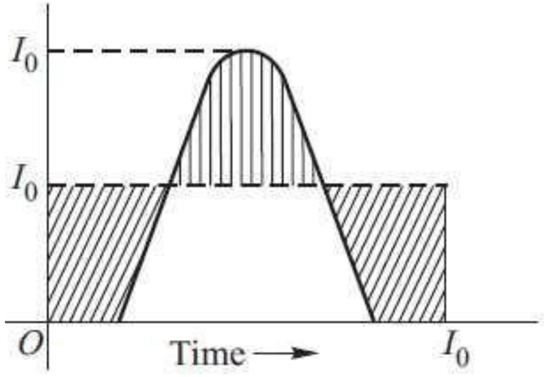
$$= \frac{I_0}{T/2} \cdot \frac{1}{\omega} \left[-\cos \omega t\right]_0^{T/2}$$

$$= \frac{2I}{T} \cdot \frac{T}{2\pi} \left[\cos 0^\circ - \cos \frac{\omega T}{2}\right]$$

$$= \frac{I_0}{\pi} \left[\cos 0^\circ - \cos \frac{\omega}{2} \cdot \frac{2\pi}{\omega}\right]$$

$$= \frac{2I_0}{\pi} = \frac{2}{\pi} \times \text{Peak value of current}$$

Similarly, $E_{mean} = \frac{2E_0}{\pi} = \frac{2}{\pi} \times$ Peak value of voltage



Root Mean Square Value

Circuit currents and voltage in A.C. circuits are generally stated as root-mean-square or rms values rather than by quoting the maximum values. The root-mean-square for a current is defined by

$$I_{rms} = \sqrt{\left(I^2\right)_{avg}}$$

That is, you take the square of the current and average it, then take the square root. When this process is carried out for a sinusoidal current

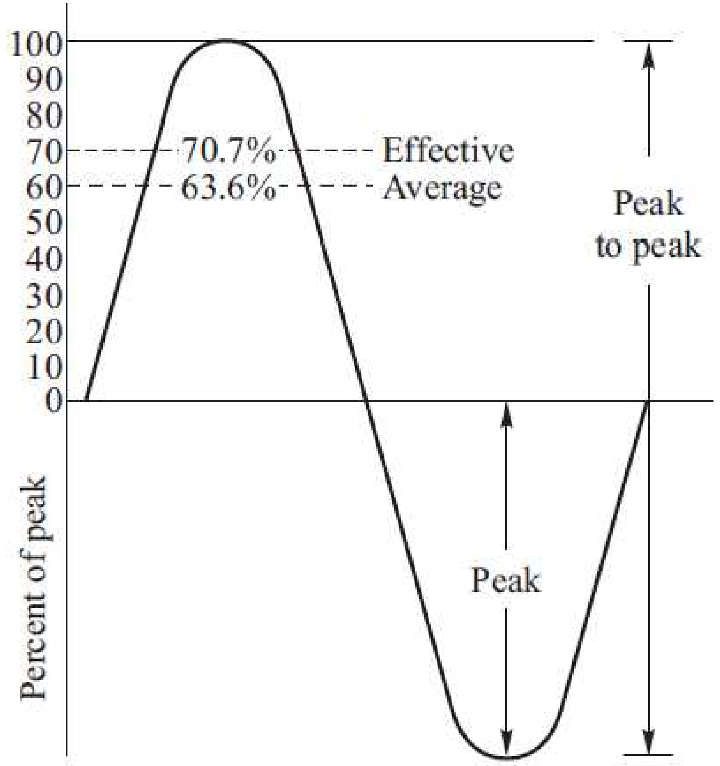
$$\left[I_m^2 \sin^2 \omega t\right]_{avg} = \frac{I_m^2}{2} \quad \text{so} \quad I_{rms} = \sqrt{\left(I^2\right)_{avg}} = \frac{I_m}{\sqrt{2}}$$

Since the A.C. voltage is also sinusoidal, the form of the rms voltage is the same. These rms values are just the effective value needed in the expression for average power to put the A.C. power in the same form as the expression for D.C. power in a resistor. In a resistor where the power factor is equal to 1.

$$P_{avg} = \frac{V_m I_m}{2} \cos\phi = V_{rms} I_{rms} \cos\phi = V_{rms} I_{rms}, \text{ for a resistor } R$$

Form Factor $= \dfrac{V_{rms}}{V_{ave}}$ or $\dfrac{I_{rms}}{I_{ave}} = 1.11$ (approx.)

Derivation of RMS Value



Derivation of RMS Value

RMS value of current is defined as $I_{rms} = \sqrt{I^{2}}$. The average value of I^2 over one complete cycle is given by

$$I^{2} = \frac{\int_0^T I^2 dt}{\int_0^T dt} = \frac{1}{T}\int_0^T I_0^{2} \sin^2 \omega t \, dt$$

$$I^{2} = \frac{I_0^{2}}{T}\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt$$

$$= \frac{I_0^{2}}{2T}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^T = \frac{I_0^{2}}{2T}[T-0]$$

$$I^{2} = \frac{I_0^{2}}{2}$$

Thus the root mean square value of an alternating current is $I_{rms} = \sqrt{I^{2}} = \sqrt{\frac{I_0^{2}}{2}}$

Similarly the RMS value of an a.c. voltage is

$$V_{rms} = \frac{V_0}{\sqrt{2}} \text{ or } \frac{E_0}{\sqrt{2}}.$$

The rms value is the effective value required in power calculations. The rms value of a sine-wave current produces the same heating effect in a resistor as an identical d.c. current.

The different factors are defined as:

$$\text{Form factor} = \frac{\textit{RMS value}}{\textit{Average value}} = \frac{0.707\, V_m}{0.637\, V_m} = 1.11$$

$$\text{Peak factor} = \frac{\textit{Maximum value}}{\textit{Average value}} = \frac{V_m}{0.707\, V_m} = 1.414$$

PHASORS

In an a.c. circuit, the e.m.f. or current vary sinusoidally with time and may be mathematically represented as

$E = E_0 \sin \omega t$ and $I = I_0 \sin (\omega t \pm \theta)$

where θ is the phase angle between alternating e.m.f. and current and $\omega = 2\pi f$.

The quantities, such as alternating e.m.f. and alternating current are called phasor.

Thus a phasor is a quantity which varies sinusoidally with time and represented as the projection of rotating vector.

Phasor Diagram

- The generator at the power station which produces our A.C. mains rotates through 360 degrees to produce one cycle of the sine wave form which makes up the supply (fig 1).
- In the fig 2 there are two sine waves.
- They are out of phase because they do not start from zero at the same time. To be in phase they must start at the same time.
- The waveform *A starts before B and is LEADING by 90 degrees*.
- Waveform *B is LAGGING A by 90 degrees*

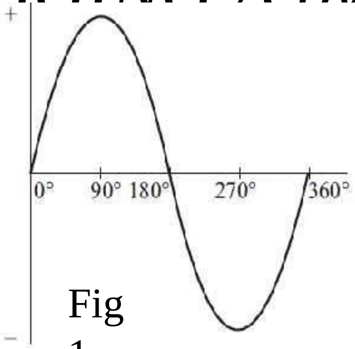


Fig 1

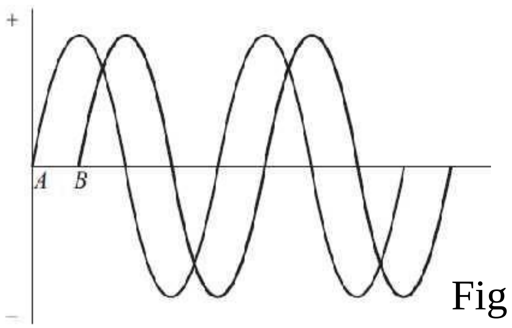
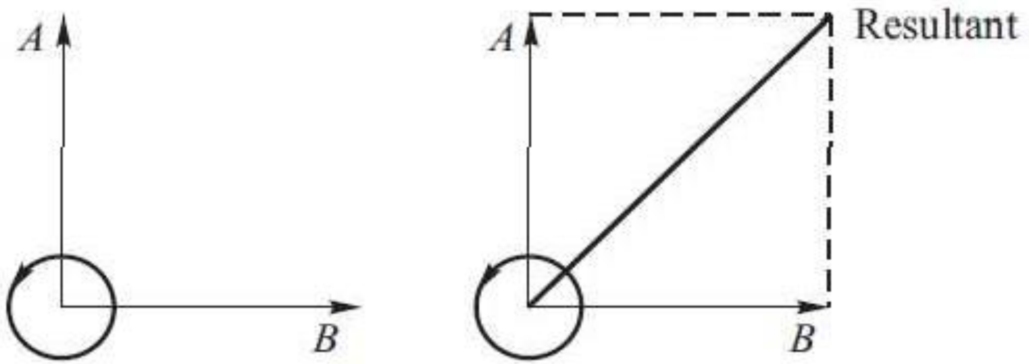


Fig 2

The next left hand diagram, known as a PHASOR DIAGRAM, shows this in another way.

The phasors are rotating anticlockwise as indicated by the arrowed circle.
A is leading B by 90 degrees.
The length of the phasors is determined by the amplitude of the voltages A and B.



$$\text{Resultant} = \sqrt{A^2 + B^2}$$

Phase and Phase Difference

The fraction of a cycle or time period that has elapsed since an alternating current or voltage last passed a given reference point, which is generally the starting point, is called its phase.

Phase of the alternating current or voltage may be expressed in time measured in seconds or fraction of a time period or the angle expressed in the degree or radians.

If two alternating current or voltages act simultaneously in the same circuit, they may do so in such a manner that their peak values do not occur at the same time.

The time interval between two positive peak values of a.c. current or voltage is known as the phase difference.

Resistance, Reactance, Impedance, Inductance

Resistance (unit – ohms) (Symbol R)

Resistance is a force that tends to resist the flow of electrical current. Resistance is usually created deliberately by a resistor, a device used to create resistance in a circuit.

Reactance (unit – ohms) (Symbol X)

Whereas resistance is created by a resistor to achieve some effect, reactance is by-product of certain electrical components.

There are two basic types of reactance: capacitive reactance and inductive reactance.

The capacitive reactance is created by capacitors, while inductive reactance is created by inductors.

Like resistance, reactance is expressed in ohms, and it behaves in much the same way as resistance, in the sense that it tends to restrict the flow of current through a circuit.

**Reactance and impedance only exist in the world of AC (alternating current).

Resistance, Reactance, Impedance, Inductance

The formula for calculating inductive reactance is as follows:

$$X_L = 2.\pi.f.L = L\omega$$

X_L = the inductive reactance (ohms)
f = the frequency of the AC flowing through the circuit (Hz) L = the inductance of the inductor (henries).

The formula for capacitive reactance is as follows:

$$X_C = \frac{1}{2.\pi.f.C} = 1/C\omega$$

X_C = the capacitive reactance (ohms) f = the frequency (Hz)
C = the capacitance of the capacitor (farads)

The total impedance of a circuit is the square root of the sum of the squares of the resistance and reactance.

$$Z = ((R^2) + (X^2))^{0.5}$$

Z = impedance (ohms) R = resistance (ohms) X = reactance (ohms)

Concept of Power Factor

For AC circuits, both inductor and capacitor offer certain amount of impedance given by

$$X_L = 2\pi f L$$

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

The inductor stores electrical energy in the form of magnetic energy and capacitor stores electrical energy in the form of electrostatic energy. Neither of them dissipates it.

Further there is a phase shift of 90 to 0°between voltage and current.

Hence for the entire circuit consisting of resistor, inductor and capacitor, there exists some phase difference between the source voltage and current.

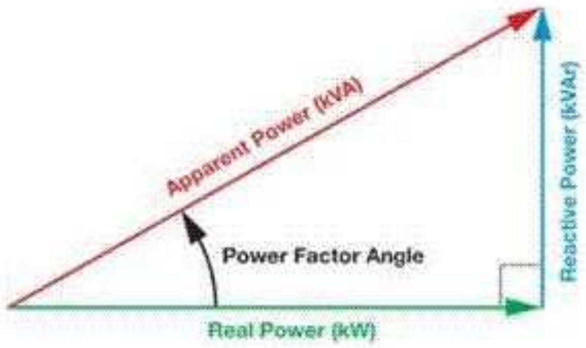
The cosine of this phase difference is called **electrical power factor**.

This factor ($0 < \cos\varphi < 1$) represents the fraction of total power that is used to do the useful work.

Apparent Power, S=VI units are V Amperes

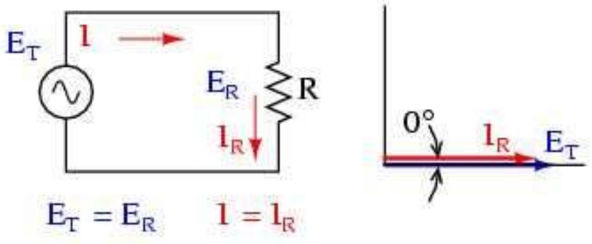
True Power or Active power, P = VI cosφ, units are Watts, W Reactive Power, Q = VI sinφ, units are VARs

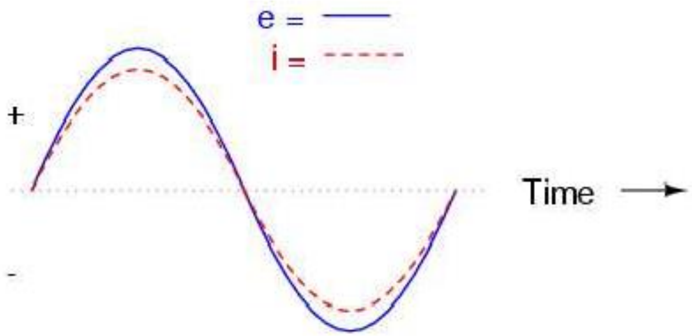
Cosφ = True Power or Active power /Apparent Power



AC resistor circuits

Pure resistive AC circuit: Resistor voltage and current are in phase.





$v = V_m \sin\omega t \quad i = I_m \sin\omega t$

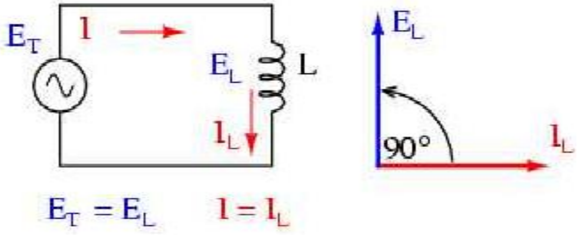
$p = vi \quad P = VI = I^2R$

Units of power are watts (W)

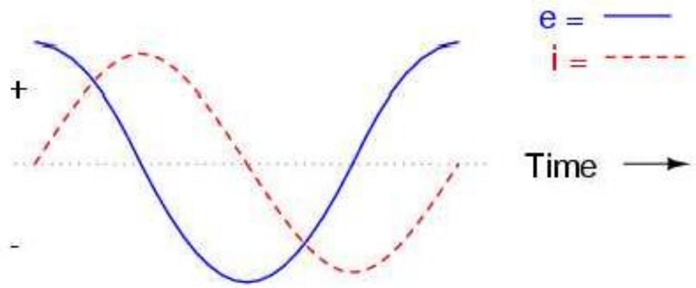
AC inductor circuits

$$e = L\frac{di}{dt}$$

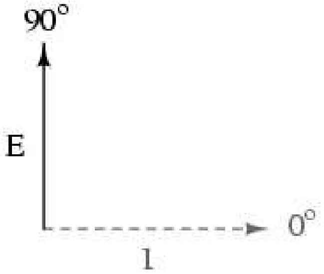
Where e is the induced emf in the inductor



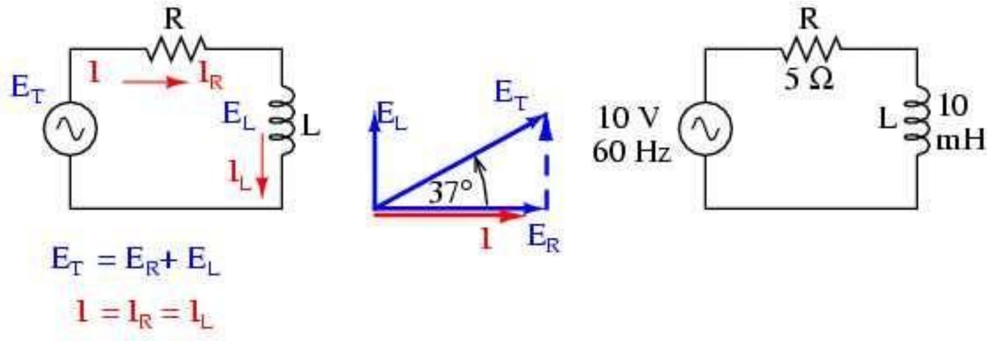
Inductor current lags inductor voltage by 90°



$v=V_m \sin\omega t$
$i=I_m \sin(\omega t-\pi/2)$
$P=VI \cos\varphi$
Since $\varphi=90^o$
$\cos\varphi=0$, $P=0$



Series resistor-inductor circuits

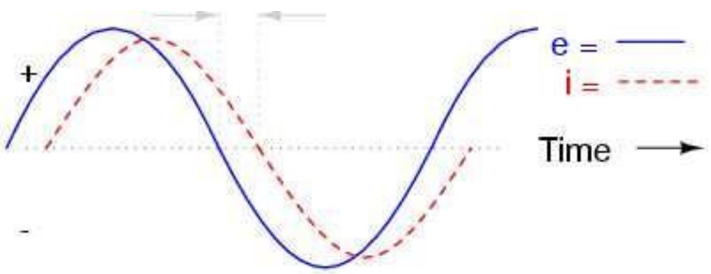


Current lags applied voltage by 0º to 90º.

Ohm's Law for AC circuits:

$$E = IZ \qquad I = \frac{E}{Z} \qquad Z = \frac{E}{I}$$

All quantities expressed in complex, not scalar, form

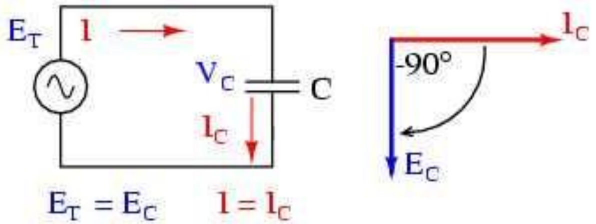


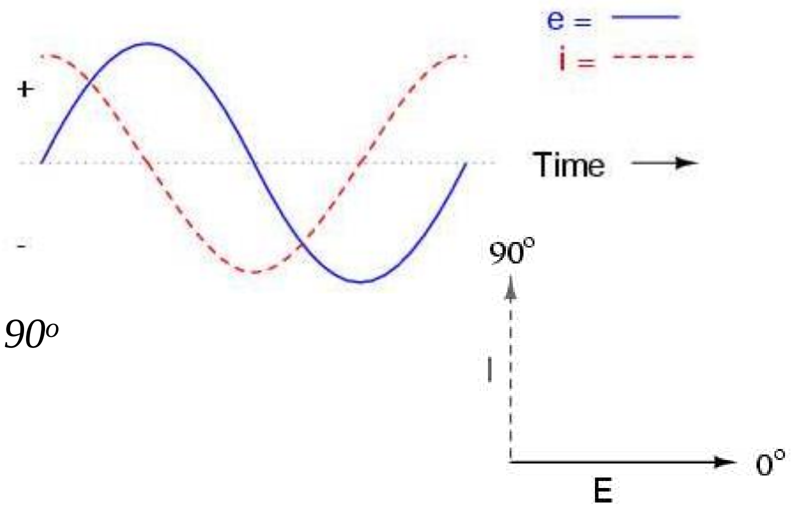
AC Capacitor Circuits

Capacitors oppose changes in voltage by drawing or supplying current as they charge or discharge to the new voltage level. The flow of electrons through a capacitor is directly proportional to the rate of change of voltage across the capacitor. This opposition to voltage change is another form of reactance.
Expressed mathematically, the relationship between the current through the capacitor and rate of voltage change across the capacitor is as such:

$$i = C\frac{de}{dt}$$

de/dt is the rate of change of instantaneous voltage (e) over time, in volts per second.

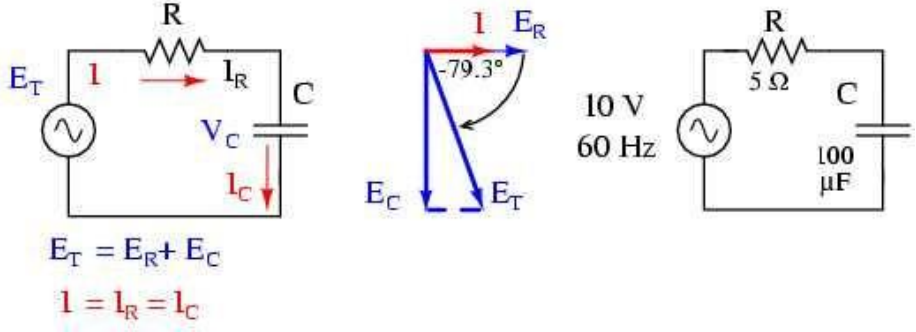




capacitor voltage lags capacitor current by 90°

$v = V_m \sin\omega t$ and $i = I_m \sin(\omega t + \pi/2)$ $P = VI\cos\varphi$; Since $\varphi = 90^o$ $\cos\varphi = 0$, $P = 0$

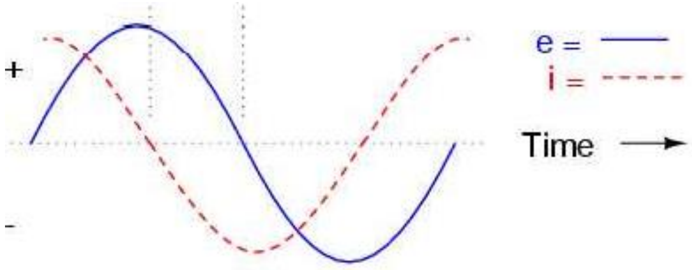
Series Resistor-capacitor Circuits



Ohm's Law for AC circuits:

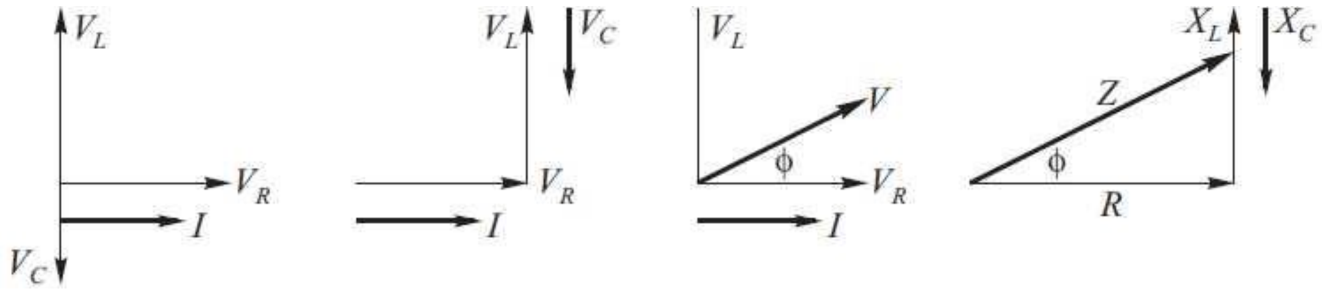
$E = IZ \qquad I = \frac{E}{Z} \qquad Z = \frac{E}{I}$

All quantities expressed in complex, not scalar, form



Series R, L, and C

The phasor diagram for the RLC series circuit shows the main features



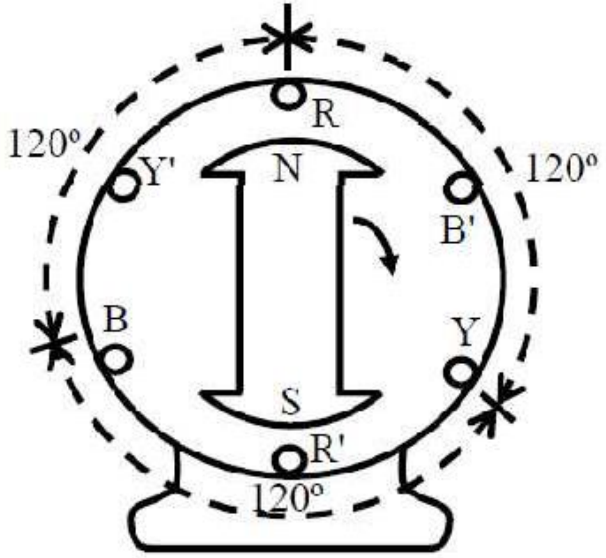
$$V = \sqrt{V_R^2 + (V_L - V_C)^2} \qquad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

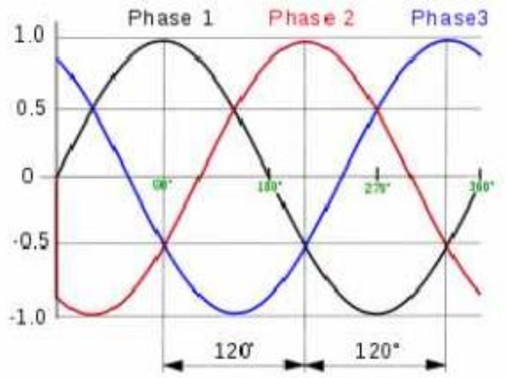
$$\phi = \tan^{-1}\frac{V_L - V_C}{V_R} \qquad \phi = \tan^{-1}\frac{X_L - X_C}{R}$$

Note that the phase angle, the difference in phase between the voltage and the current in an A.C. circuit, is the phase angle associated with the impedance Z of the circuit.

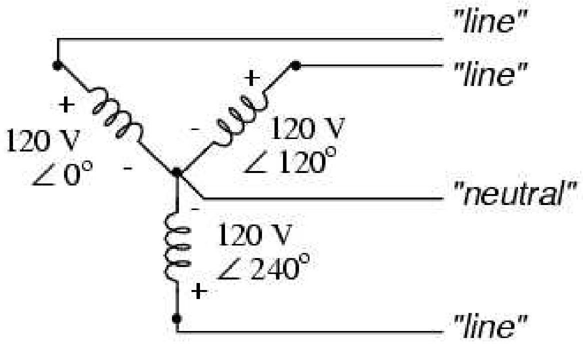
Power, P= VI cosφ

Three windings, with equal no. of turns in each one, are used, so as to obtain equal voltage in magnitude in all three phases. Also to obtain a balanced three-phase voltage, the windings are to be placed at an electrical angle of with each other, such that the voltages in each phase are also at an angle of with each other





Three-phase Voltages for Star Connection



$$e_{RN} = E_m \sin\theta; \qquad e_{YN} = E_m \sin(\theta - 120°)$$

$$e_{BN} = E_m \sin(\theta - 240°) = E_m \sin(\theta + 120°)$$

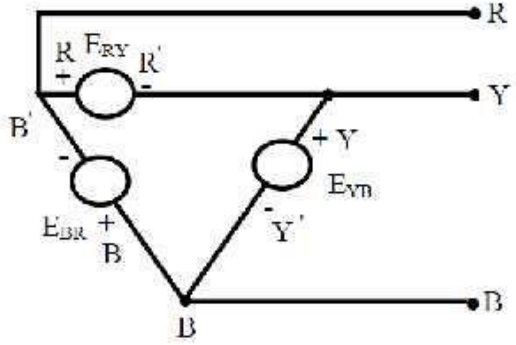
The magnitude of the line voltage, E_{RY} is $\sqrt{3}$ times the magnitude of the phase voltage E_{RN}, and E_{RY} leads E_{RN} by $30°$. Same is the case with other two line voltages

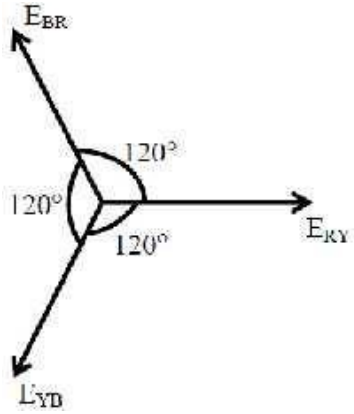
For "Y" circuits:

$$E_{line} = \sqrt{3}\ E_{phase}$$

$$I_{line} = I_{phase}$$

Three-phase Voltages for delta Connection





$E_{RY} = E\angle 0°$; $E_{YB} = E\angle -120°$; $E_{BR} = E\angle +120°$

If the phasor sum of the above three phase (or line) voltages are taken, the result is zero (0). The phase or line voltages form a balanced one, with their magnitudes being equal, and the phase being displaced from each other in sequence by $120°$.

For Δ ("delta") circuits:

$E_{line} = E_{phase}$

$I_{line} = \sqrt{3}\ I_{phase}$

Three phase Power

Apparent Power, $S = \sqrt{3}\, V_{line} I_{ine}$

$S = 3\, V_{phase} I_{phase}$

True Power or Active power, $P = \sqrt{3}\, V_{line} I_{ine} \cos\varphi$

$P = 3\, V_{phase} I_{phase} \cos\varphi$

Reactive Power, $Q = \sqrt{3}\, V_{line} I_{ine} \sin\varphi$

$Q = 3\, V_{phase} I_{phase}$

$\sin\varphi$

Thank You