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MD IFTAKHAR KABIR SAKUR

25th BATCH

COMPUTER AND COMMUNICATION ENGINEERING

International Islamic University Chittagong

COURSE CODE: CCE-1103

COURSE TITLE: Basic Electrical Engineering

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Basic concepts - Chapter-1

System of unit:-

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic Temparature	Kelvin	K
Luminous intensity (আলোর তীব্রতা)	Candela	cd.

System of Units (SI)

The derived units commonly used in electric circuit theory.

Quantity	Unit	Symbol
Electric charge	Coulomb	C
Electric potential (তড়িৎ বিভব)	volt	V
Resistance (রোধ)	ohm	Ω
Conductance (পরিবাহিতা)	Siemens	S
Inductance (আবেশাংক)	henry	H
Capacitance (ধারকত্ব)	Farad	F
Frequency (কম্পাঙ্ক)	Hertz	H

Quantity	Unit	Symbol
Force (বল)	Newton	N
Energy, work (শক্তি)	Joule	J
power	watt	W
Magnetic Flux (চৌম্বকক্ষেত্র ফ্লাক্স)	weber	Wb
Magnetic ~~Flux~~ Flux density (চৌম্বক ফ্লাক্স ঘনত্ব)	tesla	T

Factor	prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	K
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

$\boxed{\text{Charge}}$

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

চার্জ হলো একটি বৈদ্যুতিক ক্ষেত্র মাধ্যমে পারমাণবিক

কণার বৈদ্যুতিক ক্ষেত্র নিয়ে আসতি। একে e দ্বারা প্রকাশ করা হয়।

⇒ The charge $\boxed{e}$ on one electron is negative & equal in magnitude to 1.602×10^{-19} C which is called as electronic charge. The charges that occur in nature are integral multiples of the electronic charge.

=> চার্জ e এর মান -1.602×10^{-19} C যাকে electronic charge বলা হয়। ~~সেটা আসলেকে ঘটে~~ ~~সেটা~~ প্রকৃতিতে ঘটে যাওয়া চার্জগুলি বৈদ্যুতিন চার্জের একক অবিচ্ছেদ্য।

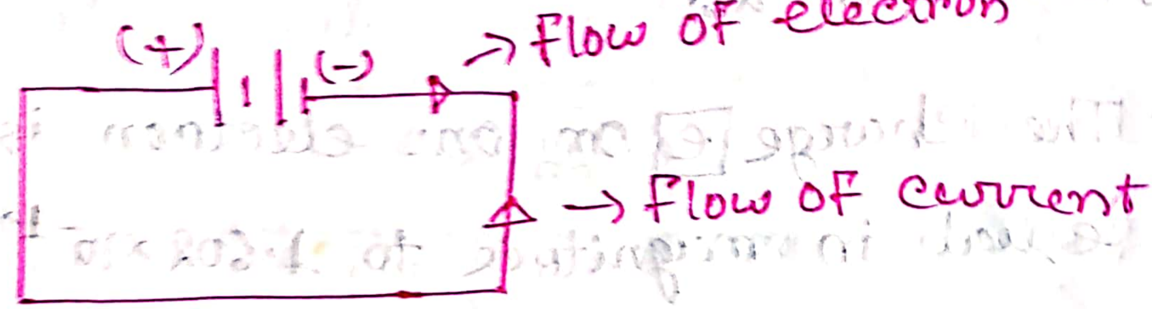
Current (I)

- ~~Dc (Direct current) is more dangerous than the AC~~
- AC is more dangerous than DC.

A.C is Five times more dangerous than DC.

[Note]

Direction of Current & Electron:-



(−) থেকে (+) এ গেলে power gain ⟩ Battery.

(+) থেকে (−) এ গেলে power loss

Measurement of current :-

(e· বিদ্যুতের মাপ)

One ampere (amp) in that current which will cause

— — —

Alexander - Sadiku

(current-1)

Electrical current:

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

$$F = \frac{2\times10^{-7} I_1 I_2 L}{s}$$

F = Force in newton
I = Current in Ampere
L = parallel length in meter
s = Distance of wire newton

• The unit of ampere can be derived as

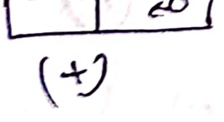
$\boxed{1 \ A = 1 \ C/s}$

প্রতি সেকেন্ডে 1C চার্জের আদান-প্রদানকে ও 1অ্যাম্পিয়ার বলে।

- A direct current (dc) is a current that remains constant with time.

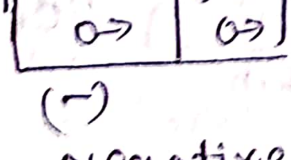
- An alternating current (AC) is a current that varies sinusoidally with time. (reverse direction)

The direction of current flow:- (Current-2)



(+)

positive ions



(−)

Negative ions

4) A conductor has a constant current of ~~5A~~ .5 A.

How many electrons pass a fixed point on the conductor in one minute?

Ans:- we know,

$1 A = 1 C/s$.

$\therefore 5 A = 5 C/s$. — (i)

$1 min = 60 s$.

ny, $1 s = \frac{1 min}{60}$ — (ii)

(ii) merging with (i)

$\frac{min}{electron}$

$\frac{1 e}{1 ele}$

$5 A = \frac{5 C}{\frac{1 min}{60}}$

$= \frac{5 \times 60 C}{1 min} = 300 C/min$ — (iii)

$1 \text{ electron} = 1.602 \times 10^{-19} C.$

$$\therefore \frac{1}{1.602\times10^{-19}} = \frac{1 \text{ electron}}{1 \, C}$$

$$\therefore \frac{300 \frac{C}{min}}{1.602\times10^{-19} \frac{electron}{C}}$$

$$= \frac{300}{1.602\times10^{-19}} \times \frac{C}{min} \times \frac{electron}{C}$$

$$= \frac{300}{1.602\times10^{-19}} \text{ electron/}\cancel{\text{coloumb}} \text{ min}$$

$$= 1.87\times10^{21} \text{ electrons/min}$$

$\boxed{\text{Voltage}}$ (1)

⇒ Voltage (Potential Difference) is the energy required to move a unit charge through an element, measured in volts (V).

বিভব- পার্থক্য

কোনো একক বস্তুকে ইউনিট চার্জকে কোন বিন্দুর

দ্বারা জায়গা পরিবর্তন করালে তাকে ভোল্টেজ (v) বলে।

⊡ Mathematically,

$$v_{ab} = \frac{d(w)}{dq} \quad \text{volt}$$

→ w is energy in joules (J) and q is charge in ~~colo colu~~ coulomb (C)

⇒ Electric voltage, V_{ab} is always across the circuit element or between two points in a circuit.
(তড়িৎ বিভব, v_{ab} সবসময় সার্কিট এর উপাদানে নয়তো সার্কিটের দুইটি পয়েন্টের মাঝে থাকে)

→ $V_{ab} > 0$; that means the potential (বিভব) of a is higher than potential of b.

→ $V_{ab} < 0$; that means the potential of a is lower than potential of b.

power of Energy:

power is the time rate of expending or absorbing energy, measured in watts (W).

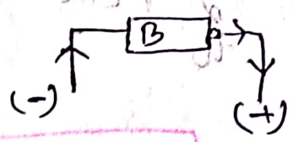
1 electron

Mathematical expression:-

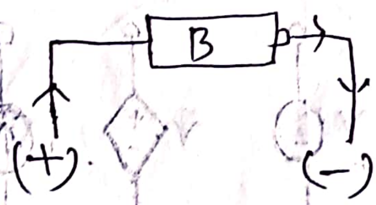
$$P = \frac{d(w)}{dt} = \frac{d(w)}{dq} \cdot \frac{d(q)}{dt} = vi$$

Note:-

* (−) থেকে (+) এ গেলে ব্যাটারি power gain (অর্জন) করে।



* (+) থেকে (−) এ গেলে ব্যাটারি power loss (হারায়) করে।



Power & Energy (ক্ষমতা ও শক্তি)

1. The law of conservation of energy

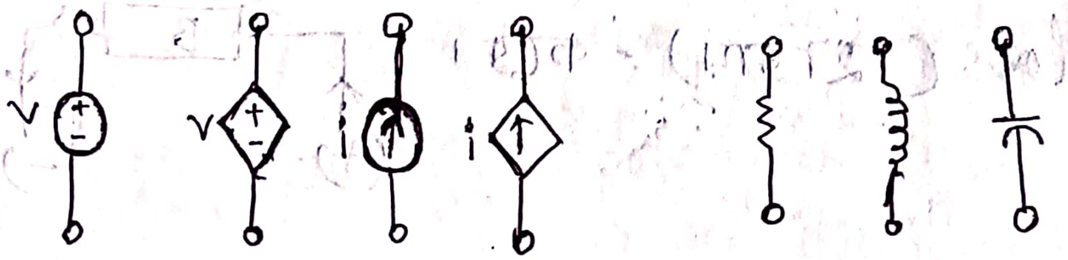
$$\sum P = 0$$ (শক্তির নিত্যতার সূত্র)

2. Energy is the capacity to do work, measured in Joules (J)
(কাজ করার ক্ষমতাকে শক্তি বলে)
[এর একক হলো জুল]

3. Mathematical expression

$$W = \int_{t_0}^{t} P\,dt = \int_{t_0}^{t} vi\,dt$$

Circuit elements



(a) (b) (c) (d) (e) (f) (g)

Independent — Dependent

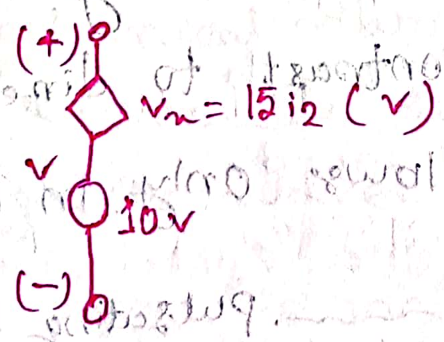
Active Elements — Passive Elements

- A dependent source is an active element in which the source quantity is controlled by another voltage or current.

- They have four different types : VCVS, CCVS, VCCS, CCCS. Keep in minds the signs of dependent sources.

$\boxed{\text{Example-02}}$

Obtain the voltage v in the branch shown in Figure 2.1.1 P for $i_2 = 1A$.



Ans:- Voltage v is the sum of the current independent voltage 10-v & dependent voltage source v_x.

Note that the factor 15 multiplying the control current carries the units Ω.

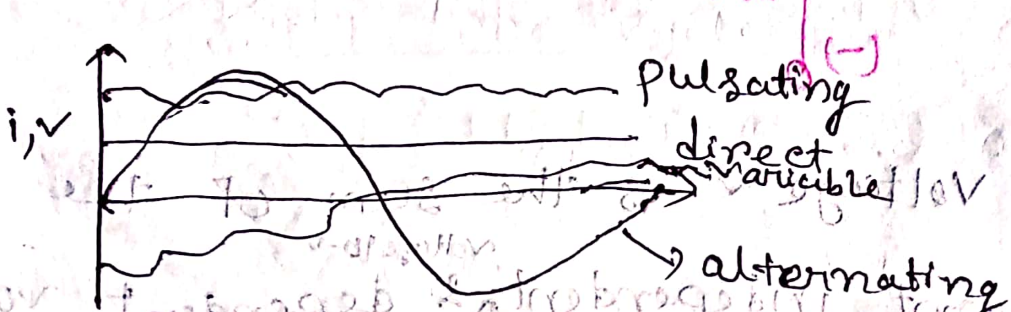
Therefore, $v = 10 + v_x$

$= 10 + 15(1) = 25\ V$

(Ans)

Alternating Current (AC) :-

Alternating current (AC) is an electric current which periodically reverses direction, in contrast to direct current (DC) which flows only in one direction.



It actually delivered to businesses, residences.

Formula:-

1. $\omega = 2\pi F$

2. $F = 1/T$

3. $\theta = \omega t$

period:- A length ~~of~~ or ~~pr~~ proportion of time.

The interval of time between successive occurrences of the same state in an oscillatory or cyclic phenomenon, such as a mechanical vibration, an alternating current, a variable star, or an electromagnetic wave.

Cycle:- A cycle is one complete repition of the sine wave pattern. It is produced by one complete revolution (360 degree) of the AC generator.

An oscillation or cycle, of the AC (Alternating Current) is defined as a single change from up to down to up, or as a change from positive to Neg. to pos. this is what said to be as cycle.

Frequency:-

Alternating current (AC) frequency is the number of cycles per second in an ac sine wave. Frequency is the rate at which current changes direction per second. Hertz (Hz) = One hertz is equal to one cycle per second.

Cycle = One complete wave of AC or votage.

Formula:-

$$\boxed{i = I_m \sin \omega t}$$

Or, $i = I_m \sin 2\pi f t$

I_m = Current in ampere (amp) (maximum)

i = Current in Ampere (minimum) (amp)

ω = frequency.

t = time. (s)

f = ~~F~~ Force in Newton (cycle/sec)

~~Math~~

* Sine have many angle when it value will reach $-\frac{1}{2}$ or -0.5 like $210°$, $330°$, $570°$ & so on.

Frequency:-

Audio Frequency range = 20 Hz - 20 KHz

Radio Frequency range = 10 KHz - ~~20~~ 30 GHz

or 20 KHz - 300 GHz

Other Frequencies,

Low Frequency (LW) → (10 to 1) Km → ~~30-300MHz~~ (30 to 300) KHz

Medium Frequency (MF) → (1 Km to 100m) → 300 KHz to 3 MHz

High Frequency (HF) → (100 to 10) m → (3 - 30) MHz

Very High Frequency (VHF) → (10 to 1) m → (30-300) MHz

Ultra High Frequency (UHF) → (1m to 10 cm) → 300 MHz to 3 GHz

Super High Frequency → (10 c.m to 1 c.m) → (3 to 30) GHz

Quantity of Electricity:-

The Quantity of electricity is represented by Coulomb.

Coulomb:- One Coulomb in that quantity of electricity which passes a references(संदर्भ) point on a Conductor in 1 second when the Conductor carries a steady current 1 amp. The relation between current & Coulomb is defined by the following equation:-

$$\boxed{Q = IT}$$

Where,

Q = quantity of Electricity

I = current

T = Time

Resistance :- (রোধ)

The property of a conductor (পরিবাহী) which requires the expenditure (ব্যয়) of energy by the moving electrons is called resistance. The unit of Resistance is **Ohm** as defined.

Ohm :-

One ohm is the resistance of a conductor in which energy is lost at the rate of 1 Joule/sec. (1 watt) when the current is 1 amp. The relation between energy and resistance is

$$\boxed{P = I^2 R}$$

P = Power (watt)
R = Resistance (ohm)
I = current

Potential Differences :-

Potential Difference is the gain or loss of energy per unit quantity of electricity

Electromotive Force:-

The rise in potential associated with battery, generator or other device in which energy is imparted to move charges will, in what follows, be called an electromotive force (emf) ~~den~~ devoted by "e".

Voltage Drop:-

The fall in ~~resistance~~ potential associated with a resistance, in which energy is given up by the moving of positive charges, will be ~~eo~~ a voltage drop denoted by v. $\frac{W}{Q}$

All of the above defination units are volt.

Volt:- One volt is the potential difference between two points on a circuit when the energy involved in moving 1 Coulomb

from one point to the other in 1 joule.
potential difference is defined by the equation,

$$\boxed{E \text{ or } V = \frac{W}{Q}}$$

where,
E = V = potential difference
W = Energy
Q = Quantity of Electricity

Chapter - 3

power & Energy Calculation:-

We know from potential difference

$$\boxed{E \text{ or, } V = \frac{W}{Q}} \quad \text{--- (1)}$$

Also, defination from quantity of electricity,

$$\boxed{Q = IT} \quad \text{--- (2)}$$

From,

$$\boxed{E = \frac{W}{IT}}$$

वा, $\boxed{W = EIT}$ — (3)

Or, $\boxed{W = VIT}$ — (4)

power is defined as the time rate of doing work,

$$\boxed{P = \frac{W}{T} = \frac{VIT}{T} = VI}$$

$\therefore P = VI$

If we know the resistance, power can also be calculated as,

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

$\therefore \boxed{P = I^2R}$ — (6)

P = power
I = ampere
R = Resistance

$= \left(\frac{P}{V}\right)^2 R$ $\left[\because I = \frac{P}{V}\right.$

So,

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

वा, $P = \frac{V^2}{R}$ —— (7)

So, Summary of all equation be like:-

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

Ohm's law:-

We know,

$P = VI$ —— (1)

Also, $P = I^2R$ —— (2)

From (1) & (2),

$VI = I^2R$

वा, $V = IR$ —— (3)

वा, $R = \frac{V}{I}$ —— (4)

वा, $I = \frac{V}{R}$ —— (5)

③, ④ & ⑤ are all ~~maintained~~ mathematical representation of ohm's law.

It stated that,

The current in a metal conductor which is maintained at a constant temperature is proportional to the potential difference V between its terminals. (প্রান্ত)

কোনো পরিবাহীর ভিতর দিয়ে যে তড়িৎ প্রবাহিত হয় তা দুই প্রান্তের ~~ভিভব~~ বিভব পার্থক্য এর সাথে তাপমাত্রার অনুপাতের সমান।

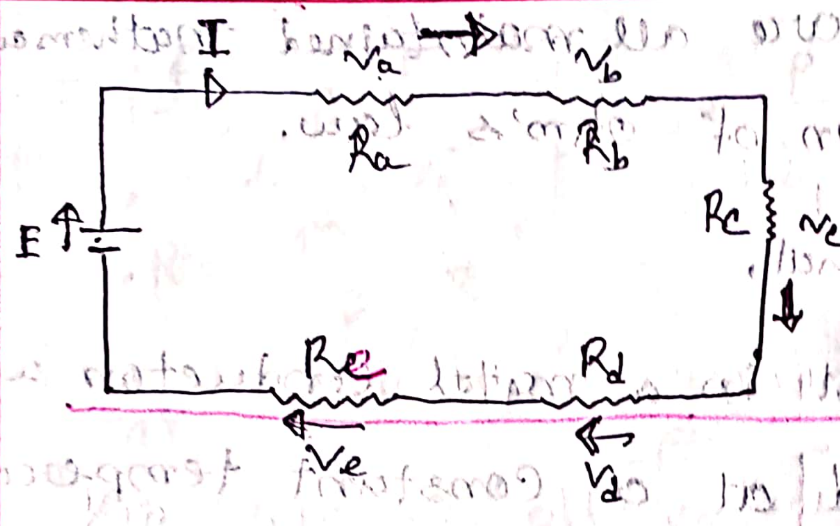
Series

$\boxed{\text{Linear \& Non-Linear Circuit}}$

Series ckt:-

① Kirchhoff's voltage law:-

A series circuit can be represents as,



Let the energy gained by the electron passing through the battery be w, and let the energy lost in the various resistances be w_a, w_b, w_c, w_d, w_e respectively.

So, from the law of conservation of energy,

[Note:- The law of conservation of energy states that energy can neighther be created nor destroyed.- only converted from one form of energy to another. This means that a system always has the same amount of energy, unless, something added from outside).

$\therefore W = W_a + W_b + W_c + W_d + W_e$ —— (1)

Dividing both side by the quantity of electricity in Q,

$$\frac{W}{Q} = \frac{W_a}{Q} + \frac{W_b}{Q} + \frac{W_c}{Q} + \frac{W_d}{Q} + \frac{W_e}{Q} \quad \text{—— (2)}$$

But W/Q is the defination of the electro-motive force (তড়িৎচালক বল) of the battery,

and $\frac{W_a}{Q}$ is the voltage drop V_a across the resistance, R_a and so on.

So, equation (2) can be written as,

$$E = V_a + V_b + V_c + V_d + V_e \quad \text{—— (3)}$$

If the current (I) flows through the circuit then we can write,

$V_a = IR_a$ and so on.

So,

$$E = IR_a + IR_b + IR_c + IR_d + IR_e \quad \text{---} (4)$$

This relationship is known as

"Kirchhoff's voltage law (KVL)"

Also,

Around any complete circuit the algebric sum of the electromotive forces equal the algebric sum of the voltage drops.

OR, Can be written as,

$$\boxed{\sum E_i = \sum V_i}$$

Equivalent Resistence :- (সমতুল্য রোধ)

We know,

$$E = IR_a + IR_b + IR_c + IR_d + IR_e$$

Or, $E = I(R_a + R_b + R_c + R_d + R_e)$

Sum. of resistance can be written as,

$$R_0 = R_a + R_b + R_c + R_d + R_e$$

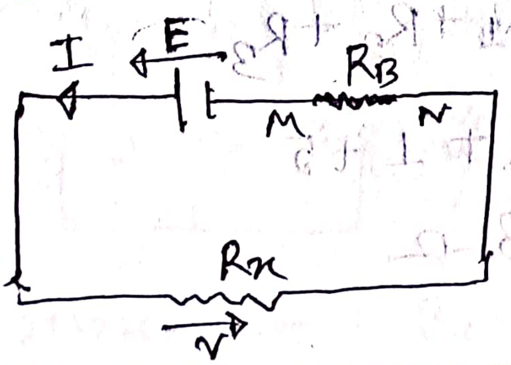
So, R_0 = equivalent resistance of series ~~ckt~~ circuit.

The equivalent Resistance of a series circuit is the sum of the individual resistance.

Internal Resistance of emf source:-

(তড়িৎ চালক শক্তির অভ্যন্তরীণ রোধ)

I



Applying KVL in ckt,

$$E = IR_B + IR_x \quad \text{—} \ (1)$$

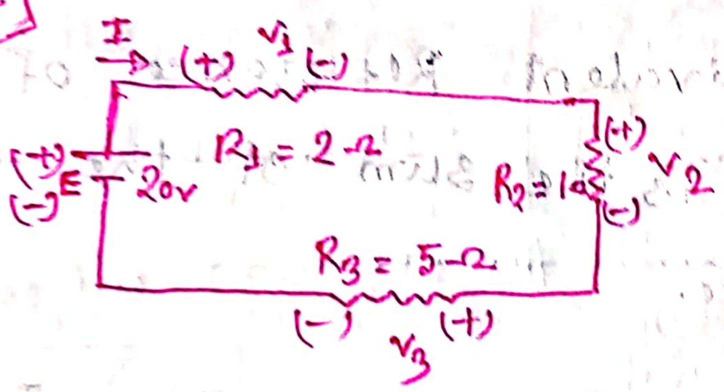
বা, $$E = IR_B + V \quad \text{—} \ (2)$$

বা, $$V = E - IR_B \quad \text{—} \ (3)$$

From, (1)

$$I = \frac{E}{(R_B + R_x)} \quad \text{—} \ (4)$$

$\boxed{\text{Example}}$



$\boxed{a}$ Find the total resistance for the series

([illegible])

Ans :- $R_0 = R_1 + R_2 + R_3$

$= 2 + 1 + 5$

$= 8\Omega$

(b) Calculate the current I :-

$$I = \frac{E}{R_0} = \frac{20}{8} = \frac{5}{2}\ A. = 2.5A.$$

(c) Determine the voltage V_1, V_2 & V_3,

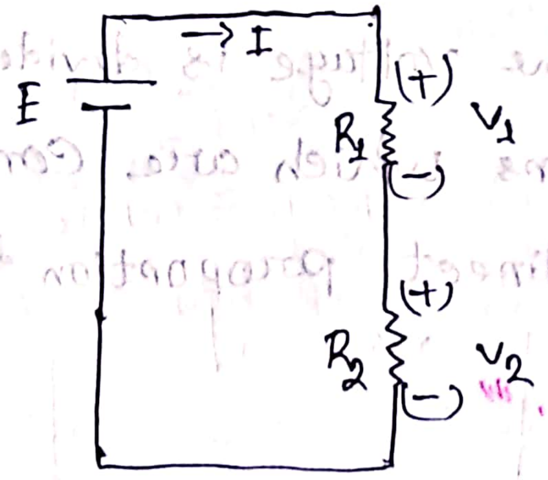
$$V_1 = IR_1 = 2.5 \times 2\ v = 5\ v.$$

$$V_2 = IR_2 = 2.5 \times 1 = 2.5\ v.$$

$$V_3 = IR_3 = \frac{5}{2} \times 5 = \frac{25}{2} = 12.5\ v.$$

(Ans)

Voltage divider Rule (Boylestad)



Total Resistance, $R_T = R_1 + R_2$

and, $I = \frac{E}{R_T}$

Also, $V_1 = IR_1$

$= \frac{E}{R_T} \cdot R_1$

Or, $\boxed{V_1 = \frac{R_1}{R_T} \cdot E}$

Similarly,

$V_2 = IR_2$

$= \frac{E}{R_T}$

Or, $\boxed{V_2 = \frac{R_2}{R_T} \cdot E}$

In note Formate we can write,

$\boxed{V_x = \frac{R_x}{R_T} \cdot E}$ → Voltage divider rule

R_x = যেই রোধের কারণে বিভক্ত হয়

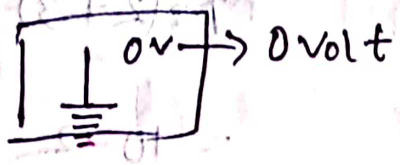
R_T = Total Resistance

E = Value of Energy

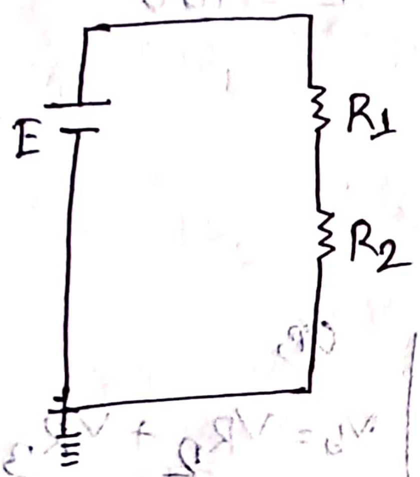
Voltage divider rule :-

The main concepts of this voltage divider rule is "the voltage is divided between two resistors which are connected in series in direct proportion to their resistance."

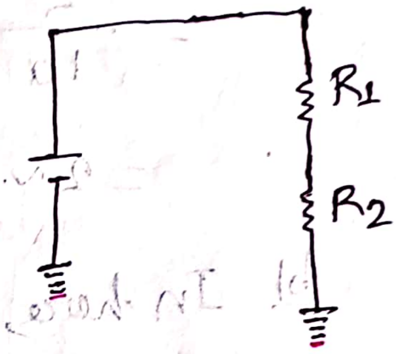
⏚ Symbol mean ground/Earth potential

Or, 

Circuit Representation:-



Or,



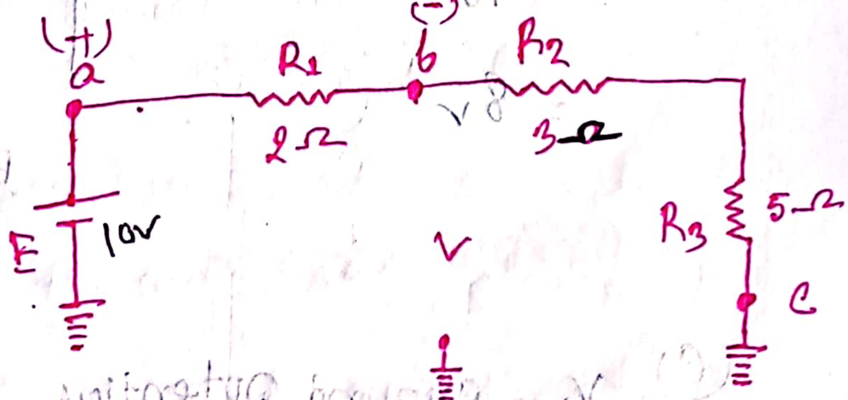
Example

For the network of following Figure Calculate:-

a) V_{ab}

b) V_b

c) V_c



Solution:-

a)

$$R_T = (2+3+5)\,\Omega = 10\,\Omega$$

$$R_1 = 2\,\Omega$$

$$E = 10V$$

$$V_{ab} = \frac{R_1}{R_T} \cdot E = \frac{2}{10} \cdot 10 = 2\,V.$$

b) In here,

$$V_b = \frac{R_2 + R_3}{R_T} \cdot E = \frac{3+5}{10} \cdot 10 = 8\,V$$

or,

$$V_b = V_{R_2} + V_{R_3} = \frac{R_2}{R_T} \cdot E + \frac{R_3}{R_T} \cdot E = \frac{(R_2+R_3)}{R_T} \cdot E$$

$$E = V_{ab} + V_b$$

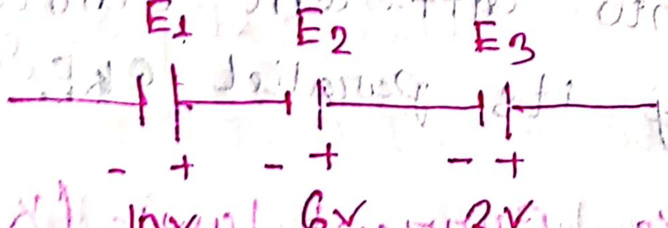
$$V_b = E - V_{ab} = 10 - 2 = 8\,V.$$

(Ans)

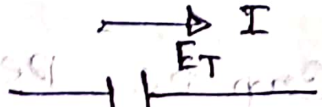
(c) V_c = ground potential $= 0\,\Omega$

Voltage sources in series :-

1)

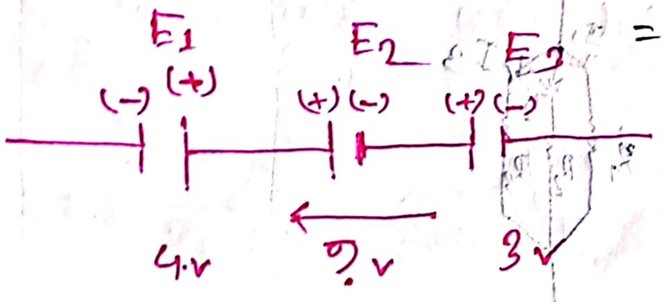


=>

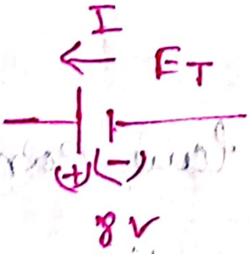


$$E_T = E_1 + E_2 + E_3$$
$$= (10 + 6 + 2)\,v$$
$$= 18v$$

2)



=>



$$E_T = E_2 + E_3 - E_1$$
$$= 9 + 3 - 4$$
$$= 8v$$

(Ans)

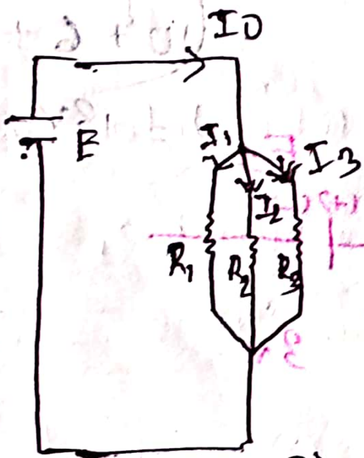
parallel circuit (সমান্তরাল সার্কিট) :-

If two elements, brands or networks are connected in a common point this is called parallel circuit.

Or, If the total current of the circuit is divided into different current then we can say its parallel ckt.

Kirchhoff's Current laws :- (KCL)

A parallel circuit can be represent.



Pic-3

So, Kirchoff's current law can be stated that, at any junction point, the sum of the currents entering the point equals the sum of the currents leaving the point. In a symbolic manner,

$$\Sigma I_i = \Sigma I_o$$

where,

I_i = Incoming current

I_o = Outgoing "

So, According to KCL from the picture we can write:-

$$I_0 = I_1 + I_2 + I_3 \quad \text{—①}$$

If we apply KVL In pie for individual branch, then we can write,

$$E = I_1 R_1$$

বা, $I_1 = \dfrac{E}{R_1}$ —②

and, $E = I_2 R_2$

বা, $I_2 = \dfrac{E}{R_2}$ —③

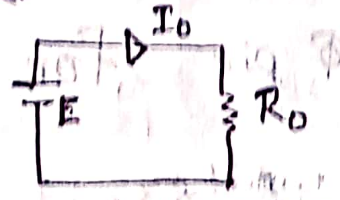
and, $E = I_3 R_3$

বা, $I_3 = \dfrac{E}{R_3}$ —④

putting the value of I_1, I_2 & I_3 in equation ①

$$I_0 = \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3} \quad \text{—— (5)}$$

So, the pic can also be re-draw as like:-



-[pic-4]

R_0 is the total an equivalent resistance of parallel resistance of pic-3

So, from [pic-4] we may write,

$$\boxed{I_0 = \frac{E}{R_0}} \quad \text{—— (6)}$$

From-5, we can write,

$$\frac{E}{R_0} = \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3}$$

$$\text{or, } \frac{1}{R_0} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\text{or, } \frac{1}{R_0} = \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$$

$$\therefore R_0 = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

The resistance is called the group resistance or the equivalent resistance of parallel circuit.

The rule of calculating parallel resistance can be stated that,
The equivalent resistance of a parallel circuit is the reciprocal (ব্যস্তানুপাতিক) sum of the individual resistance.

Conductance:- (পরিবাহিতা)

The reciprocal (ব্যস্তানুপাতিক) of a resistance is called conductance. It is denoted by G. and its units is represent mho (spell ba of ohm) Also the symbol of mho is ℧

$$\boxed{G = \frac{1}{R}}$$

VVIm

Show that if two resistance R_1 & R_2 are in parallel the equivalent resistance is given by,

$$\boxed{R_o = \frac{R_1 R_2}{R_1 + R_2}}$$

Example:-

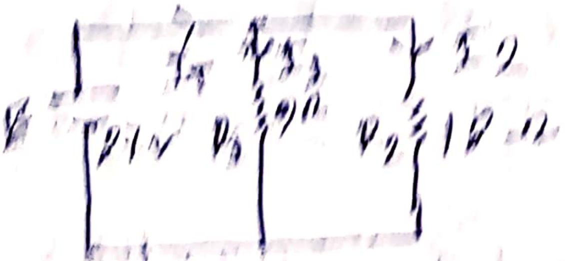
For the parallel network of following figure calculate

a) Find R_T b) Determine I_T

c) Calculate I_1 & I_2

d) Determine power for each ~~position~~ Resistor.

e) Find G_1 & G_2.



(a) $R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{9 \times 18}{\frac{9\times 18}{9+18}} = \frac{27}{162} = \frac{1}{6}$

$= \frac{162}{27} = 6\ \Omega$

(b) we know,

$E = I_T R_T$

or, $I_T = \frac{E}{R_T} = \frac{27}{6} = \frac{9}{2}\ A = 4.5\ A.$

(c) we know,

$V_1 = I_1 R_1$

or, $I_1 = \frac{V_1}{R_1} = \frac{27}{9} = 3\ A$

$V_2 = I_2 R_2$

or, $I_2 = \frac{V_2}{R_2} = \frac{27}{18} = \frac{3}{2} = 1.5\ A.$

$\boxed{d}$

$P_1 = V_1 I_1 = E I_1 = 27 \times 3 = 81$ watt

$P_2 = V_2 I_2 = E I_2 = 27 \times 1.5 = 40.5$ watt

$\boxed{e}$

$G_1 = \frac{1}{R_1} = \frac{1}{9} = 0.11$ ℧

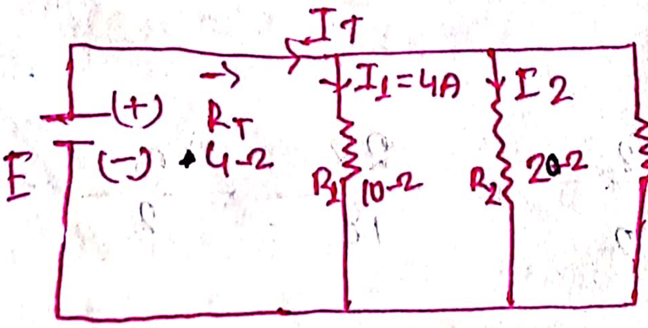
$G_2 = \frac{1}{R_2} = \frac{1}{18} = 0.05$ mho

$\boxed{f}$ Given the information provided in Fig. Find

a) Determine R_3 b) Calculate E

c) Find I_T d) Find I_2

e) Determine P_2



$\boxed{a}$ We know,

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

Or, $\frac{1}{4} = \frac{1}{10} + \frac{1}{20} + \frac{1}{R_3}$

Or, $0.25 = 0.1 + 0.05 + \frac{1}{R_3}$

Or, $0.25 - 0.1 - 0.05 = \frac{1}{R_3}$

Or, $\frac{1}{R_3} = \cancel{\frac{7}{20}}\ \frac{1}{10}$

Or, $R_3 = 10\ \Omega$

(Ans)

b) $E = V = I_1 R_1 = (4 \times 10)v = 40v$

d) we know,

$V = I_2 R_2$; or, $I_2 = \frac{V}{R_2} = \frac{40}{20} = 2A.$

~~So, $I_T = I_1 + I$.~~

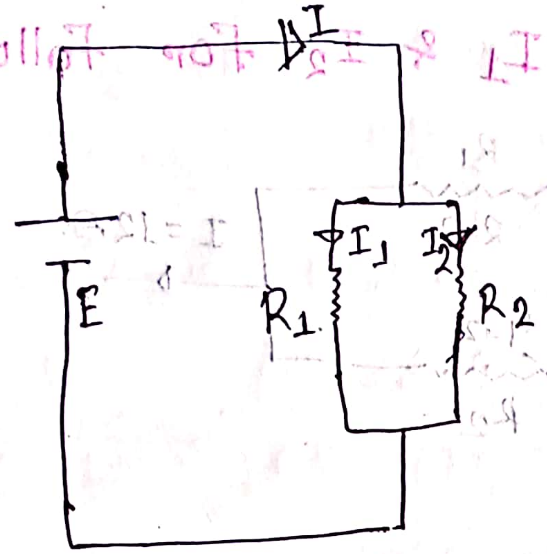
c) $V = E = I_T R_T$

Or, $I_T = \frac{E}{R_T} = \frac{40}{4} = 10\ A.$

e) $P_2 = V_2 I_2 = 40 \times 2 = 80$ watt

[we can also use,
$P = I_2^2 R_2 = \frac{V_2^2}{R_2}$]

For two resistance connected in parallel :-



In here,

$$I = \frac{E}{R_T} \quad \& \text{ also, } R_T = \frac{R_1 R_2}{R_1 + R_2}$$

and, $I_x = \frac{I_x R_x}{R_T}$

$I_x = \frac{I \cdot R_x}{R_T}$

so, $I_1 = \frac{I \cdot R_T}{R_1}$

or, $I_1 = \frac{\frac{R_1 R_2}{R_1 + R_2}}{R_1} \cdot I$

$$= \frac{R_1 \cdot R_2}{R_1 (R_1 + R_2)} \cdot I$$

$$\therefore I_1 = \frac{R_2}{(R_1 + R_2)} \cdot I$$

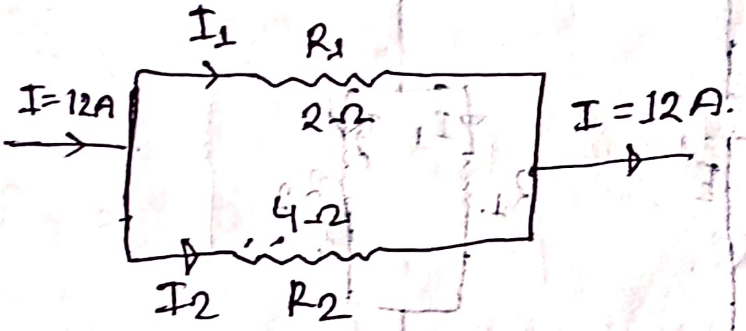
$$I_2 = \frac{R_T}{R_2} \cdot I$$

$$= \frac{\frac{R_1 R_2}{R_1 + R_2}}{R_2} \cdot I$$

$$= \frac{R_1 R_2}{R_2 (R_1 + R_2)} \cdot I$$

$$\therefore I_2 = \frac{R_1}{(R_1 + R_2)} \cdot I$$

Example Determine the magnitude of the current I_1 & I_2 for following figure:-



=> From CDR,

$$I_1 = \frac{R_2}{R_1+R_2} \cdot I$$

$$= \frac{4}{2+4} \cdot 12$$

$$= \frac{48}{6} = 8A.$$

From KCL,

$$I = I_1 + I_2 \qquad [\because \Sigma I_{entering} = \Sigma I_{leaving}]$$

or, $12 = 8 + I_2$

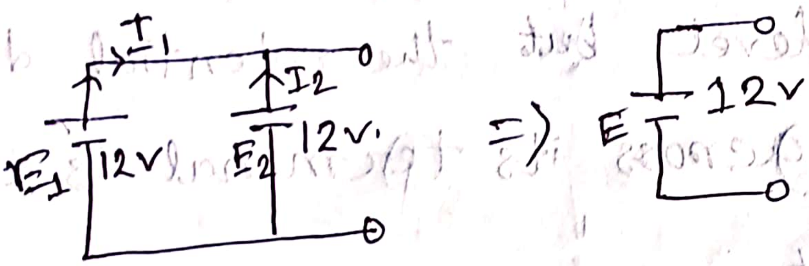
or, $I_2 = 4A.$

Or, $I_2 = \frac{R_1}{R_1 + R_2} \cdot I$

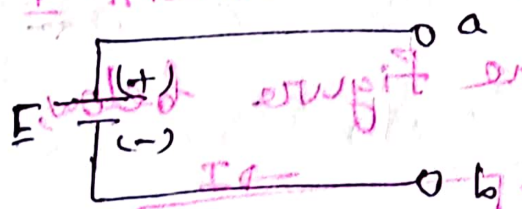
$= \frac{2}{2+4} \cdot 12$

$= 4A.$

Voltage source in parallel:-



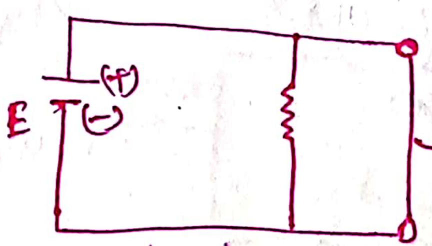
Open & short circuit:-



For open ckt current, $I = 0$

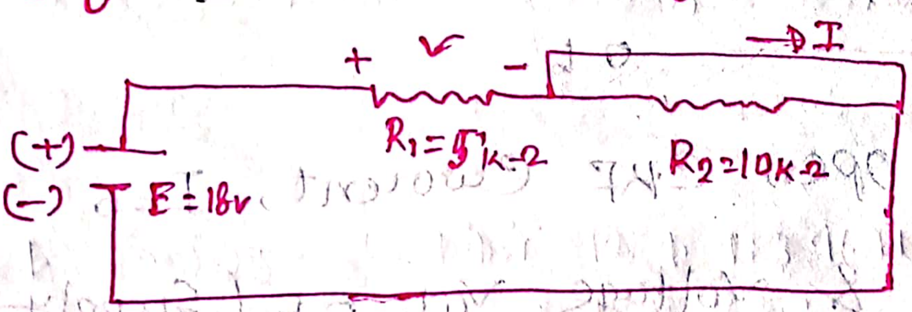
& voltage $V_{ab} = E$ (Supply voltage)

An open circuit can have a potential difference (voltage across its terminals but the current is always zero amperes.



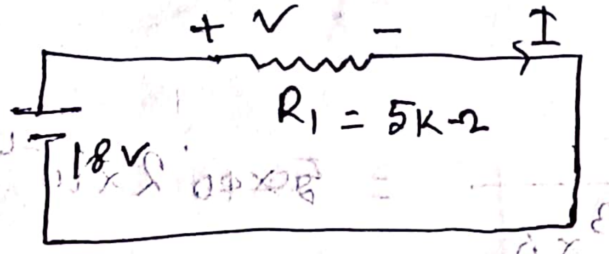
A short circuit can carry a current of any level but the potential difference (voltage) across its terminal is always zero watt.

Example :- Calculate the current I & the voltage V for the figure below,



Ans :- R_2 is a short circuited

so, $R_2 = 0$ & the circuit will be,



$[\because 5k\Omega = 5\times10^3\Omega$

So, $I = \frac{E}{R_1} = \frac{18}{5\times10^3} =$

$= 0.0036\,A$

$= 3.6\,mA$

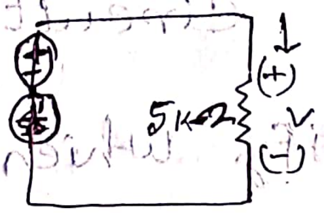
and $V = E = 18V$

(Ans)

Type-01

Math Solve

E, R



Determine current (i), the conductance G, the power P

Solution:- $E = V = 30V$

$R = 5k\Omega = 5\times10^3\Omega$

$i = \frac{V}{R} = \frac{30}{5\times10^3} = 6\times10^{-3} = 6\,mA$ (Ans)

Conductance:-

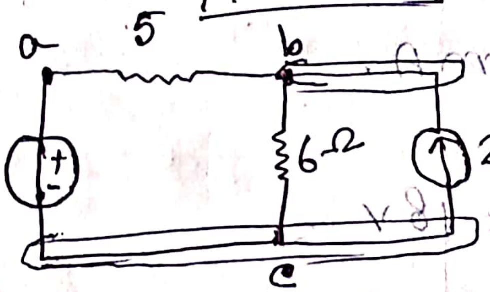
$$G = \frac{1}{R} = \frac{1}{6\times10^{3}\times5} = 2\times10^{-4}\ \text{mho}$$

Power:-

$$P = vi = 30(6\times10^{-3}) = 180\ \text{mW}$$

$\boxed{\text{Type-02}}$

$\boxed{\text{Math}}$-02



Determine the number of branches and nodes in the circuit shown in figure. Indentify which elements are in series and which are in parallel.

⇒ **Branches:-** প্রত্যেকটা পথকে ব্রাঞ্চ বলে। electricity বিভক্ত হলে তা ব্রাঞ্চ।

A branch represents a single element such as a voltage source or a resistor.

The element connected to an electrical circuit is generally two terminal element. when, one circuit element is connected to the circuit, it connects itself throug through both of its terminals, to be a part of a closed path.

Nodes:- [মনে রাখো, যেখানে কারেন্ট বিভাজিত হয়]

Node is a point in a network where (যেখানে) two or more branches are connected. A node is usually indicated by a dot in a circuit. If a short circuit connects two nodes, the two nodes constitude a single node.

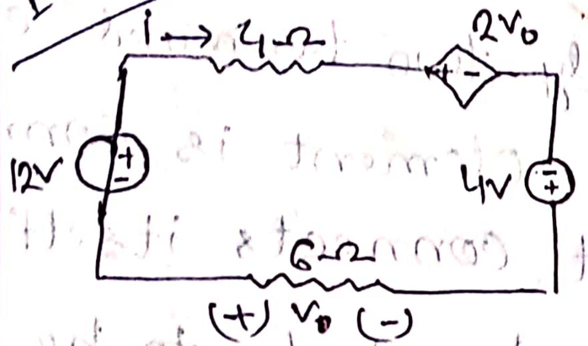
Answer of math - 02

Total number of branches are 4.

Node:- Total numbers of nodes are 3.

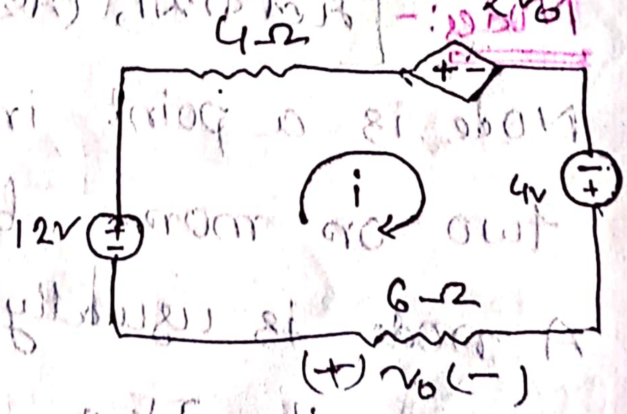
Ohm's law It is a formula used to calculate the relationship between voltage, current & resistance in an electrical circuit. Law, $\boxed{E = IR}$; $V = IR$

Example 2.5 Type - 03



(a)

⇒ Determine v_0 & i in the circuit shown in Figure.



Ans:-

We apply KVL in the figure,

~~-12 + 4~~

$-V_1 + V_2 + V_3 - V_4 + V_5$

$= -12 + 4i + 2v_0 - 4 + 6i$

$= -16 + 10i + 2\times 6i$ [∵ $v_0 = -6i$ Applying ohm's law to the 6 Ω resistor gives]

$= -16 + 10i - 12i$

$= -16 - 2i$ Or, $i = \frac{16}{-2} = -8A.$

$= 8A.$

$$So,\ v_0 = \cancel{I_0}\, iR$$
$$= 8 \times 6\ V$$
$$= 48v.$$

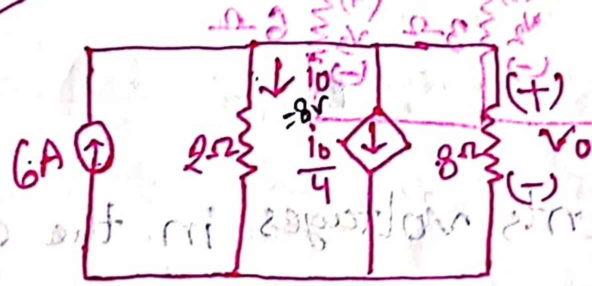
নিয়ম:-

ব্যাটারি (-) হলে (+)
(ভ)↑ থেকে শুরু। মোড়ে গেলে চিহ্ন পাল্টে যাবে।

⊛ ভোল্টেজ বের করতে বললে ভোল্টেজ এর সূত্র ব্যবহার করতে হবে।

$\boxed{\text{Type - 04}}$

Example 2.7



Find v_0 and i_0 in the circuit :-

⟹ Applying KCL,

$\cancel{-\ 6 - i_0 - \frac{i_0}{4}}$

$\cancel{i_0 = \frac{6}{2} = 3\Omega = I_1}$

$\cancel{I_2 = \frac{i_0}{4} = \frac{3}{4}}$

$$6 + \frac{i_0}{4} = i_0$$

$$or,\ \frac{24 + i_0}{4} = i_0$$

$$\cancel{I_0 =}\ or,\ 24 + i_0 = 4i_0$$

Theory

Current Divider Rule

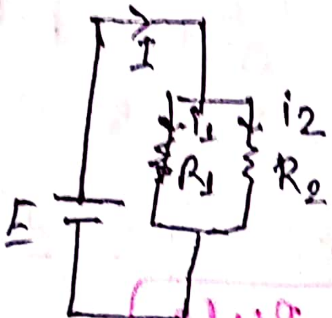
The current through any branch of a parallel ~~resistance~~ resistive network is equal to the total resistance of the parallel network divided by the resistor of interest & multiplied by the total current entering the parallel configuration.

So, it may write, $I_n = \frac{R_T}{R_n} \cdot I$

For two parallel elements of equal value, the current will ~~value~~ divide equally,

(4) CDR used in parallel circuit

For parallel elements with different values, the smaller the resistance, the greater the share of input current.



Let, R_T the equivalent resistance of two parallel resistance R_1 & R_2.

Current Divider Rule

$$E = IR_T \quad \text{— (i)}$$

E or, $V = I_1 R_1$

Or, $I_1 = \dfrac{E}{R_1} = \dfrac{R_T}{R_1} \cdot I \quad \text{— (ii)}$

and

E or $V = I_2 R_2$

Or, $I_2 = \dfrac{E}{R_2} = \dfrac{R_T}{R_2} \cdot I \quad \text{— (iii)}$

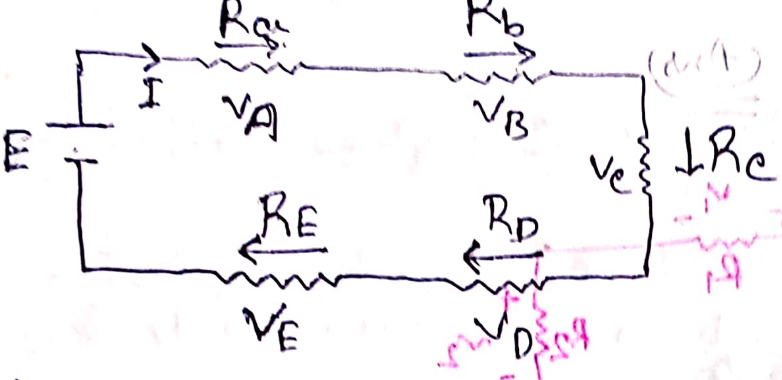
~~To~~ From eqn (ii) & (iii),

যে current এর মান বের করব তার বিপরীত রোধ

$$\boxed{I_x = \frac{R_T}{R_x} I}$$

$$\boxed{I_x = \frac{R_y}{R_x + R_y} I}$$

Math of KVL :-



সংকেত, মানগুলো electricity এর মানের ফলাফল হলো $= I / I_0$ এই মান থেকে $V = IR$ এই সূত্র এর অংশ সমন্বিত। তাই R ও V/E দিলে KVL use করতে হয়।

Given, $E = 30v.$

$R_a = R_b = R_c = R_d = R_E = 6\ \Omega$

$I = ?$ & $v = ?$

=> Let's use KVL,

$$E = IR_a + IR_b + IR_c + IR_d + IR_E$$

$$= I \cdot 6 + I \cdot 6 + I \cdot 6 + I \cdot 6 + I \cdot 6$$

$$= 30I$$

Here,

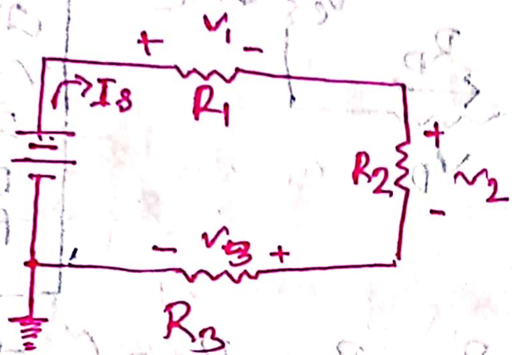
$30I = 30v$

or, $I = 1$ amp.

By ohm's law, the voltage drops V_a, V_b & so forth are each,

$V = IR = 1 \times 6 = 6v.$

(Ans)



Given, $E = 20v$, $R_1 = 2\Omega$, $R_2 = 1\Omega$, $R_3 = 5\Omega$, ~~$V_3 = 15v$~~

$R_T = ?$, $I_s = ?$, $v_1 = ?$, $v_2 = ?$

$\Rightarrow R_T = (2+1+5)\Omega = 8\Omega$

$\cancel{I_T = \frac{E}{R_T} = \frac{20}{2} = 10A.}$

$\cancel{I_2 = \frac{E}{R_2} = \frac{20}{1} = 20A.}$

$\cancel{I_3 =}$

~~Applying KVL,~~

$\cancel{E = V_1 + V_2 + V_3}$

$$I_S = \frac{E}{R_T} = \frac{20}{8} = \frac{5}{2} = 2.5A.$$

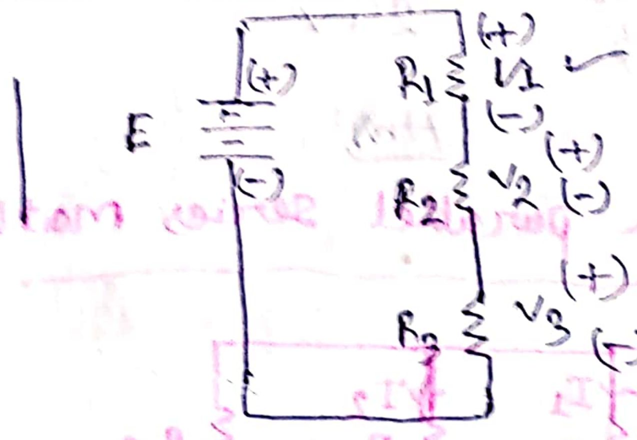
$$V_1 = I_1 R_1 = I_S R_1 = 2.5 \times 2 = 5v.$$

$$V_2 = I_2 R_2 = I_S R_2 = 2.5 \times 1 = 2.5v$$

(Ans)

Note:- সিরিজে current এর মানের কোনো পরিবর্তন হয় না। তাই $I_S = I_1 = I_2$

math of voltage Divider Rule :-



Given, $E = 45v$; $R_1 = 2k\Omega$; $R_2 = 5k\Omega$

$R_3 = 8k\Omega$,

$V_1 = ?$, $V_3 = ?$ => Using VDR

Using VDR on the Figure,

$$V_1 = R_1 \cdot \frac{E}{R_T} \quad \text{—(i)} \qquad \& \qquad V_3 = R_3 \cdot \frac{E}{R_T} \quad \text{—(ii)}$$

Here,

$E = 45V$

$R_T = (2+5+8)\,k\Omega$

$= 15\,k\Omega$

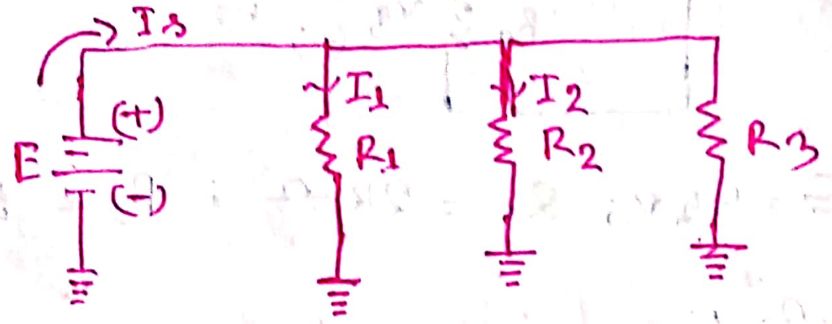
• Applying them on equation 1 & 2

$V_1 = 2 \cdot \frac{45}{15} = 6V.$

$V_2 = 8 \cdot \frac{45}{15} = 24V$

(Ans)

☐ Normal parallel series math:-



Given,

$R_T = 4\Omega$, $R_1 = 10\Omega$; $R_2 = 20\Omega$, $I_1 = 4$

$R_3 = ?$ $I_2 = ?$ $E = ?$ $I_S = ?$

$I_1 = R_1$

$V = IR$

$E = I_2 R_2$

$$\begin{array}{r|l} 2 & 4, 10, 20 \\ \hline 5 & 2, 5, 10 \\ \hline & 2, 1, 2 \end{array}$$

(a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

or, $\frac{1}{R_3} = \frac{1}{R_T} - \frac{1}{R_1} - \frac{1}{R_2}$

or, $\frac{1}{R_3} = \frac{1}{4} - \frac{1}{10} - \frac{1}{20}$

or, $\frac{1}{R_3} = \frac{10-4-2}{40}$

or, $\frac{1}{R_3} = \frac{4}{10}$

$\therefore R_3 = 10\ \Omega$ (Ans)

~~(b) $I_2 = \frac{E}{R_2}$ — (i)~~

(c) $E = V_1 = I_1 R_1 = 4 \times 10 = 40V$

(b) $I_2 = \frac{E}{R_2} = \frac{40}{20} = 2A$.

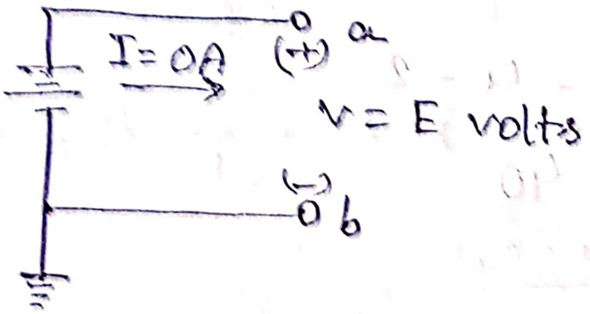
→ R For parallel

(d) Total current, $I_3 = \frac{E}{R_T} = \frac{40}{4} = 10A$.

(Ans)

⊞ Open circuit :- $\boxed{\text{zero ampere}}$

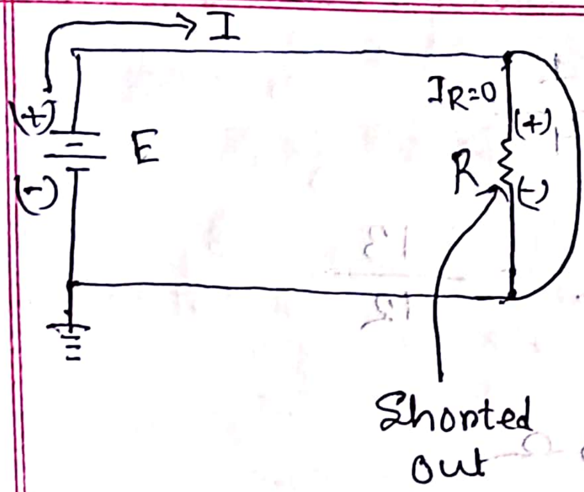
An open circuit can have a potential difference (voltage) across its terminals, but the current is always zero ampere.



an open circuit exists between terminals a and b. The voltage across the open-circuit terminals in the supply voltage, but the current is zero due to the absence of a complete circuit.

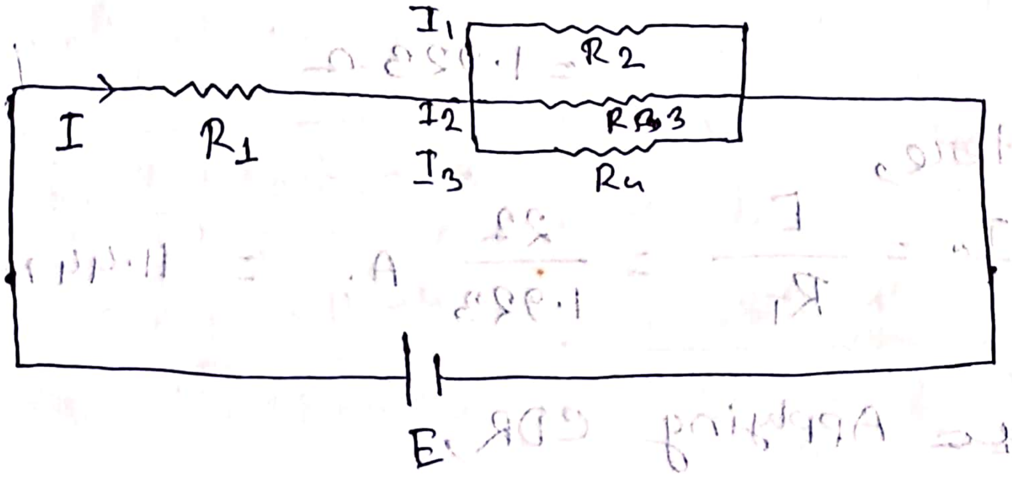
⊞ Short circuit :- $\boxed{\text{zero volts}}$

A short circuit can carry of a level determined by the external circuit but the potential difference (voltage) across the terminal is always (zero) volts.



The voltage across the short circuit is always zero volts because the resistance of the short circuit is assumed to be ~~ee~~ essentially zero ohms, and $V = IR = I(0\,\Omega) = 0\,V$.

Math:- (parallel circuit) ⇒ [with 3 Resistance]



Given,

$R_1 = 1\,\Omega$; $R_2 = 2\,\Omega$; $R_3 = 3\,\Omega$; $R_4 = 4\,\Omega$;

$E = 22\,V$. $I = ?$; $I_1 = ?$; $I_2 = ?$; $I_3 = ?$

⇒ Here,

parallel circuit, $\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$

$$2 \,\underline{|\, 2,\ 3,\ 4}$$
$$\quad 1,\ 3,\ 2$$

Or, $\frac{1}{R_P} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4}$

$$= \frac{6+4+3}{12} = \frac{13}{12}$$

$\therefore R_P = \frac{12}{13} = 0.923\,\Omega$

$\therefore R_T = R_S + R_P = (1 + 0.923)\,\Omega$

$$= 1.923\,\Omega$$

Here,

$$I = \frac{E}{R_T} = \frac{22}{1.923}\ A. = 11.44\ A.$$

~~I_1~~ = Applying CDR,

$$\cancel{I_1 = \frac{1.923}{*} \times 22 =}$$

$$I_1 = \frac{R_3 R_4}{R_2R_3 + R_3R_4 + R_4R_2} \cdot I$$

$$= \frac{3 \times 4}{2\times 3 + 3\times 4 + 4 \times 2} \times 11.44 = 5.28\,A.$$

$$I_2 = \frac{R_2 R_4}{R_3 R_2 + R_2 R_4 + R_3 R_4}$$

$$= \frac{2 \times 4}{3\times2 + 2\times4 + 3\times4} \times 11.44 = \frac{8}{\cancel{6+8+12}} = \frac{8}{26} = \cancel{\frac{2}{3}}$$

$$\cancel{= 0.44}$$

$$= \frac{8}{6+8+12} \times 11.44 = \frac{8}{26} \times 11.44 = 3.52\,A.$$

$$I_3 = \frac{R_2 \cdot R_3}{R_4 R_2 + R_2 \cdot R_3 + R_4 R_3}$$

$$= \frac{2\times3 \times 11.44}{4\times2 + 2\times3 + 4\times3} = \frac{6\times11.44}{8+6+12} = \frac{6}{26} \times 11.44$$

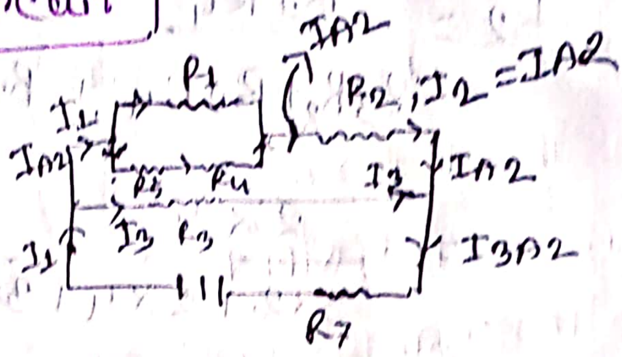
$$= 2.64\,A.$$

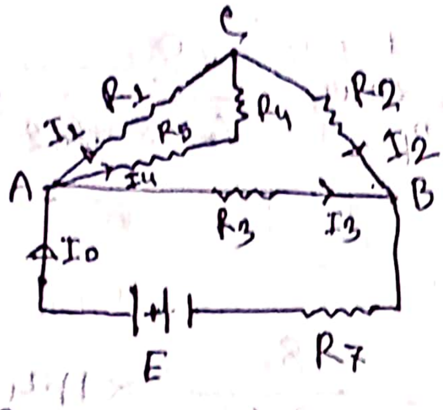
(Ans)

যদি (P) এর মান বের করতে বলে তবে,
$P = I^2R$ এর ব্যবহার করতে হবে।

A

Exercise- Different circuit





Given,

$R_1 = 5\Omega$; $R_2 = 6\Omega$; $R_3 = 7\Omega$; $R_4 = 3\Omega$; $R_5 = 4\Omega$;

$R_7 = 1\Omega$; $E = 10V$

$I_0 = ?$ all voltage Drop $= ?$

$\Rightarrow$ R_5 & R_4 are in series,

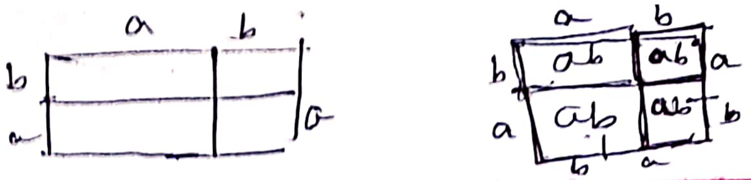
$R_{54} = 4 + 3 = 7\Omega$

R_1 & R_{54} are in parallel,

$$R_A = \frac{R_1 \times R_{54}}{R_1 + R_{54}} = \frac{5 \times 7}{5+7} = \frac{35}{12} = 2.92\Omega$$

so, R_A & R_2 are in series,

$R_{A2} = R_A + R_2 = 2.92 + 6 = 8.92\Omega$



$a+b$

$2ab+b^2+b^2$

$(a+b)^2=$

R_{A2} & R_3 are in parallel,

$$\text{So, } R_B = \frac{R_{A2}\times R_3}{R_{A2}+R_3} = \frac{8.92\times 7}{8.92+7} = 3.92\ \Omega$$

Now, R_B & R_7 are in series.

$$R_{B7} = 3.92+1 = 4.92\ \Omega$$

$$\text{So, } I_0 = \frac{E}{R_{B7}} = \frac{10}{4.92}\ A = 2.033\ A.$$

So, All voltage Droop:-

Applying, CDR,

$$I_1 = I_{A2}\cdot\frac{R_{45}}{R_1+R_{45}} = \frac{7\ \Omega\times I_{A2}}{5+7}$$

Note:-

এখানে, I_0 না দিয়ে I_{A2} হয়েছে কারণ :-
সার্কিটকে ছোট করা হয়েছে। Current সম্পূর্ণ সার্কিটে দুই লোড
এবং লোড (I_1, I_2, I_4, I_5) অন্য লোড I_3 ও I_7 হয়েছে।

আবার আরও ক্ষুদ্র সার্কিটে R_1, R_2, R_5, R_4 (I_1, I_2, I_5, I_4) রয়েছে। তাই এখানে; I_{A2} ব্যবহার করতে হবে।

CDR এর ক্ষেত্রে আসলে রোধের তার মান কমানো যা যে কারেন্টের মান বের করা হয় তার বিপরীত রোধ। কারণ ঐ তার দিয়ে তড়িৎপ্রবাহ ঐ তার মানেরই সমান। রোধ, কারেন্ট একই নিয়ম।

Now,

$$I_{A2} = \frac{R_{A2}\cdot R_{B3}}{R_{A2}+R_{B3}}\cdot I_0 = \frac{\cancel{8.92\times}\,7}{8.92+7}\cdot 2.033$$

$$= 0.9\ A.$$

$$I_3 = \frac{R_{A2}}{R_3+R_{A2}}\times I_0$$

$$= \frac{8.92}{7+8.92}\times 2.033\ A.$$

$$= 1.14\ A.$$

$$I_1 = \frac{R_{45}}{R_1+R_{45}}\times I_{A2} = \frac{7}{5+7}\times 0.9$$

$$= 0.525 A.$$

$I_2 = \cancel{\frac{I}{}}\ I_{A2} = 0.9A.$

$I_4 = \frac{R_1}{R_1+R_{45}} \times I_{A2} = \frac{5}{5+7} \times 0.9$

$= 0.375\ A. = I_5$

$\cancel{I_{3}} = \text{---}$

$I_7 = I_3 + I_{A2} =$

$= 1.14 + 0.9 = 2.04A.$

Now,

$v_1 = I_1 R_1 = 0.525 \times 5 = 2.625V$

$v_2 = I_2 R_2 = (0.9 \times 6)\ V = 5.4\ V$

$v_3 = I_3 R_3 = (1.14 \times 7)\ V = 7.98V$

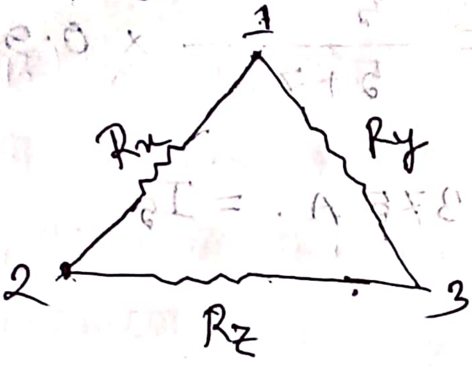
$v_4 = I_4 R_4 = 0.375 \times 3 = \cancel{1.0125V}\ 1.125V$

$v_5 = I_5 R_5 = 0.375 \times 4 = \cancel{13.5V}\ 1.5V$

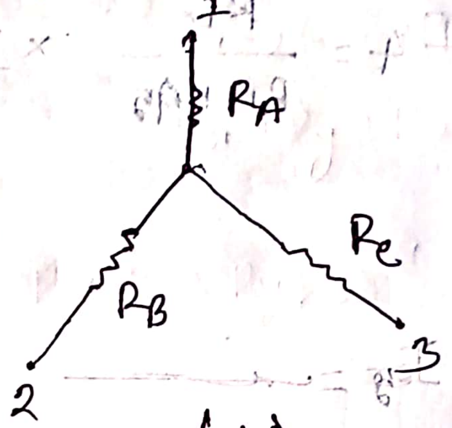
$v_{67} = I_7 R_7 = 2.04 \times 1 = 2.04V$

(Ans)

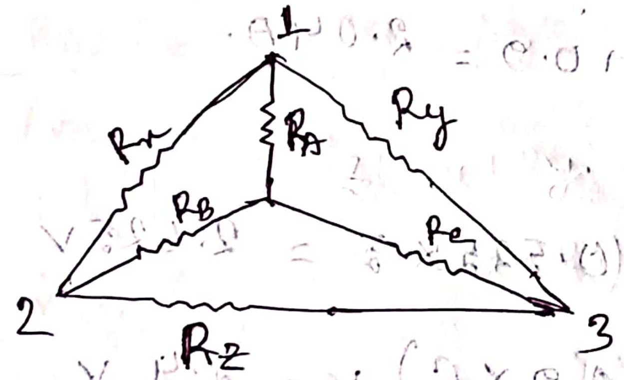
Delta (Δ) - wye (Y) transformation :-



(a)



(b)



For wye,

$$R_{12} = R_A + R_B \quad \text{—— (i)}$$

$$R_{23} = R_B + R_c \quad \text{—— (ii)}$$

$$R_{31} = R_c + R_A \quad \text{—— (iii)}$$

For Delta,

$$R_{12} = \frac{R_x(R_y+R_z)}{R_x+(R_y+R_z)} \quad \text{—— (iv)}$$

$$R_{23} = \frac{R_z(R_x+R_y)}{R_z+(R_x+R_y)} \quad \text{——— (v)}$$

$$R_{31} = \frac{R_y(R_z+R_x)}{R_y+(R_z+R_x)} \quad \text{——— (vi)}$$

Now,

$$R_A+R_B = \frac{R_x(R_y+R_z)}{R_x+(R_y+R_z)} \quad \text{——— (vii)}$$

$$R_B+R_C = \frac{R_z(R_x+R_y)}{R_z+(R_x+R_y)} \quad \text{——— (viii)}$$

$$R_C+R_A = \frac{R_y(R_z+R_x)}{R_y+(R_z+R_x)} \quad \text{——— (ix)}$$

Now, (vii) − (ix),

$$R_A+R_B-R_C-R_A = \frac{R_x(R_y+R_z)}{R_x+(R_y+R_z)} - \frac{R_y(R_z+R_x)}{R_y+R_z+R_x}$$

or, $$R_B-R_C = \frac{R_xR_y+R_xR_z-R_yR_z-R_xR_y}{R_y+R_z+R_x}$$

or, $$R_B-R_C = \frac{R_xR_z-R_yR_z}{R_x+R_y+R_z} \quad \text{——— (x)}$$

$$R_B + R_C - R_B + R_C = \frac{R_y(R_x+R_z)}{R_y+(R_x+R_z)} - \frac{R_xR_z - R_yR_z}{R_x+R_y+R_z}$$

$$\text{Or, } 2R_C = \frac{R_xR_y + R_yR_z - R_xR_z + R_yR_z}{R_x+R_y+R_z}$$

$$\text{Or, } 2R_C = \frac{2R_yR_z}{R_x+R_y+R_z}$$

$$\text{Or, } R_C = \frac{R_yR_z}{R_x+R_y+R_z} \quad \text{(xi)}$$

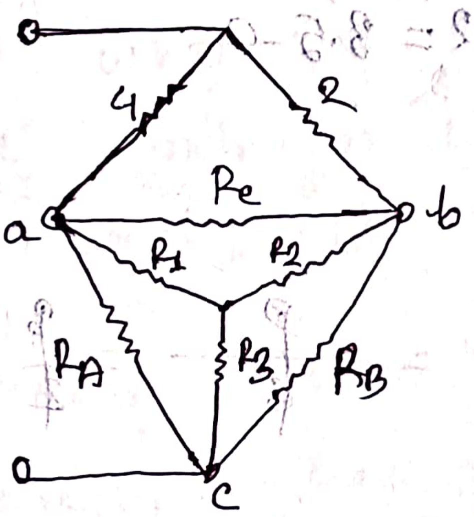
In the same way,

$$R_A = \frac{R_x R_y}{R_x + R_y + R_z} \quad \text{———} \quad (xii)$$

$$R_B = \frac{R_x R_z}{R_x + R_y + R_z} \quad \text{———} \quad (xiii)$$

— — —

Math Exercise of Delta & wye Circuit



Given,

$R_A = 3\,\Omega$

$R_B = 3\,\Omega$

$R_C = 6\,\Omega$

$R_T = ?$

From Δabc to Y transformation,

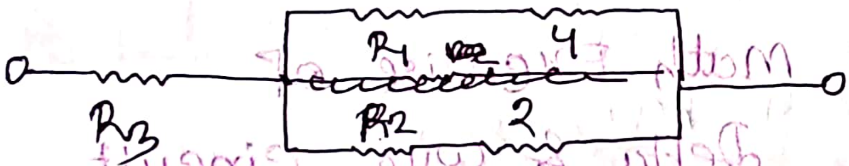
$$R_1 = \frac{R_A R_C}{R_A + R_B + R_C} = \frac{3 \times 6}{3+3+6} = \frac{18}{\cancel{15}\,12} = \frac{\cancel{6}\,3}{\cancel{5}\,2}\,\Omega = \cancel{1.2\,\Omega}$$

$$= 1.5\,\Omega$$

$$R_2 = \frac{R_C \cdot R_B}{R_A + R_B + R_C} = \frac{6 \times 3}{3+3+6} = \frac{18}{12} = \frac{3}{2} = 1.5\,\Omega$$

$$R_3 = \frac{R_A \cdot R_B}{R_A + R_B + R_C} = \frac{3 \cdot 3}{3+3+6} = \frac{9}{12} = \frac{3}{4} = 0.75\,\Omega$$

Now,



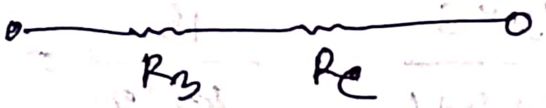
$R_{A4} = R_1 + 4 = 1.5 + 4 = 5.5\,\Omega$

$R_{B2} = R_2 + 2 = 1.5 + 2 = 3.5\,\Omega$

$R_e = \cancel{R_A'}\ R_A \parallel R_B$

$$= \frac{R_{A4} \cdot R_{B2}}{R_{A4} + R_{B2}} = \cancel{\frac{9}{6}} = \cancel{\frac{3}{4}} = \cancel{1.5}$$

$$= \frac{5.5 \times 3.5}{5.5 + 3.5} = 2.14\,\Omega$$



$R_T = R_3 + R_e$

$= 0.75 + 2.14$

$= 2.89\,\Omega$ (Ans)

Electrical Network Theorem

1) Mesh / Loop analysis.

2) Nodal Analysis.

3) Superposition Theorem. (Result of superposition principle suited to the network analysis of electrical circuits)

4) Reciprocity Theorem:-

=> In any branch or current due to a single source of voltage (v) in the network is equal to the current through that branch is which the source was originally placed, when the source is again put in the branch. in which the current was originally obtained.

5) ~~Thevenin's Theorem.~~

5) Thevenin's Theorem:-

Any linear electrical network containing only voltage sources, current sources & resistances can be replaced at terminals

A-B by an equivalent combination of a voltage source V_{th} in a series connection with a resistance R_{th}.

6) Norton's Theorem:-

Any linear circuit containing several energy sources and resistances can be replaced by a single constant current generator in parallel with a single resistor.

Branch Current Method:-

নিয়ম:-

১) যদি সার্কিটে কোনো ডিরেকশান বা নাম দেওয়া না থাকে তবে নিজে নিজে দেওয়া যাবে।

২) Current এর sign (+), (−) দেওয়া। এর ফলে KVL বের করতে সুবিধা বেশি হয়।
[বেশিরভাগ সময়ই (−) হতে (+) এ যায়]

৩) প্রতিটি Node-এ KCL লিখতে হবে।
KCL বের করার নিয়ম:-
Current entering = Current outgoing.

৪) প্রতিটি Loop-এর মধ্যে KVL লিখতে হবে।
KVL বের করার নিয়ম:-
i) Clockwise or Anticlock wise
ii) যে পয়েন্টে শুরু করতে হবে, ঐ পয়েন্টেই শেষ করতে হবে। (+) হতে (−) এ গেলে voltage drop.

৫) যে equation পাওয়া যাবে ওগুলো হিসাব করে solve করতে হবে।

- কোনো সার্কিটের current বের করাই হলো মূল লক্ষ্য। যার ফলে ৯০% কাজ শেষ হয়।

⊛ Note:-

(i) Resistor এর ভিতর ঢুকতে (+) আর বের হলে (−), এভাবেই current এর Direction এর উপর নির্ভর করবে।

(ii) I এর মান = KCL
V এর মান = KVL

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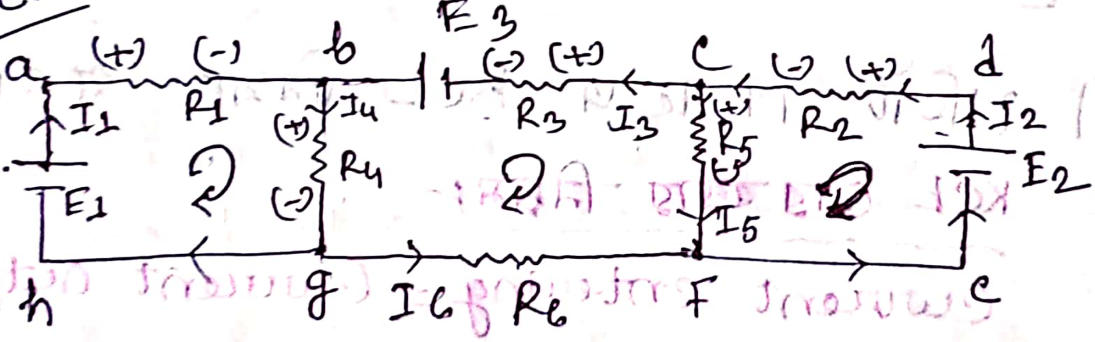
math of B.C.M



Given;

$E_1 = 25v$; $E_2 = 15v$; $E_3 = 10v$; $R_1 = 40\Omega$; $R_2 = 20\Omega$;

$R_3 = R_6 = 10\Omega$; $R_4 = R_5 = 100\Omega$

⊛ Find all Branch current,

⇒ Applying KCL,

$I_1 + I_3 = I_4$ —— (i)

$I_4 = I_1 + I_6$ —— (ii)

$\cancel{I_5 = I_2 - I}$

$I_2 - I_3 = I_5$ —— (iii)

$I_5 = I_2 - I_6$ —— (iv)

Merging equation (i) & (ii)

$I_1 + I_3 = I_1 + I_6$

or, $I_3 = I_6$ —— (v)

~~Merging equation (iii) & (iv)~~

$\cancel{I_2 - I_3 = I_2 - I_6}$

$\cancel{\text{or, } I_3 =}$

so, $I_1 + I_6 = I_4$ —— (vi)

or, $I_1 = I_4 - I_6$ —— (vii)

And, $I_5 = I_2 - I_6$ ——

or, $I_2 = I_5 + I_6$ —— (viii)

Applying KVL,

$E_1 = I_1 R_1 + I_4 R_4$

or, $25 = I_1 \cdot 40 + I_4 \cdot 100$

$E_2 = I_5 R_5 + I_2 R_2$ [এখানে current যেদিক ভিতর ঢুকছে সেই চিহ্ন হিসেবে বসানো হয়েছে]

or, $15 = I_5 \cdot 100 + I_2 \cdot 20$

$E_3 = I_3 R_3 + I_6 R_6 - I_4 R_4 - I_5 R_5$

or, $10 = 10 I_3 + \overset{10I_6}{\cancel{10R_6}} - 100 I_4 - 100 I_5$

Again,

$25 = I_1 \cdot 40 + (I_1 + I_6)\, 100$

or, $25 = 40 I_1 + 100 I_1 + 100 I_6$

or, $25 = 140 I_1 + 100 I_6$ ——— (ix)

And,

$15 = (I_2 - I_6)\, 100 + 20 I_2$

or, $15 = 100 I_2 - 100 I_6 + 20 I_2$

or, $15 = 120 I_2 - 100 I_6$ ——— (x)

Also,

$10 = 10 I_3 + 10 R_6 - (I_1 + I_6)\, 100 - (I_2 - I_6)\, 100$

or, $10 = 10 I_3 + 10 R_6 - 100 I_1 - 100 I_6 - 100 I_2 + 100 I_6$

or,

$10 = 10I_3 + 10I_6 - 100I_1 - 100I_2$

or, $10 = 20I_6 - 100I_1 - 100I_2$ ——— (xi)

Now,

$$D = \begin{vmatrix} 140 & 0 & 100 \\ 0 & 120 & -100 \\ -100 & -100 & 20 \end{vmatrix}$$

$$= 140\{120\times 20 + (100\times 100)\} - 0\{(-100\times 100)\} - 100(-120\times 100)$$

$$= \cancel{100\{} \; 1736000 - 1200000$$

$$= 536000$$

$$I_1 = \frac{\begin{vmatrix} 25 & 0 & 100 \\ 15 & 120 & -100 \\ 10 & -100 & 20 \end{vmatrix}}{D} = \frac{\{25(120\times 20 + -100\times -100)\} - \{15(-100\times 100)\} + \{10(120\times 100)\}}{D}$$

$$= \frac{310000 + 150000 + 120000}{D}$$

$$= \frac{580000}{536000} = 1.08\ A.$$ [হিসাবে ভুল আছে]

$$I_2 = \frac{\begin{vmatrix} 140 & 25 & 100 \\ 0 & 15 & -100 \\ -100 & 10 & 20 \end{vmatrix}}{D}$$

$$= \frac{\{140(15\times20+10\times100) - \{100(25\times-100 \mp 15\times100)\}}{D}$$

$$= \frac{182000 + 400000}{536000}$$

$= 1.08$ A.

Note:-

নিয়ম কি আছে, হিসাবে গড়মিল করাছে

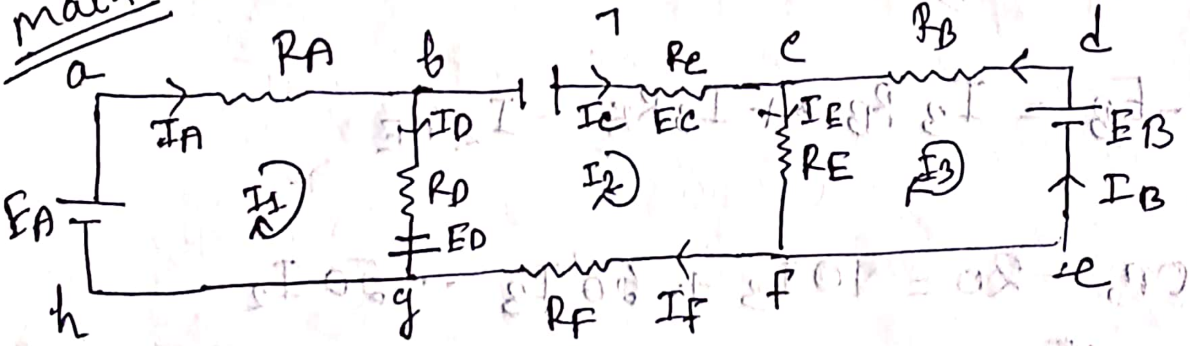
Loop current Method :-

Loop এর নির্দিষ্ট current দিয়ে মান

① প্রতি Loop এর মধ্যে Current ধরে নিবো।

② প্রতি লুপে KVL লিখতে হবে। KVL লেখবো Current এর সাপেক্ষে।
(এটি Branch current এর মতো হবে না)

math



Given,

$E_A = 30$; $E_B = 20V$; $E_C = 5V$; $E_D = 10V$.

$R_A = 20\Omega$; $R_B = 10\Omega$; $R_C = 30\Omega$; $R_D = 40\Omega$

$R_E = 50\Omega$; $R_F = 25\Omega$

At abgh,

$E_A + E_D = I_1 R_A + I_1 R_D - I_2 R_D$

Or, $30 + 10 = I_1 20 + I_1 40 - I_2 \cdot 40$

Or, $40 = 60 I_1 - 40 I_2$ —— (i)

At befg,

$E_C - E_D = I_2 R_C + I_2 R_F - \cancel{E_2} I_1 R_D$

Or, $5 - 10 = 30 I_2 + 25 I_2 - 40 \cdot I_1$

Or, $-5 = 55 I_2 - 40 I_1$ —— (ii)

At cdef,

$-E_B = I_3 R_B + I_3 R_E - I_2 R_E$

Or, $-20 = 10 I_3 + 50 I_3 - 50 I_2$
$- \cancel{E}_1$

Or, $-20 = 60 I_3 - 50 I_2$ —— (iii)

From equation (i), (ii) & (iii)

$40 = 60 I_1 - 40 I_2 + 0$

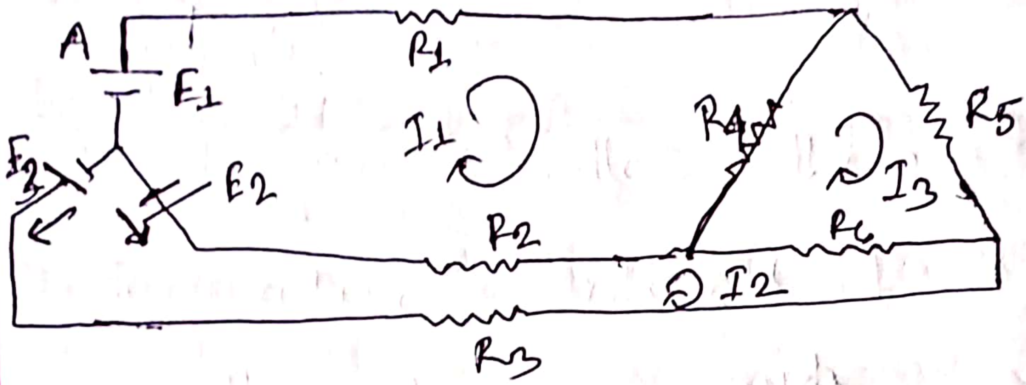
$\cancel{-5 = 55 I_2}$

$-5 = -40 I_1 + 55 I_2 + 0$

$-20 = 0 - 50 I_2 + 60 I_3$

(বাকিটুকু পূর্বের মতো)

Mesh current:-



Given,

$E_1 = 4V$ $R_1 = 11\Omega$ $R_4 = 15\Omega$

$E_2 = 12V$ $R_2 = 9\Omega$ $R_5 = 2\Omega$

$E_3 = 8V$ $R_3 = 5\Omega$ $R_6 = 6\Omega$

Mesh current = ?

$\Rightarrow$

$I_1 = -0.3664 A.$

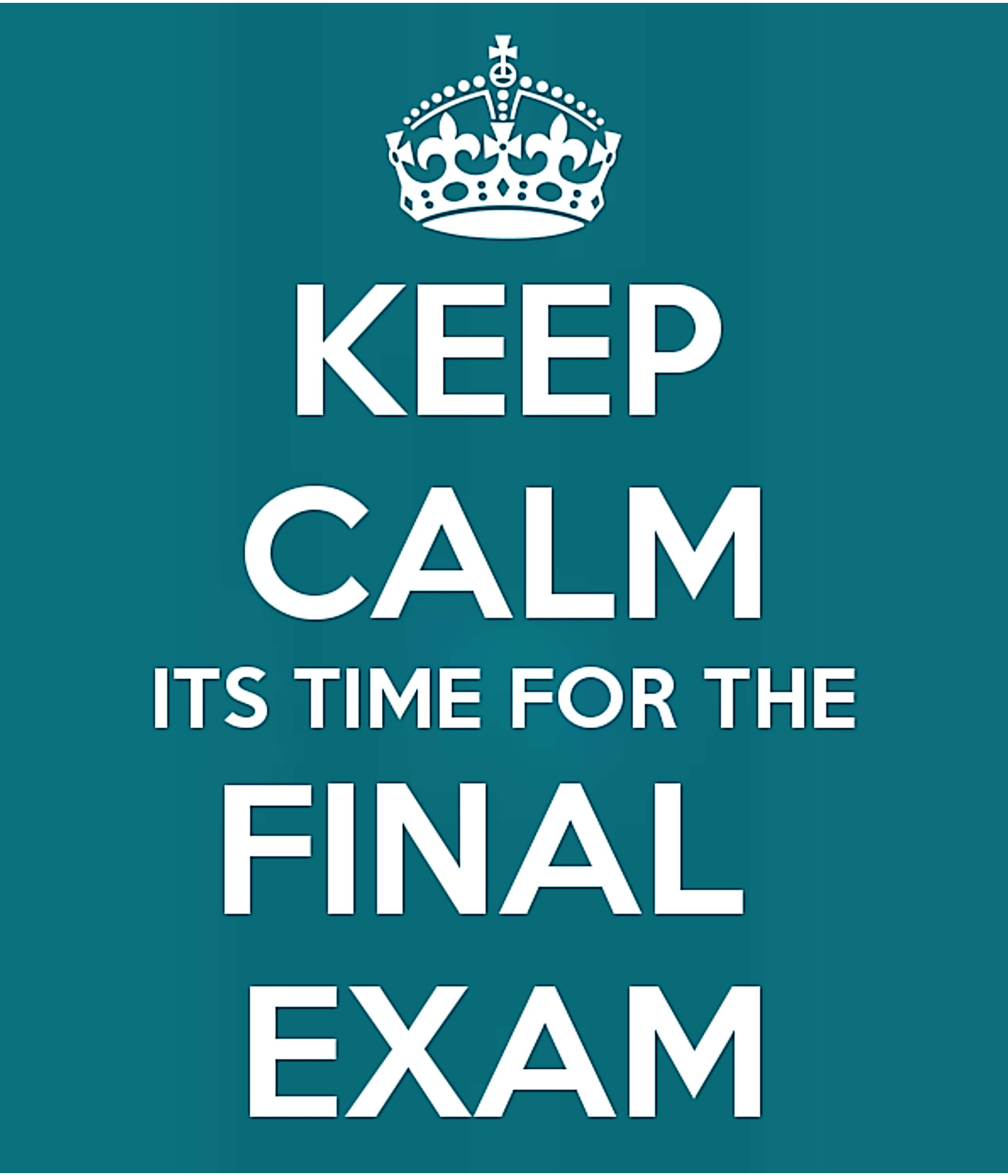
$I_2 = -0.052 A$

(আগের মতোই)

$I_3 = -0.29A.$

Mid Term Finishes here $\Leftarrow$

Final starts here $\Rightarrow$


KEEP
CALM
ITS TIME FOR THE
FINAL
EXAM

Final

Lesson :- AC Circuits

9.1

- A sinusoid is a signal that has the form of the sine or cosine function.
- A sinusoidal current is usually referred to as alternating current (ac). Such a current reverses at regular time intervals and has alternately positive & negative values.
- Circuits driven by sinusoidal current or valtuge sources are called as ac circuits.
- It is form of voltage generated througout the world and supplied to homes, factories, laboratories, and so on.
- Through Fourier analysis, any practical periodic signal can be represent by a

sum of sinusoids.

X ⊛ Sinusoid helps to analysis of periodic signals.

⊛ It can handle mathematically. The derivative & integral of a sinusoid are themselves sinusoids.

⊞ A sinusoidal forcing function produces both a transient (অস্থায়ী) & a steady-state (স্থায়ী) response.

& The transient response dies with time & only the steady-state response remains.

⊛ When transient response has become negligibly small compared with the steady-state response, we say that the circuit is operating at sinusoidal ~~sted~~ steady-state.

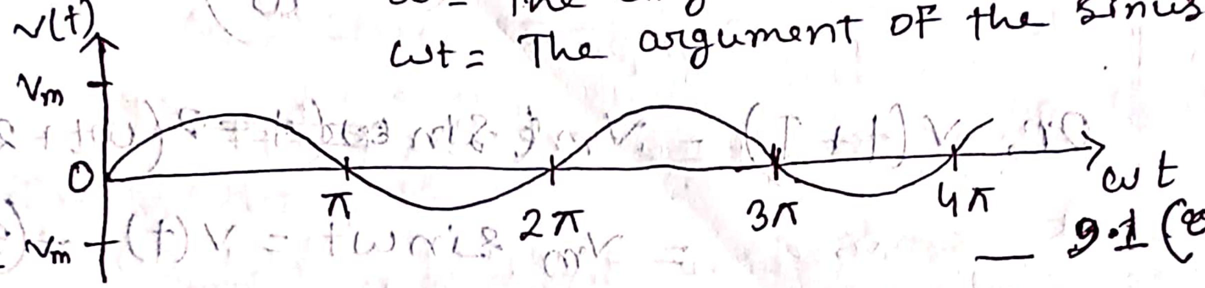
9.2 |

Sinusoids :- $v(t) = V_m \sin \omega T$ (তাৎক্ষণিক voltage) — (9.1)

V_m = The amplitude of the sinusoid

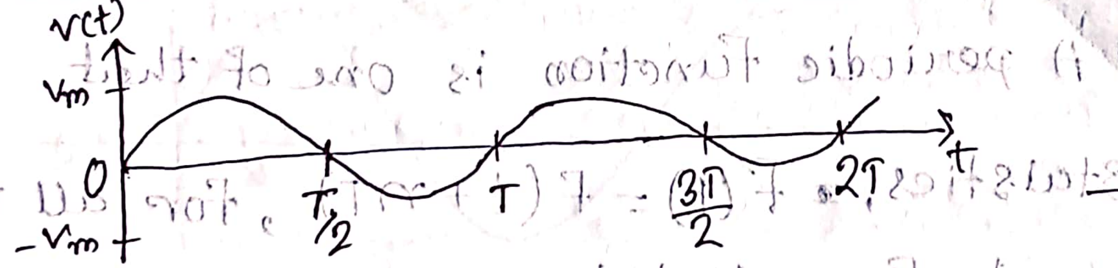
ω = The angular frequency in rad/s

ωt = The argument of the sinusoid.



— 9.1 (a)

=) A function of its argument



— 9.1 (b)

=) A function of time.

So, from two plots, $\omega T = 2\pi$

$$\text{or, } T = \frac{2\pi}{\omega} \quad \text{— (9.2)}$$

So, from 9.1 equation if we replace it $t = (t+T)$ then we get,

$$v(t+T) = V_m \sin \omega (t+T)$$

Or, $v(t+T) = V_m \sin \omega \left(t + \frac{2\pi}{\omega}\right)$

Or, $v(t+T) = V_m \sin (\omega t + 2\pi)$

$= V_m \sin \omega t = v(t)$ —(9.3)

Hence,

$$v(t+T) = v(t) \quad \text{—(9.4)}$$

---

* A periodic function is one of that staisfies, $f(t) = f(t+nT)$, for all t and for all integers n

---

* $f = \frac{1}{T}$ —(9.5) [T is a periodic function. It is the time of one complete cycle or seconds/cycle.

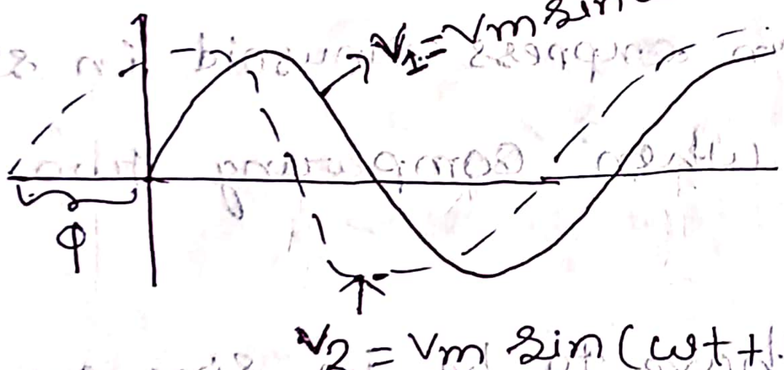
* It is clear from (9.5) & (9.2) that

$\boxed{\omega = 2\pi f}$ $\boxed{rad/s}$ $\boxed{f = Hz \text{ or}, s^{-1}}$

☐ More general expression for the sinusoid :-

$$v(t) = V_m \sin(\omega t + \phi) \quad --- (9.7)$$

Here, $(\omega t + \phi)$ is the argument & ϕ is the phase. Both argument and phase can be in radians or degrees.



Here, v_1 starts first in time. v_2 leads v_1. ∴ We can say that v_2 leads v_1 by ϕ, or, v_1 lags v_2 ~~by~~ by ϕ. If $\phi \neq 0$, we also say that v_1 and v_2 are out of phase. But, if $\phi = 0$, the v_1 and v_2 are said to be in phase ;

They reach their minima & maxima exactly the same time.

We can compare v_1 & v_2 in this manner. Because they operate at the same frequency, they don't need to have the same amplitude.

☐ We can express sinusoid in sine or cosine. When comparing two sinusoids.

But both have to be in sine or cosine with positive amplitudes.

$$\sin(A \pm B) = \sin A \cdot \cos B \pm \cos A \sin B \quad -(9.9)$$

$$\cos(A \pm B) = \cos A \cdot \cos B \mp \sin A \cdot \sin B$$

And also,

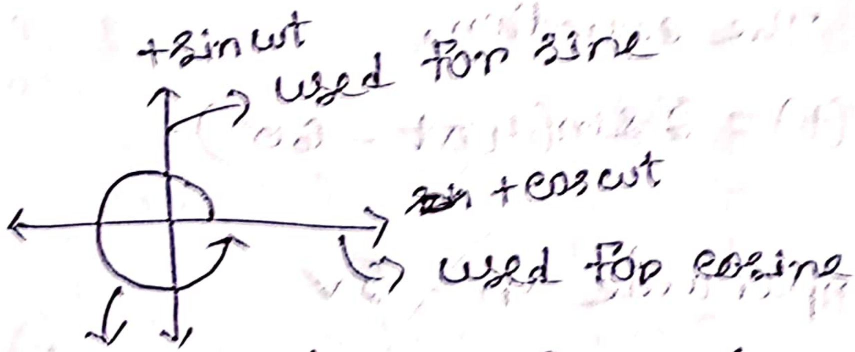
$$\sin(\omega t \pm 180^\circ) = -\sin\omega t$$

$$\cos(\omega t \pm 180^\circ) = -\cos\omega t$$

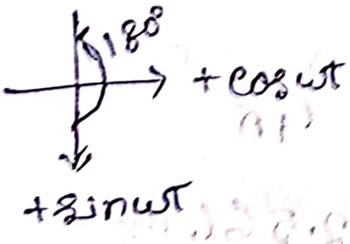
$$\sin(\omega t \pm 90^\circ) = \pm\cos\omega t \qquad (9.10)$$

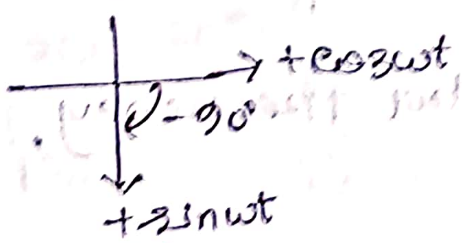
$$\cos(\omega t \pm 90^\circ) = \mp\sin\omega t$$

*



Counterclockwise (বামাবর্তে)





* $A\cos\omega t + B\sin\omega t = C\cos(\omega t - \theta) \qquad 9.11$

where,

$$C = \sqrt{A^2 + B^2} \; ; \; \theta = \tan^{-1}\frac{B}{A} \qquad (9.12)$$

~~Gi~~

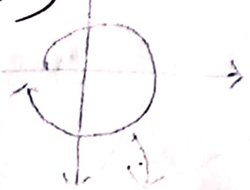
Math-01

Given the sinusoid $5\sin(4\pi t - 60^\circ)$

Calculate its amplitude, phase, angular frequency, period and frequency.

$\Rightarrow$ The equation,

$v(t) = 5\sin(4\pi t - 60^\circ)$



Amplitude $V_m = 5V$

Phase, $\phi = -60^\circ$

Angular frequency, $\omega = 4\pi$

$= 12.566\ Hz$

period, $T = \frac{2\pi}{\omega} = \frac{2\pi}{4\pi} = \frac{1}{2} = 0.5\ s.$

Frequency, $F = \frac{1}{T} = \frac{1}{0.5} = 2\ Hz$

$$\sin(-\theta) = -\sin\theta$$
$$\cos(-\theta) = \cos\theta$$
$$\tan(-\theta) = -\tan\theta$$

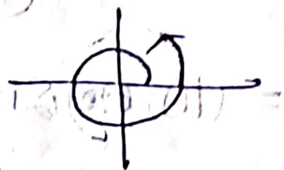
Calculate the <u>phase angle</u> (φ) between $v_1 = -10\cos(\omega t + 50^\circ)$ and $v_2 = 12\sin(\omega t - 10^\circ)$. State which sinuside is leading.

Method one :-

We will have to convert them into same Form.

$$v_1 = -10\cos(\omega t + 50) \qquad \rightarrow \omega = \frac{2\pi}{T}, \quad \omega t = 2\pi$$

$$= -10\cos(\overset{\omega t}{\cancel{2\pi}} + 50)$$



$$= 10\cos(\overset{\omega t}{\cancel{2\pi}} + 50 + -180^\circ)$$

$$= 10\cos(\overset{\omega t}{\cancel{2\pi}} - 130^\circ) \quad \text{——— (1)}$$

and,

$$v_2 = 12\sin(\omega t - 10^\circ) = 12\cos(\omega t - 10^\circ - 90^\circ)$$

$$= 12\sin(\omega t - 100^\circ) \quad \text{——— (2)}$$

From equation (1) & (2), we can write that the phase difference between

v_1 & v_2 is $30°$,

$$v_2 = 12\cos(\omega t - 130° + 30°)$$

or, $$v_2 = 12\cos(\omega t + 260°)$$

$\boxed{\text{method - 2}}$

Alternatively, we may express v_1 in sine form:-

$$v_1 = -10\cos(\omega t + 50°)$$

$$= 10\,\cancel{\cos}\,\sin(\omega t + 50° - 90°)$$

$$= 10\sin(\omega t - 40°)$$

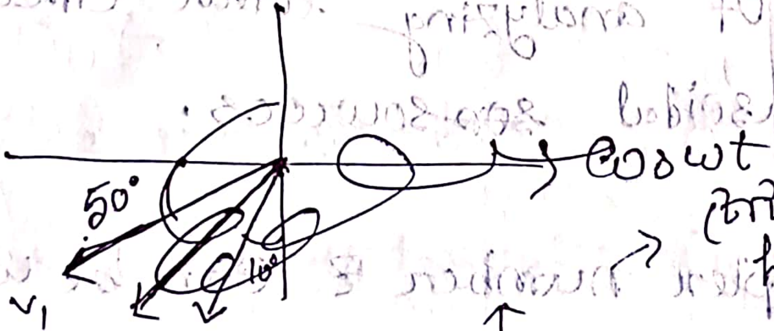
$$= 10\sin(\omega t - 10° - 30°)$$

But, $v_2 = 12\sin(\omega t - 10°)$

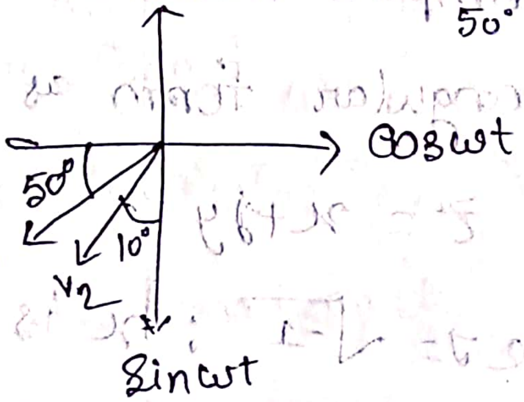
Comparing the two shows that v_1 lags v_2 by $30°$. This is the same as saying that v_2 leads v_1 by $30°$.

Method - 03

We may regard v_1 as simply $-10\cos\omega t$ with a phase shift of $+50^\circ$. Hence v_1 is as shown in Fig. similarly, v_2 is $12\sin\omega t$ with a phase shift of -10°, as shown in fig. It is easy to see from figure that v_2 leads v_1 by 30°, that is $(90^\circ - 50^\circ - 10^\circ)$.



টোটাল কোণ 90°, here from x axis $50^\circ = v_1$ & $v_2 = 80^\circ$;



Phasors :-

Sinusoids are easily expressed in terms of phasors.

A phasor is a complex number that represents the amplitude ([illegible]) and phase of a sinusoid.

Phasors provide a simple means of analyzing linear circuits excited by sinusoidal ~~sor~~ sources.

A complex number z can be written in rectangular form as :

$$z = x + jy$$

where $j = \sqrt{-1}$; x is the real part of z.

y is the imaginary part of z.

x & y do not represent a location

as in two dimensional vector analysis but rather the real and imaginary parts of z in the complex plane.

The complex number z can also be written in polar or exponential form as:-

$$z = r\angle\phi = re^{j\phi}$$

where r is the magnitude of z & ϕ is the phase of z.

z can be represented in three ways:-

$z = x + jy$ [Rectangular Form]

$z = r\angle\phi$ [polar Form]

$z = re^{j\phi}$ [Exponential Form ([illegible])]

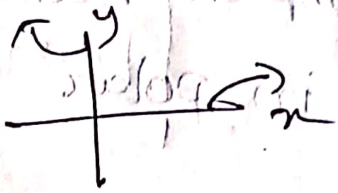
The x (axis) represent the real part and the y (axis) represents the imaginary part of a complex number.

we can get r and ϕ as,

$$r = \sqrt{x^2+y^2} \quad ; \quad \phi = \tan^{-1}\frac{y}{x}$$

we can obtain x and y as,

$$x = r\cos\phi$$



$$y = r\sin\phi$$

z may be written as,

$$\boxed{z = x+jy = r\angle\phi = r(\cos\phi + j\sin\phi)}$$

Complex numbers are better performed in rectangular form.

Multiplication and division are better done in polar form.

$$z = x+jy = r\angle\phi$$

$$z_1 = x_1+jy_1 = r\angle\phi_1$$

$$z_2 = x_2+jy_2 = r_2\angle\phi_2$$

Complex এর হিসাব-নিকাশ

Addision:-

$$z_1 + z_2 = (x_1 + x_2) + j(y_1 + y_2)$$

Substraction:-

$$z_1 - z_2 = (x_1 - x_2) + j(y_1 - y_2)$$

Multiplication:-

$$z_1 \cdot z_2 = \cancel{(x_1 - x_2)} \; r_1 r_2 \angle \phi_1 + \phi_2$$

Division:-

$$\frac{z_1}{z_2} = \frac{r_1}{r_2} \angle \phi_1 - \phi_2$$

Reciprocal:- (গাণিতিক/ পূরক)

$$\frac{1}{z} = \frac{1}{r} \angle -\phi$$

Square root:-

$$\sqrt{z} = \frac{1}{r} \angle -\phi$$

Complex Conjugate:-

$$z^* = x - jy = r\angle -\phi = re^{-j\phi}$$

$$\boxed{\frac{1}{j} = -j}$$

The idea of phasor representation is based on Euler's identity.

In general,

$$\boxed{e^{\pm j\varphi} = \cos\varphi \pm j\sin\varphi}$$

Which shows that we may regard $\cos\varphi$ and $\sin\varphi$ as the real and imaginary parts of $e^{j\varphi}$; we may write:

$$\cos\varphi = Re(e^{j\varphi})$$

$$\sin\varphi = Im(e^{j\varphi})$$

Re = real part
Im = Imaginary part
of $v(t) = V_m \cos(\omega t + \varphi)$

So,

$$v(t) = V_m \cos(\omega t + \varphi) = Re\left(V_m e^{j(\omega t + \varphi)}\right)$$

$$v(t) = Re\left(V_m e^{j\varphi} \cdot e^{j\omega t}\right)$$

where,

$$V = V_m e^{j\varphi} = V_m \angle\varphi \quad \text{—(9.24)}$$

~~where~~ A phasor is a complex representation of the magnitude & phase of a sinusoid.

গণ্য

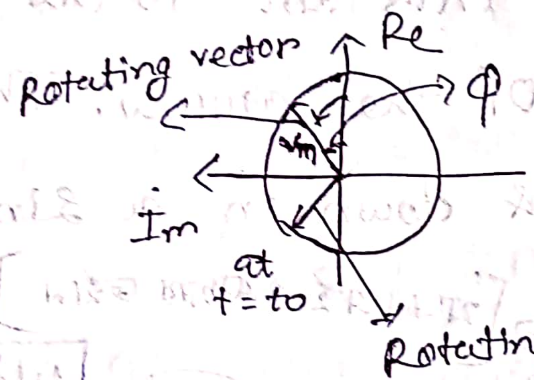
- A phasor may be regarded as a mathematical equivalent of a sinusoid with the time dependence dropped.

সমতুল্য নির্ভরতা বাদ

- If we use sine for the phasor instead of Cosine, then

$$\boxed{\begin{aligned} v(t) &= V_m \sin(\omega t+\phi) \\ &= Im(V_m e^{j(\omega t+\phi)}) \end{aligned}}$$

and the corresponding phasor is the same as that eqn (9.24)



$\sin \omega t$ — time, frequency

Figure - 9.7 (a)

1) Sinor rotating Counterclockwise.

2) Its projections on the real axis, as a function of time.

Sine and Cosine rotating vector

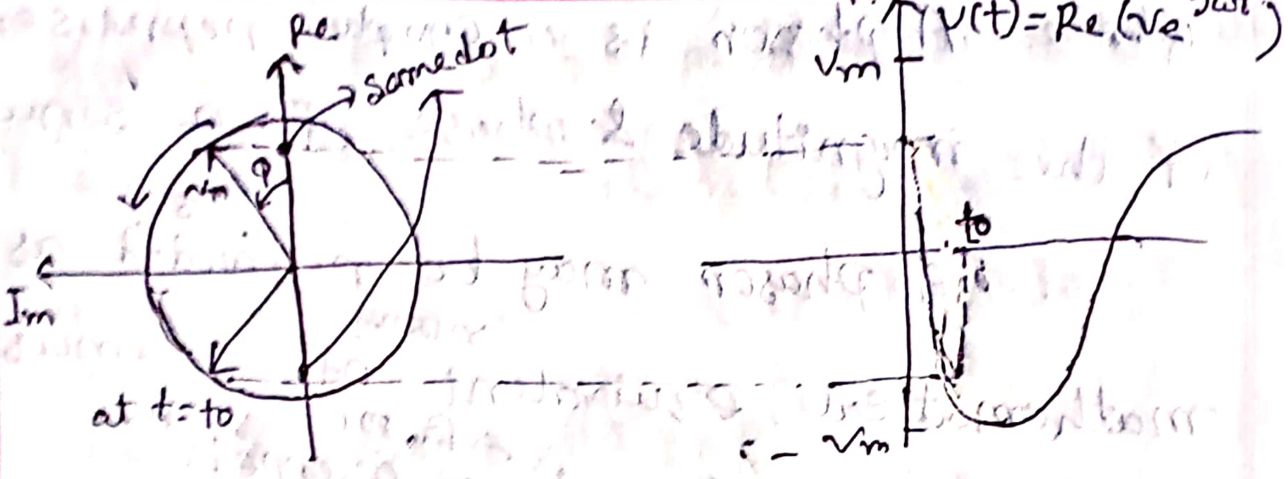


Figure: 9.7 (b)

Description:-

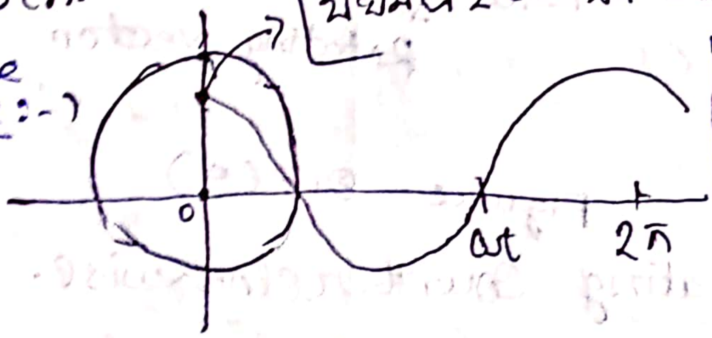
$\sin \omega t \to$ time
$\quad \hookrightarrow$ frequency

$\nearrow \to$ arrow

Here arrow V_m is the rotating vector. And making a circle. That dot is going up & down. This dot is the projection of the tip of the arrow. This dot is going up & down in a sin wave pattern.

[যখন এই অবস্থায় তখন]

In sine wave:-



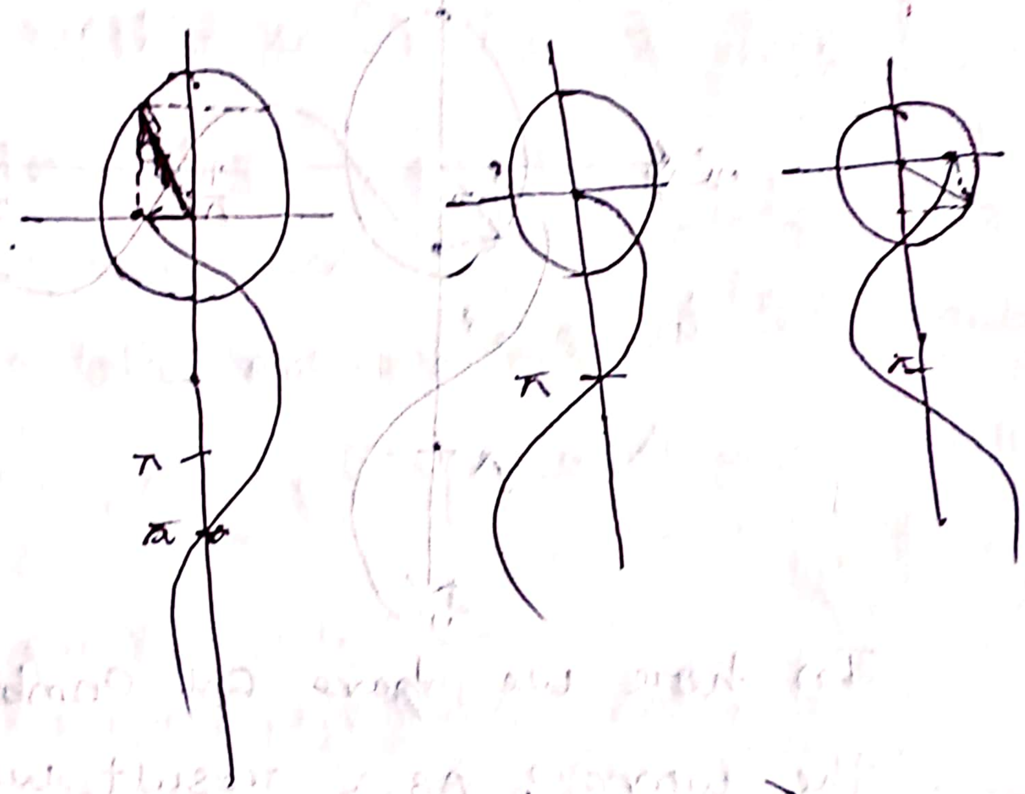
when this curve goes to zero then it is said as $\sin \omega t$

এই ভাবে উঠা নামা করতে থাকলে wave রূপ ও পরিবর্তন হয়।

এও পরিবর্তন হয়।

Now in cosine wave:-

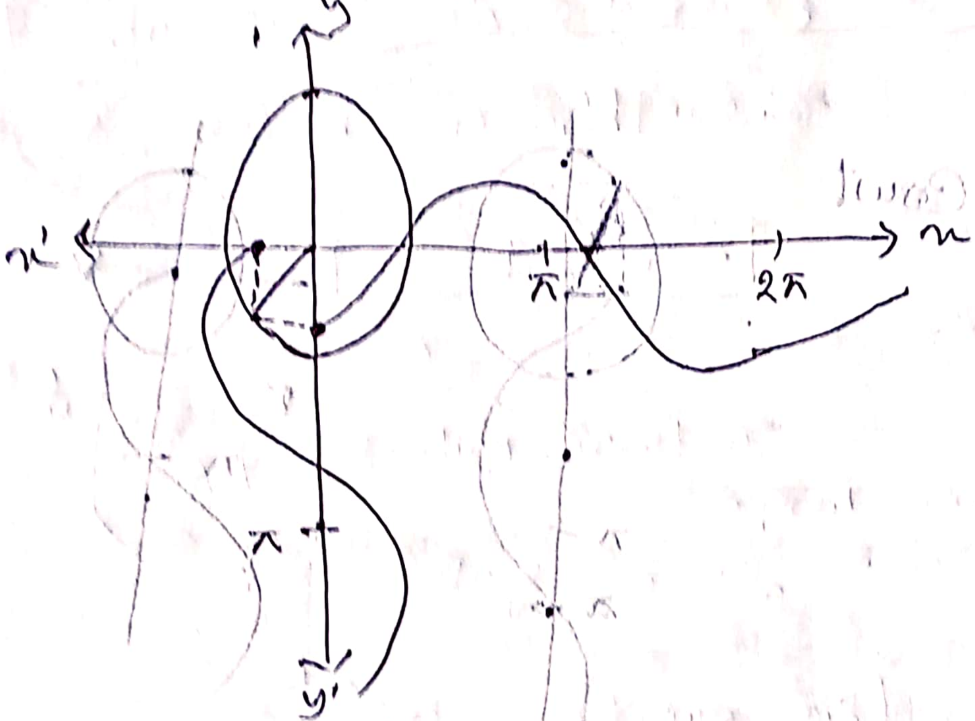
Cowt



~~এ~~ এই Curve wave টা Cosine এর তাই যখন x axis এর উপর ঘুরতে থাকবে আর Arrow টা Sine এর সঙ্গে ঘুরতে থাকবে এবং wave এর Dot যেটি x অক্ষের উপর তার ~~কে~~ সঙ্গে arrow এর দূরত্ব বের করা সহজ হয়।

CamScanner

If we combine both sine & cosine rotating vector then:-



In here we have ~~got~~ combined both of the wave. As a result we can see both are in ~~there~~ their own axis. ~~Sine~~ ~~sin.~~ The dot of sin wave is in y axis and the dot of cos wave is in x axis. (It is good in 3D animation)

V is thus the phasor representation of the sinusoid $v(t)$

For figure → 9.7 (a, b)

- Equation, $v(t) = Re(\mathbf{V}e^{j\omega t}) = \mathbf{V}e^{j\omega t}$ on the complex plane.

As time increases the sinor rotates on a circle of radius V_m at an angular velocity ω in the counterclockwise direction 9.7 (a)

we may regard (বিবেচনা) $v(t)$ as the projection of the sinor $\mathbf{V}e^{j\omega t}$ on the real axis. 9.7 (b)

The sinor may be regarded as rotating phasor. Thus, whenever a sinusoid is expressed as a phasor, the term $e^{j\omega t}$ is implicitly present. (অন্তর্নিহিতভাবে)

When dealing with the phasors ~~to~~ keep in mind the frequency ω of the phasor.

Since a phasor has magnitude and ~~face~~ phase (direction) it behaves as a vector and is printed in boldface.

So, $\mathbf{V} = V_m \angle \phi$ $\mathbf{I} = I_m \angle \phi$

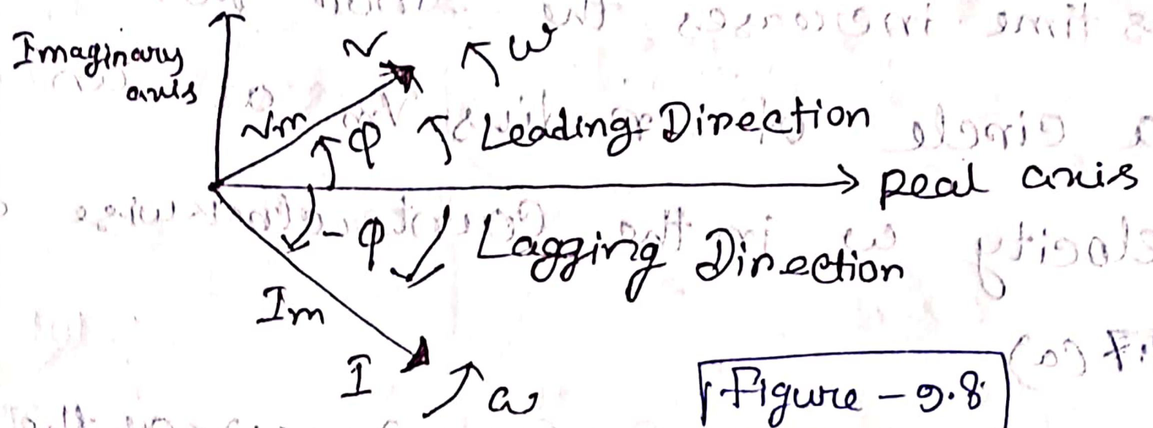


Figure – 9.8

So, Figure-9.8 a graphical representation of phasors is known as a phasor Diagram.

Lighface letters for Complex numbers and fot boldface letter for Phasors

$$v(t) = V_m \cos(\omega t + \phi)$$

Time-Domain representation

$$\mathbf{V} = V_m \angle \phi \quad (9.25)$$

Phasor-domain representation

$30^\circ - 90^\circ = -60^\circ$

Time Domain representation	Phasor D. Rep.
~~Vm Cos(ω~~	
$V_m \cos(\omega t + \phi)$	$\longrightarrow V_m \angle \phi$
$V_m \sin(\omega t + \phi)$	$\longrightarrow V_m \angle \phi - 90^\circ$
$I_m \cos(\omega t + \theta)$	$\longrightarrow I_m \angle \theta$
$I_m \sin(\omega t + \theta)$	$\longrightarrow I_m \angle \theta - 90^\circ$

In here, we see that to get the phasor representation of a sinusoid we expresss it in cosine form to take the magnitude and phase.

The frequency (or time) factor $e^{j\omega t}$ is suppressed in (9.25) equation. The frequency is not explicitly shown in the phasor domain representation because ω is constant. As a result, The phasor domain is

ω = Frequency $\quad J = \sqrt{-1}$ => Imaginary number

V = Phasor representation of a sinusoid

also known as the Frequency domain.

=> If, $v(t) = \cancel{V_m \sin}\ Re(Ve^{J\omega t}) = V_m \cos(\omega t + \phi)$

so that,

$$\frac{dv}{dt} = -\omega V_m \sin(\omega t + \phi) = \omega V_m \cos(\omega t + \phi + 90^\circ)$$

$$= Re(\omega V_m e^{J\omega t} \cdot e^{J\phi} \cdot e^{J90^\circ})$$

$$= Re(J\omega V e^{J\omega t})$$

Note:-

(1) $\frac{d}{dt}(v) \Rightarrow J\omega V$ ——— (9.27)

(Time domain) (Phasor Domain)

⊛ Diff. a sinusoid is equivalent to multiplying its corresponding phasor by $J\omega$

(2) $\int v\,dt \Rightarrow \frac{V}{J\omega}$ ——— (9.28)

(T. D.) (P. D.)

⊛ Integrating a sinusoid is equivalent to dividing its corresponding phasor by $J\omega$

Difference between $V(t)$ & V

1. $v(t)$ is the instantaneous or time domain representation.

   V is the frequency or phasor domain representation.

2. $v(t)$ is time dependentce

   V is not dependentce.

3. $v(t)$ is always real

   V is generally complex.

<u>Note:-</u>

This phasor actually used when frequency is constant.

It is used for manipulating (সুন্দরভাবে ব্যবহার করা) two or more sinusoidal signals only if they are of the same frequency.

How to Solve phasor's Mathematics

(i)

voltage, $v = \underbrace{170}_{\text{amplitude}} \cos(377t - 40^\circ)$ [v]

$\cancel{v_m} = 170$

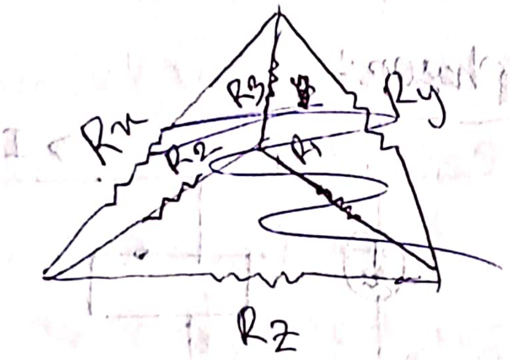
$\Rightarrow$ Phasor, $V = 170 \angle \overset{\text{phases}}{-40^\circ}$ $\overset{\text{unit}}{[v]}$

$\Rightarrow 170 e^{j(-40^\circ)}$

(b) $i = 10 \sin(1000t + 20^\circ)$ (A)

$i = \underline{10} \cos(1000t + 20^\circ - 90^\circ)$

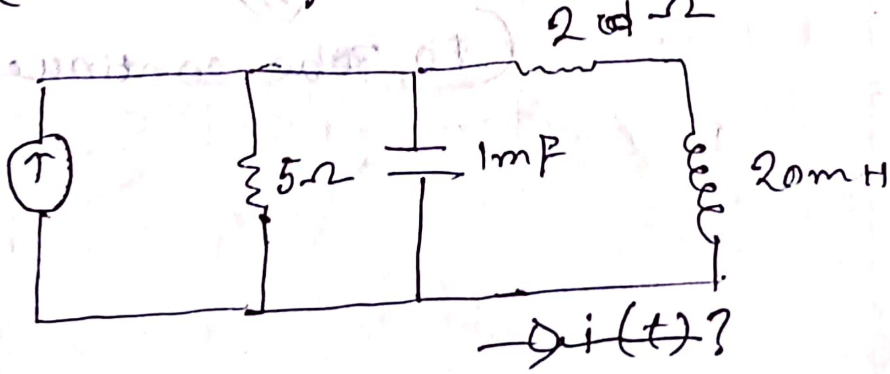
Phasor, $v = 10 \angle \cancel{-90^\circ} -70^\circ$ [v]



$$R_1 = \frac{R_y R_z}{R_x + R_y + R_z}$$

Extra math

4 cos (100t − 20°) A. → i(t)?

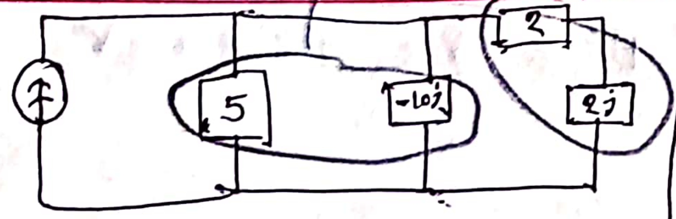


=> ~~Solve~~ How to solve?

① Convert to phasor :-

parallel

series

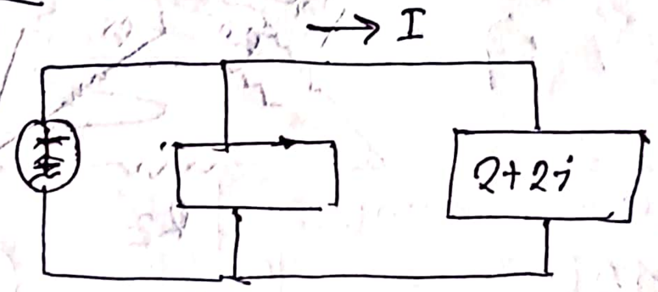


$\frac{-j}{\omega C} = \frac{-j}{100(0.001)}$

frequency 1mF

$j\omega L = j100(0.02)$

(2) Solve in phasor:-



$\frac{5(-10j)}{5+-10j}$

$= \frac{-50j}{5-10j}$

(To be continued)

Math Solution (A-Z)

#Phasor

(±) $V_m \cos(\omega t) = V_m \cos(\omega t + 0°)$
$= V_m \angle 0°$

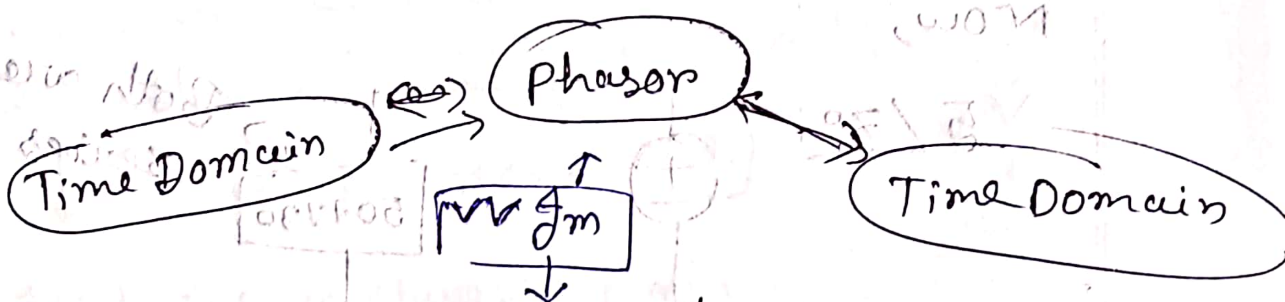
(±) $I_m \cos(\omega t + 30°) = I_m \angle 30°$

(±) $V_m \sin(\omega t) = V_m \cos(\omega t - 90°)$
$= V_m \angle -90°$

(±) $V_m \sin(\omega t + 40°)$
$= V_m \cos(\omega t + 40 - 90°)$
$= V_m \cos(\omega t - 50°)$
$= V_m \angle -50°$

(±) $7 \cos(377t + 15°) = 7 \angle 15°$ → Phasor

Time domain, $i = 7(15°) = 7\cos(377t + 15°)$



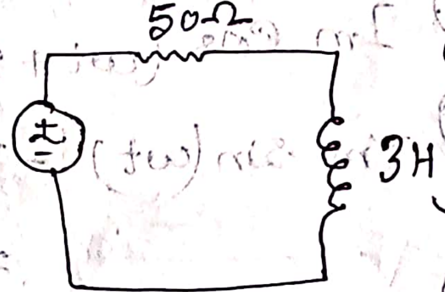
Resistance ⇒ —R— Phasor → —R— ($j\omega$)

Capacitor ⟺ —| |— C → $\frac{1}{j\omega C} = -\frac{j}{\omega C}$

Inductor ⟺ —L— → $j\omega L$

So, $\frac{1}{j\omega c} = \frac{j}{j} \cdot \frac{j}{j^2 \omega c} = \frac{+j}{-1\omega c} = \frac{-j}{\omega c}$

[1] $5\cos(10t + 7^\circ)$
I

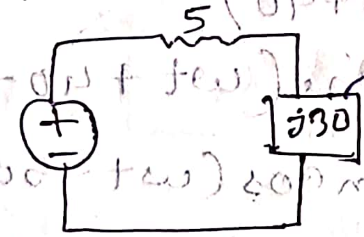


$\omega =$

Step ⊛ Solving:- $\omega = 10$ rads^{-1}

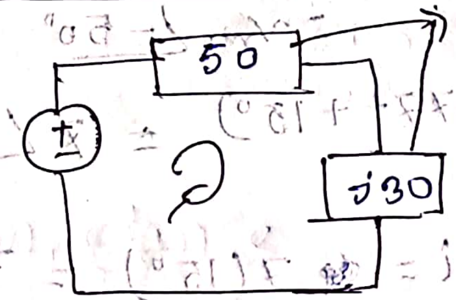
① Convert from time domain → Phasor

$\Rightarrow 5\angle 7^\circ$



$j\omega L = j \times 10 \times 3$
$= j30$

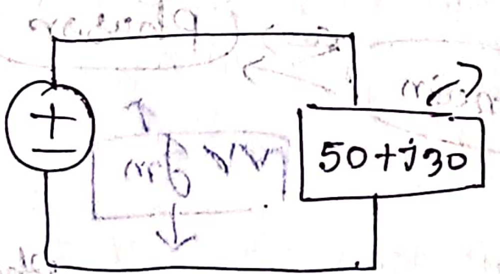
Or, $5\angle 7^\circ$



These two are Impedance

Now,

$5\angle 7^\circ$



Both are in series

Step ② Solve in phasor:-

So, $V = I \cdot Z$

Or, $5\angle 7^\circ = I \cdot (50 + j30^\circ)$

$\boxed{j = 1\angle 90^\circ}$ Polar form $r\angle\theta$ => কোণ থাকবে ~~Calc.~~ এখানে i/j থাকে না। | Rectangular Form এ i থাকে / j থা

So, $I = \dfrac{5\angle 7^\circ}{50 + j30^\circ} = 0.86\angle -24^\circ$

Step-3

Convert from phasor → time.

$I = 0.086\angle -24^\circ$ → ω এর মান 10 তাই

$i(t) = 0.086 \cos(10t - 24^\circ)$

Calculator এ ব্যবহার:-

ক. complex mode → সমীকরণ তোলা → Ans → S<=>D

To get in ~~Pto~~ polar:-

Ans → shift → 2 → 3 → Ans => S<=>D

For complex number:-

press button $\boxed{i}$ instead of $\boxed{j}$

To get the rectangular form:-

Ans => shift → $\boxed{2}$ → $\boxed{4}$ → $\boxed{=}$

(*) If we press S<=>D we will get decimal ~~From~~ form

Summary of voltage-current Relationship

Element		Time Domain		Frequency Domain
Resistance R	$\longrightarrow$	$v = Ri$	$\longrightarrow$	$V = RI$
Inductor L	$\longrightarrow$	$v = L\cdot\frac{di}{dt}$	$\longrightarrow$	$V = j\omega L I$
Capacitor C	$\longrightarrow$	$i = C\frac{dv}{dt}$	$\longrightarrow$	$V = \frac{I}{j\omega C}$

(Math মুখস্থ করতে হবে)

Impedance & Admittance

$$\boxed{\frac{V}{I} = R \,;\; \frac{V}{I} = j\omega L \,;\; \frac{V}{I} = \frac{1}{j\omega C}} \quad (9.39)$$

As all ~~are~~ three expressions, we obtain Ohm's law in phasor form for any type of element,

$$\boxed{Z = \frac{V}{I} \quad \text{or,} \quad V = ZI} \quad (9.40)$$

where Z is a frequency-dependent quantity known as impedance, measured in ohms.

The impedence Z of a circuit is the ratio of the phasor voltage V to the phasor current I, measured in ohms (Ω)

Although the impedence is the ratio of two phasors, it is not a phasor, because it does not correspond to a sinusoidally varying quantity.

Impedence & admittances of passive elements:- (Table - 9.3)

Element	Impedance	Admittance
R	$Z = R$	$Y = \frac{1}{R}$
L	$Z = j\omega L$	$Y = \frac{1}{j\omega L}$
C	$Z = \frac{1}{j\omega C}$	$Y = j\omega C$

Although the impedance is the ratio of two phasors, it is not a phasor, because it does not correspond to a sinusoidally varying quantity.

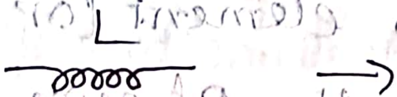
From table (9.3) summarizes their impedances & from there we notice

$Z_L = jωL$

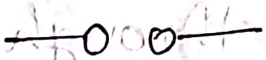
$Z_C = -j/ωC$

An iductor acts like a short circuit & ~~an~~ a capacitor acts like an open circuit.

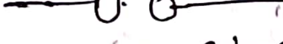
when $ω \to \infty$ $Z_L \to \infty$ and $Z_C = 0$, indicating that the inductor is an open circuit to high frequencies, while the capacitor is a short circuit.



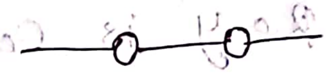
Short circuit at DC



open circuit at high Frequencies



open circuit at DC



Short circuit at high frequencies

As a complex quantity, the impedance may be expressed,

$$Z = R + jx \quad \text{—(9.41)}$$

In polar Form, $Z = |Z| \angle \theta$ —(9.42)

$$Z = R + jx = |Z| \angle \theta \quad \text{—(9.43)}$$

$$|Z| = \sqrt{R^2 + x^2} \;;\quad \theta = \tan^{-1} \frac{X}{R} \quad \text{—(9.44)}$$

$$R = |Z| \cos\theta \;;\quad x = |Z| \sin\theta \quad \text{—(9.45)}$$

The admittance Y of an element (or a circuit) is the ratio of the phasor current through it to the phasor voltage,

$$\boxed{Y = G + jB} \quad \text{——} (9.47)$$

where, $G = \text{Re}\,Y$ is called the conductance (संचालन)
and $B = \text{Im}\,Y$ is called the susceptance.

(Susceptance ~~It~~ is the imaginary part of admittance, where the real part is conductance. The ~~reciprocal~~ reciprocal (व्युत्क्रम) of admittance is impedance where the imaginary part is reactance and real part is resistance)

Admittance, conductance and susceptance are all expressed in the unit of siemens (or ~~mo~~ mhos).

$$G + jB = \frac{1}{R + jX} \quad \text{———} (9.48)$$

$(R+jx)(R-jx)$
$R^2-(jx)^2 \quad R^2-j.j.x^2$

By rationalization,

$$G+jB = \frac{1}{R+jx} \cdot \frac{R-jx}{R-jx} =$$

$$= \frac{R-jx}{R^2-(jx)^2} = \frac{R-jx}{R^2+x^2} \quad -(9.49)$$

(কিভাবে আসলো আছে)

Equating (সমীকরণ করে) the real and imaginary parts gives,

$$G = \frac{R}{R^2+x^2}, \quad B = -\frac{x}{R^2+x^2} \quad -(9.5)$$

Showing that $G \neq 1/R$ as it is in resistive circuits. Of course, if $x=0$, then $G = 1/R$

Formula of Impedance :-

① $Z = \sqrt{R^2+(X_L-X_C)^2}$

② $Z = R + \frac{1}{jwC}$

Voltage accross the Capacitor,

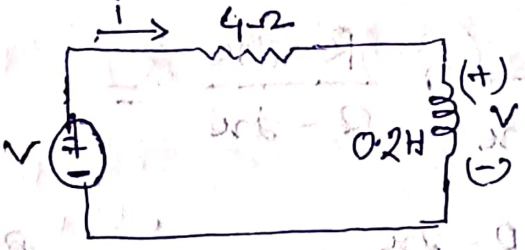
$V = IZ_C = \frac{I}{jwC}$

Z = impedance
R = Resistance
X_L = Inductive Reactance
X_C = Capacitive Reactance

w = Frequency
C = Current

Incomplete

Math :- Determine $v(t)$ and $i(t)$



$V_s = 20 \sin(10t + 30°) V$

=> From the voltage source,

$20 \sin(10t + 30°)$

so, $\omega = 10$; $V_s = 20\angle 30° V$

The impedance is,

$Z = R + \frac{1}{j\omega C} = 5 + \frac{1}{j \cdot 10}$

Kirchoff's Laws in the Frequency Domain:-

We cannot do circuit analysis in the frequency domain without Kirchhoff's current and voltage laws. Therefore, we need to express them in the frequency domain.

For KVL let $v_1, v_2, \ldots, v_n$ be the voltage around a closed loop.

Then, $v_1 + v_2 + \ldots\ldots + v_n = 0$ ——— (9.51)

In the sinusoidal steady state, each voltage may be written ~~as~~ in cosine form, so that equation (9.51) becomes,

$$V_{m1}\cos(\omega t+\theta_1) + V_{m2}\cos(\omega t+\theta_2) + \ldots +$$

$$V_{mn}\cos(\omega t+\theta_n) = 0 \quad \text{——— (9.52)}$$

This can be written as,

$$Re\left[(V_{m1}e^{j\theta_1} + V_{m2}e^{j\theta_2} + \ldots + V_{mn}e^{j\theta_n})e^{j\omega t}\right] = 0$$

——— (9.53)

If we let; $v_K = V_{mK} e^{j\theta_K}$, then,

$$Re[(V_1 + V_2 + \dots + V_n)e^{j\omega t}] = 0 \quad \text{--- (9.54)}$$

Since, $e^{j\omega t} \neq 0$,

$$V_1 + V_2 + \dots + V_n = 0 \quad \text{--- (9.55)}$$

If we let $i_1, i_2, \dots, i_n$ be the current leaving or entering a closed surface in a network at time t, then

$$i_1 + i_2 + \dots + i_n = 0 \quad \text{--- (9.56)}$$

If these are the phasors form of the sinusoids then,

$$I_1 + I_2 + \dots + I_n = 0 \quad \text{--- (9.57)}$$

which Kirchoff's current law in the frequency domain.

As ~~KVE~~ KVL, KCL holds in the frequency domain, it is easy to do many things, such as impedance combination, ~~nodal~~ ... and ~~mesh analyses,~~ s

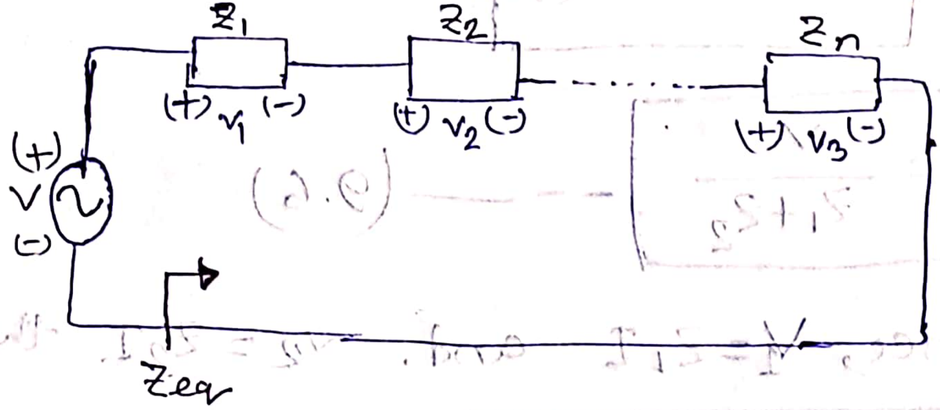
Impedances Combinations

N series connected impedances, the same current I flows through the impedances.

Applying KVL around the loop gives,

$$V = V_1 + V_2 + \ldots\ldots + V_n$$

$$= I(Z_1 + Z_2 + \ldots\ldots + Z_n) \quad \text{— (9.58)}$$

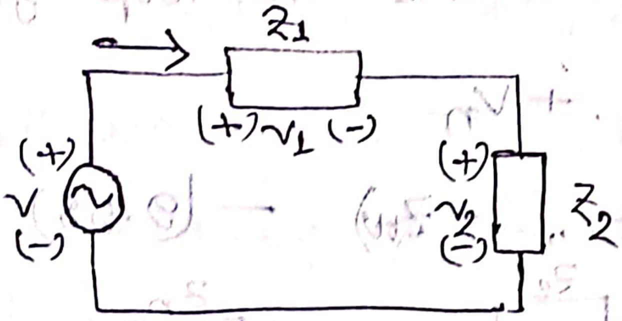


The equivalent impedances at the input terminal is,

$$Z_{eq} = \frac{V}{I} = Z_1 + Z_2 + \ldots\ldots + Z_n$$

$$\boxed{Z_{eq} = Z_1 + Z_2 + \ldots\ldots + Z_n} \quad \text{— (9.59)}$$

The total or equivalent impedance of series connected impedances is the sum of the individual impedances. This similar to the series connection of resistances.



$$\boxed{I = \frac{V}{Z_1 + Z_2}} \quad \text{------} \quad (9.6)$$

Since, $V_1 = Z_1 I$ and. $v_2 = Z_2 I$ then,

$$\boxed{\begin{aligned} v_1 &= \frac{Z_1}{Z_1 + Z_2} \cdot v \\ v_2 &= \frac{Z_2}{Z_1 + Z_2} \cdot v \end{aligned}} \quad \text{------} \quad (9.61)$$

which is the voltage division relationship.

In the same manner, we can obtain the equivalent impedance or admittance of the N-parallel connected impedances shown in Fig. 9.2. The voltage accross each . . .

Lesson- AC circuits

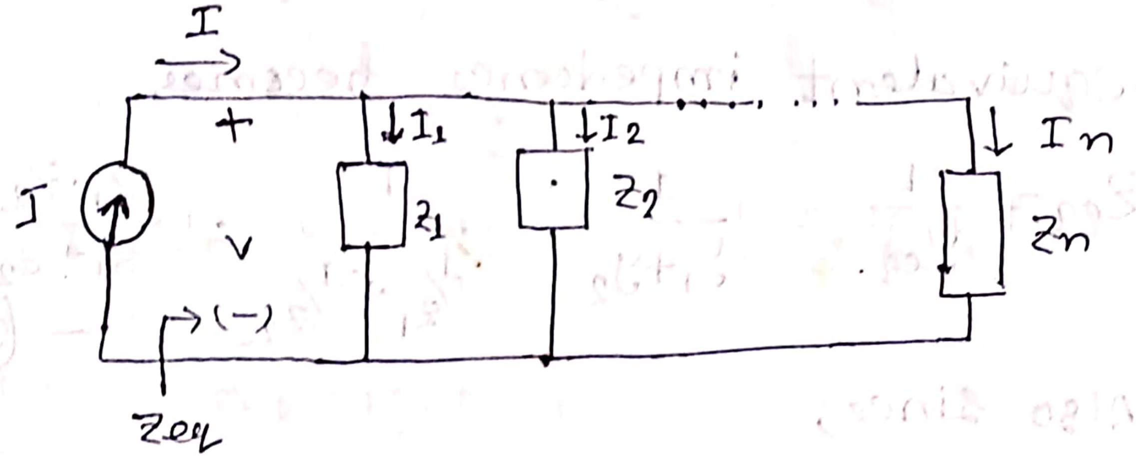
..... [After Notebook-1]

impedance ~~in~~ is the same. Applying KCL at the top node,

$$I = I_1 + I_2 + \ldots\ldots + I_n$$

$$= V\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \ldots + \frac{1}{Z_n}\right) \quad -(9.62)$$

☐ N - impedances in parallel:-



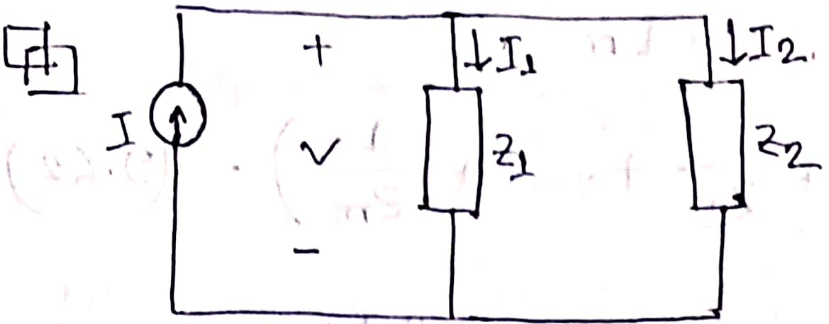
The equivalent impedance is,

$$\frac{1}{Z_{eq}} = \frac{I}{V} = \frac{1}{Z_1} + \frac{1}{Z_2} + \ldots + \frac{1}{Z_n} \quad -(9.63)$$

and the equivalent admittance is,

$$Y_{eq} = Y_1 + Y_2 + \ldots + Y_n \quad ---- (9.64)$$

This indicates that the equivalent admittance of a parallel connection of admittances is the sum of the individual admittances.



When $N=2$, as shown in Figure, the equivalent impedance becomes,

$$Z_{eq} = \frac{1}{Y_{eq}} = \frac{1}{Y_1+Y_2} = \frac{1}{1/Z_1 + 1/Z_2} = \frac{Z_1 \cdot Z_2}{Z_1+Z_2} \quad \text{— (9.65)}$$

Also since,

$$V = I Z_{eq} = I_1 Z_1 = I_2 Z_2$$

the currents in the impedances are,

$$I_1 = \frac{Z_2}{Z_1+Z_2} \cdot I$$

$$I_2 = \frac{Z_1}{Z_1+Z_2} \cdot I \quad \text{— (9.66)}$$

which is the current-division principle.

The delta-to-wye and wye-to-delta transformations that we applied to resistive circuits are also valid for impedances. With reference to Fig (9.22) the conversion formulas are as follows.

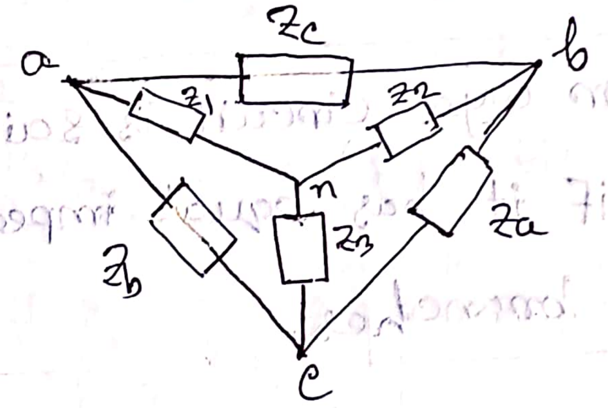


Figure - 9.22 (Superimposed Y and Δ networks).

Y-Δ conversion :-

1. $Z_a = \dfrac{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}{Z_1}$

2. $Z_b = \dfrac{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}{Z_2}$

3. $Z_c = \dfrac{Z_1 Z_2 + Z_2 Z_3 + Z_3 \cdot Z_1}{Z_3}$

Δ-Y conversion:-

1) $Z_1 = \frac{Z_b Z_c}{Z_a + Z_b + Z_c}$

2) $Z_2 = \frac{Z_c Z_a}{Z_a + Z_b + Z_c}$

3) $Z_3 = \frac{Z_a Z_b}{Z_a + Z_b + Z_c}$

A delta or wye circuit is said to be balanced if it has equal impedances in all three branches.

When a Δ-Y circuit is balanced, Equation (9.67) and (9.68) become,

$$\boxed{Z_\Delta = 3Z_Y \quad \text{or,} \quad Z_Y = \tfrac{1}{3} Z_\Delta} \quad \text{— (9.69)}$$

where, $Z_Y = Z_1 = Z_2 = Z_3$

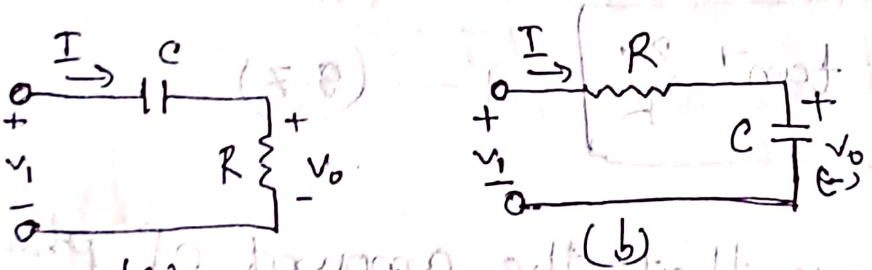
and, $Z_\Delta = Z_a = Z_b = Z_c$

Applications :-

9.8.1 Phase Shifters :-

A phase-shifting circuit is often employed to correct an undesirable phase shift already present in a circuit or to produce special desired effects.

An RC circuit is suitable for this purpose



(a) (b)

(Fig → 9.31)

because it's capacitor causes the circuit current to lead the applied voltage.

Two commonly used RC circuits are shown in Figure 9.31. (RL circuits or any reactive circuits could also serve the same purpose).

Q.1) (a) The circuit current I leads the applied voltage. ~~of~~ V_i by some phase angle θ,

where $0 < \theta < 90°$, depending on the values of R and C.

If $X_c = -1/\omega C$,

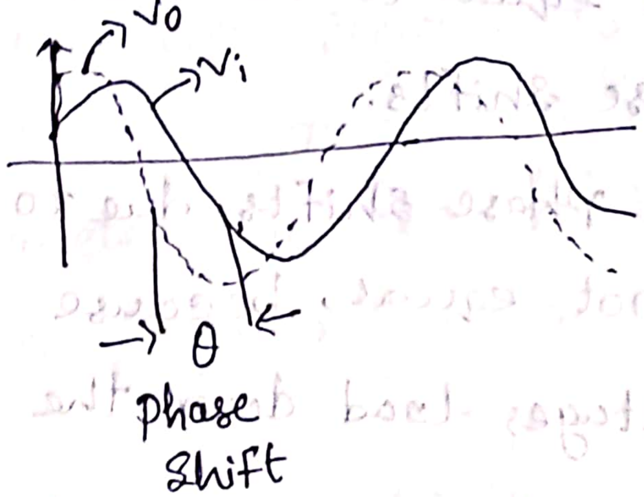
then the total impedance is $Z = R + jX_c$

and the phase shift is given by,

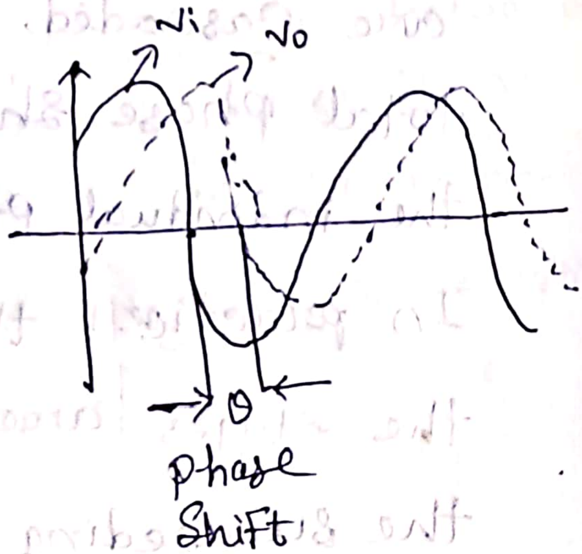
$$\boxed{\theta = \tan^{-1} \frac{X_c}{R}} \quad \text{——— (9.7)}$$

This shows that the amount of phase shift depends on the values of ~~R~~, ~~C~~ R, C. and the operating frequency. Since the output voltage V_o across the resistor is in phase with the current, V_o leads (positive phase shift) V_i.

9.31 (b):- The output is taken across the capacitor. The current I leads the input voltage v_i by θ, but the output voltage $v_o(t)$ across the capacitor lags (negative phase shift) the input voltage $v_i(t)$ as illustrated below:-



(a)



(b)

We should keep in mind that the simple RC circuits in Fig (9.31) also act as voltage dividers.

As the phase shift θ approaches 90°, the output voltage v_0 approaches zero. For this reason, these simple RC circuits are used only when small amounts of phase shift are required.

If it is desired to have phase shifts greater than 60°, simple RC networks are cascaded, thereby providing a total phase shift equal to the sum of the individual phase shifts.

In practice, the phase shifts due to the stages are not equal, because the succeeding stages load down the earlier stages ~~us~~ unless op amps are used to separated the stages.

~~9.8.2~~

9.8.2 (AC Bridges) :-

An Ac bridge Circuit is used in measuring the inductance L of an inductor or the Capacitance C of a Capacitor.

It is similar in form to the wheatstone bridge for measuring an unknown resistance and Flo Follows the same principle. To measure L and C, however, an ac source is needed as well as an ac meter instead of the galvano-meter. The ac meter may be a sensitive ac ammeter or voltmeter.

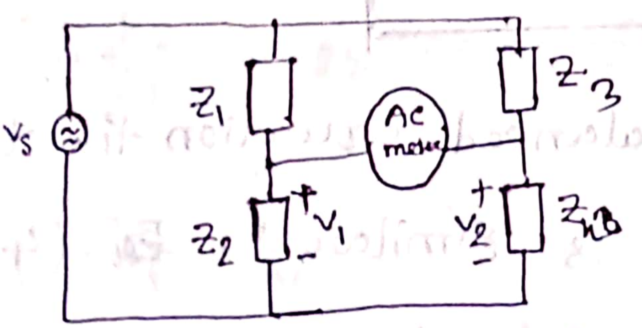


Figure: 9.37 (A general ac bridge)

Consider the general ac bridge circuit displayed in (Fig. 9.37). The bridge is balanced when no current flows through the meter. This means that $V_1 = V_2$.

Applying the voltage division principle,

$$V_1 = \frac{Z_2}{Z_1 + Z_2} \cdot V_S = V_2 = \frac{Z_x}{Z_3 + Z_x} \cdot V_S \quad \text{——} (9.71)$$

Thus,

$$\frac{Z_2}{Z_1 + Z_2} = \frac{Z_x}{Z_3 + Z_x}$$

$$\Rightarrow Z_2 Z_3 = Z_1 Z_x \quad \text{——} (9.72)$$

or, $$\boxed{Z_x = \frac{Z_3}{Z_1} \cdot Z_2}$$

This is the balanced equation for the ac bridge and is similar to Eq. (4.30) for the resistance bridge except that the R's are replaced by Z's.

Specific, ac bridges for measuring L and C are shown in Figure (9.38), where L_x and C_x are the unknown inductance and capacitance to be measured. while L_s and C_s are a standard inductance and capacitance (the value of which are known to great precision). In each case, two resistors R_1 and R_2 are varied until the ac meter reads zero. Then the bridge is balanced.

From ~~Eq.~~ (Eq. 9.73), we obtain,

$$L_x = \frac{R_2}{R_1} L_s \quad \text{---} (9.74)$$

and,

$$C_x = \frac{R_1}{R_2} \cdot C_s \quad \text{---} (9.75)$$

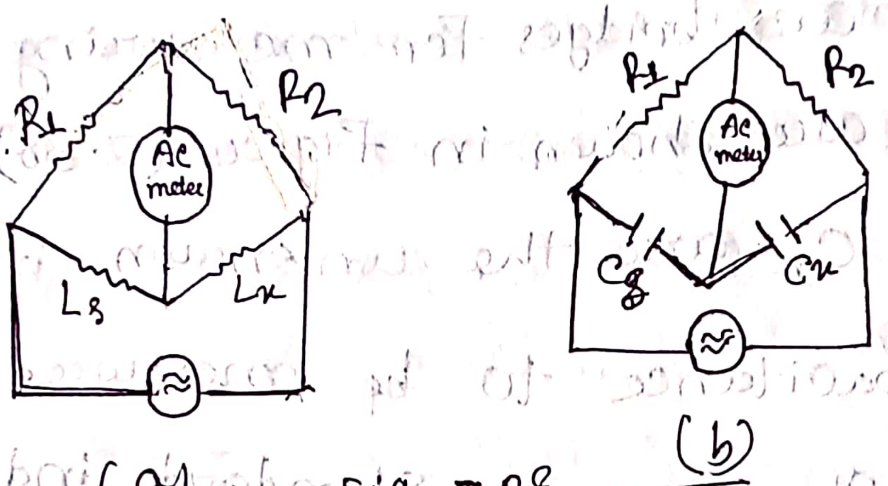


Fig-9.38.

~~The blan~~ (Specific ac bridges : (a) For measuring L
(b) For measuring C.)

The balancing of the ac bridges in Fig (9.38) does not depend on the Frequency F of the ac source. Since F does not appear in the relationships in Eqs (9.74) and (9.75)

Summary

1. A sinusoid is a signal in the form of the sine or cosine function. It has the general form,

$$v(t) = V_m \cos(\omega t + \phi)$$

where V_m is the amplitude, $\omega = 2\pi f$ is the angular frequency, $(\omega t + \phi)$ is the argument and ϕ is the phase.

2. A phasor is a complex quantity that represents both the magnitude and the phase of a sinusoid. Given the sinusoid,

$$v(t) = V_m \cos(\omega t + \phi)$$

its phasor V is,

$$V = V_m \angle \phi$$

3. In ac circuits, voltage and current phasors always have a fixed relation to

to one another at any moment of time. If $v(t) = V_m \cos(\omega t + \phi)$ represents ~~its phasor V is,~~ the current through the ~~$V = V_m \angle \phi$~~ element, then $\phi_i = \phi_v$.

if the element is a resistor, ϕ_i ~~lead~~ leads ϕ_v by $90°$ if the element is a capacitor, and ϕ_i lags ϕ_v by $90°$ if the element is a capacitor, and ϕ_i lags ϕ_v by $90°$ if the element is an inductor.

4. The impedance Z of a circuit is the ratio of the phasor voltage accross it to the phasor current through it :-

$$Z = \frac{V}{I} = R(\omega) + jX(\omega)$$

The admittance Y is the reciprocal of impedance:-

$$Y = \frac{1}{Z} = G(\omega) + jB(\omega)$$

Impedances are combined in series or in parallel the same way as resistances in series or parallel ; that is, impedances in series add while admittances in parallel add.

5) For a resistor, $Z = R$ For an inductor $Z = jX = j\omega L$, ~~ad~~ and For a capacitor $Z = -jX = 1/j\omega C$

6) Basic circuit laws (Ohm's and Kirchhoff's) apply to ac circuits in the same manner as they do for dc circuits, that is,

$$V = ZI$$

$$\sum I_K = 0 \quad (KCL)$$

$$\sum V_K = 0 \quad (KVL)$$

7| The techniques of voltage/current division, series/parallel combination of impedance/admittance, circuit reduction, and Y-Δ transformation all apply to ac circuit analysis.

8| AC circuits are applied in phase-shifters and bridges.

math of Phasor & AC circuit will be after lesson-11

Lesson-11

AC Power Analysis

11.1 :-

Introduction :-

power analysis is of paramount importance. power is the most important quantity in electric utilities, electric and communication systems, because such systems involve transmission of power from one point to another. Also every industrial and household device has a power rating that indicates how much power the equipment requires. The most common form of electric power is 50 or 60 Hz ac power. The choice of ac over dc allowed high-voltage power transmission from the power generating plant to the consumer

11.2 :-

Instantaneous and Average power:-

$$\boxed{P(t) = v(t) \cdot i(t)}$$

The instantaneous power p(t) absorbed by and element is the product of the instantaneous voltage v(t) across the element and the instantaneous current i(t) through it. Assuming the passive sign convention.

⊛ The instantaneous power (in watts) is the power at any instant of time.

It is the rate at which an element absorbs energy. Consider the general case of instantaneous power absorbed by an arbitrary combination of circuit elements under sinusoidal excitation.

$$v(t) = V_m \cos(\omega t + \theta_v) \quad \text{—— (11.2a)}$$

$$i(t) = I_m \cos(\omega t + \theta_i) \quad \text{—— (11.2b)}$$

Here,

V_m & I_m = The amplitudes (or, peak values)

θ_v & θ_i = The phase angles of the voltage and current.

The instantaneous power absorbed by the circuit is :-

$$p(t) = v(t) \cdot v(i)$$

$$= V_m I_m \cos(\omega t + \theta_v) \cdot \cos(\omega t + \theta_i)$$

If we apply trigonometric identity,

$$\boxed{\cos A \cdot \cos B = \tfrac{1}{2}\left[\cos(A-B) + \cos(A+B)\right]} \quad \text{— (11.4)}$$

$$p(t) = \tfrac{1}{2} V_m I_m \cos(\theta_v - \theta_i) + \tfrac{1}{2} V_m I_m \cos(2\omega t + \theta_v + \theta_i)$$

—— (11.5)

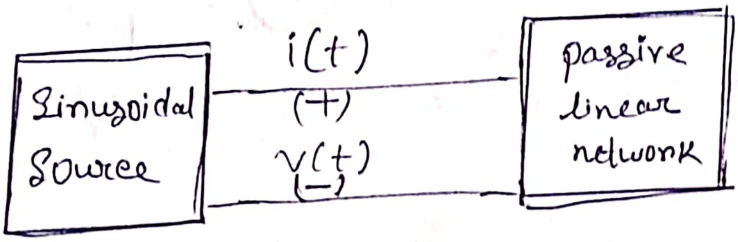
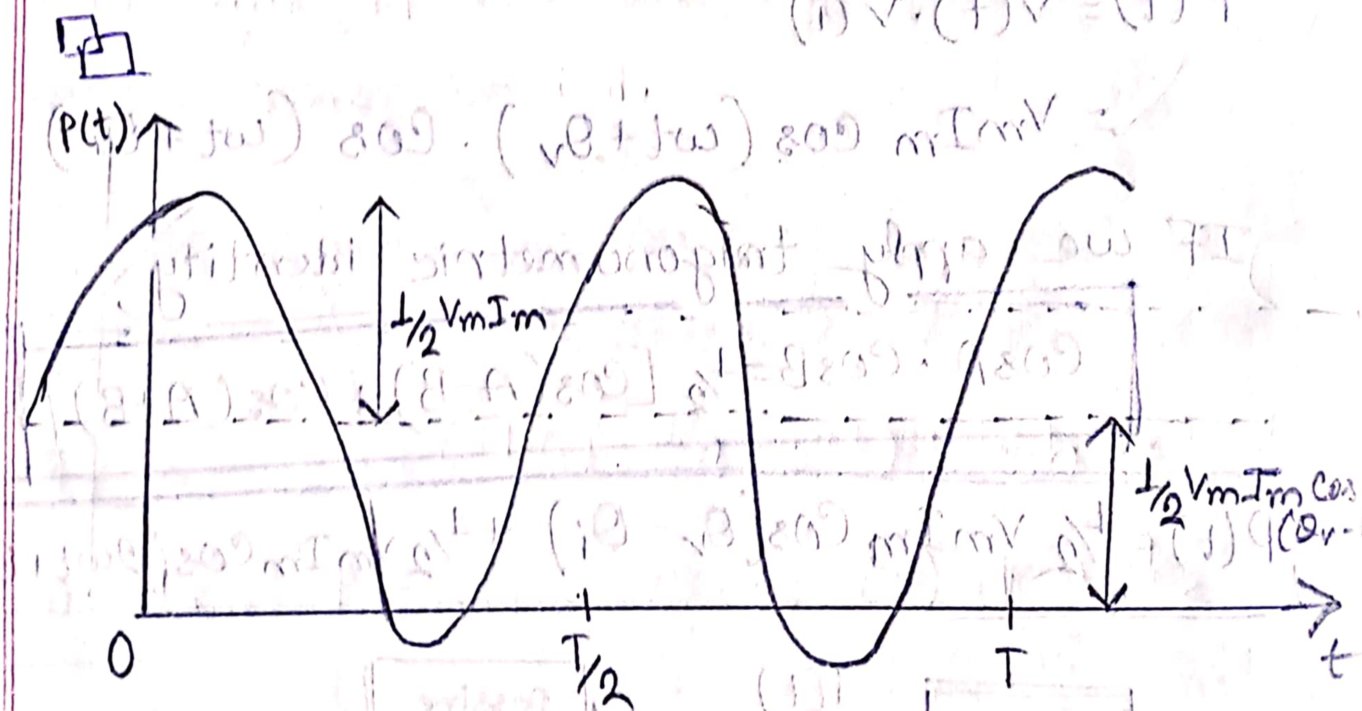


Figure: 11.1

This shows us that the instantaneous power has two parts. The first part is constant on time & independent. Its value depends on the phase difference between the voltage and the current.

The second part is a sinusoidal function whose frequency is 2ω, which is twice the angular frequency of the voltage or current.



Here, $T = 2\pi/\omega$ which is the period of voltage or current. We observe that $p(t)$ is periodic,

$p(t) = p(t + T_0)$ & has a period of $T_0 = T/2$.

Since its frequency is twice that of voltage or current.

We also observe that $p(t)$ is positive for some part of each cycle and negative for the rest of the cycle.

When $p(t)$ is positive, power is absorbed by the circuit. When negative, power is absorbed by the source.

That is, the power is transferred from the circuit to the source.

This is possible because of the storage elements (capacitors and inductors) in the circuit.

The instantaneous power changes with time and is therefore difficult to measure. The average power is more convenient (সুবিধাজনক) to measure.

In fact, the wattmeter, the instrument for measuring power, responds to average power.

⊛ The average power, in watts, is the average of the instantaneous power over one period.

$$\boxed{\text{The average power, } P = \frac{1}{T}\int_0^T p(t)\,dt} \quad \text{--- (11.6)}$$

If we apply (11.6) on $p(t)$ which is $T_0 = T/2$,

$$P = \frac{1}{T}\int_0^T \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)\,dt + \cancel{\frac{1}{2}}$$

$$\frac{1}{T}\int_0^T \frac{1}{2} V_m I_m \cos(2\omega t + \theta_v + \theta_i)\,dt$$

$$= \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i) \frac{1}{T} \int_0^T dt + \frac{1}{2} V_m I_m \frac{1}{T} \int_0^T \cos(2\omega t + \theta_v + \theta_i)\, dt \qquad (11.7)$$

The first integrand is constant, and the average of a constant is the same constant.

The second integrand is a ~~sino~~ sinusoid. We know that the average of a sinusoid over its period is zero because the area under the sinusoid doing a positive half cycle is canceled by the area under it during the following negative half-cycle.

As the second ~~th~~ term in (Eq 11.7) vanishes and the average power becomes,

$$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i) \qquad (11.8)$$

Since, $\cos(\theta_v - \theta_i) = \cos(\theta_i - \theta_v)$, what is important is the difference in the phases of the voltage and current.

P(t) is time varying while P doesn't depend on time.

To find the instantaneous power, we must necessarily have v(t) and i(t) in the time domain. But we can find the average power when voltage and current are expressed in the time domain as in eq(11.8) or when they are expressed in the ~~time domain~~ frequency domain.

The phasors forms of v(t) and i(t),

$V = V_m \angle \theta_v$ and $I = I_m \angle \theta_i$ respectively.

P is calculated using eq(11.8) or using phasors V and I.

To use phasors,

$$\frac{1}{2} V I^* = \frac{1}{2} V_m I_m \angle \theta_v - \theta_i$$

$$= \frac{1}{2} V_m I_m \left[\cos(\theta_v - \theta_i) + j\sin(\theta_v - \theta_i)\right] \quad (11.9)$$

we recognize the real part of this expression as the average power, P, according to equation (11.8). Thus;

$$\boxed{\begin{aligned} P &= \tfrac{1}{2}\,\mathrm{Re}[V I^*] \\ &= \tfrac{1}{2} V_m I_m \cos(\theta_v - \theta_i) \end{aligned}} \quad \text{--- } (11.10)$$

Consider two special cases (eqn 11.10)

When $\theta_v = \theta_i$, the voltage and current are in phase. This implies a purely resistive circuit or resistive load R,

$$\boxed{\begin{aligned} P &= \tfrac{1}{2} V_m I_m \\ &= \tfrac{1}{2} I_m^2 R \\ &= \tfrac{1}{2} |I|^2 R \end{aligned}} \quad \text{--- --- --- } (11.11)$$

where $|I|^2 = I \times I^*$.

Equation (11.11) shows that a purely resistive circuit ~~or resistive load R,~~ absorbs power at all times. When $\theta_v - \theta_i = \pm 90°$, we have a purely reactive circuit, and

$$\boxed{\begin{aligned} P &= \tfrac{1}{2} V_m I_m \cos 90° \\ &= 0 \end{aligned}} \quad \text{--- (11.12)}$$

* A resistive load (R) absorbs power at all times, ~~while a reac~~
* A reactive load (L or C) absorbs zero average power.

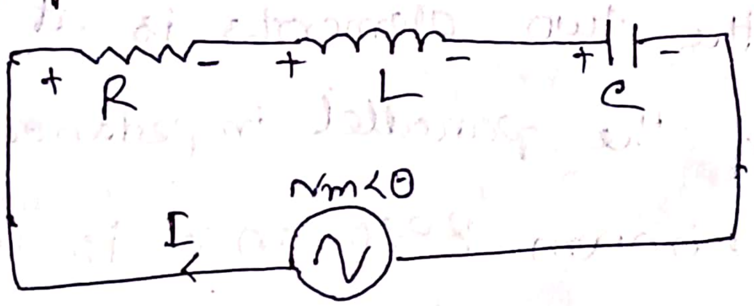
Lesson

Resonance (অনুনাদ)

⇒ Electrical resonance occurs in an electric circuit at a particular resonant (প্রতিধ্বনিময়) frequency when the impedances or admittances of circuit elements cancel each other. In some circuits, this happens when the impedance between the input and output of the circuit is almost zero and the transfer function is close to one.

Series Resonance Circuit :-

Resonance occurs in a series circuit when the supply frequency causes the voltages across L and c to be equal and opposite in phase.



LC circuit :-

Resonance of a circuit involving capacitors and inductors occurs because the collapsing magnetic field of the inductor generates an electric current in its windings and charges the capacitor, and then the discharging capacitor provides an electric current that builds the magnetic fields in the inductor. This process is repeated ~~successfully~~ continuously.

An analogy is a mechanical pendulum, and both are a from of simple harmonic oscillator.

At resonance, the series impedance of the two elements is at a minimum and the parallel impedance is at maximum. Resonance is used for

-tuning and filtering, because it occurs at a particular frequency for given values of inductance and capacitance.

parallel Resonance:-

parallel Resonance or near-to-resonance circuits can be used to prevent the waste of electrical energy, which would otherwise occur while the inductor built its field or capacitor charged and discharged.

Example:-

Asynchronous motors waste inductive current while synchronous ones waste capacitive current.

The use of the two types in parallel makes the inductor feed the capacitor maintaining the same resonant current in the circuit, and converting all the current into useful.

Formula:-

$$\omega L = \frac{1}{\omega C}$$

So, $\omega = \frac{1}{\sqrt{LC}}$

where, $\omega = 2\pi F$

in which F is the resonance Frequency in hertz, L = henries, C = Farads,

Inductance

Quality Factor:-

The quality of the resonance (how ~~to~~ long it will ring when excited) is determined by its Q Factor (A Function of resistance) :-

$$Q = \frac{1}{R}\sqrt{L/C}$$

An idealized lossless LC circuit has infinite Q.

but all actual circuits have some resistance and Finite Q, and are usually approximated more realistically by an RLC circuit.

RLC/QILCR circuit :-

An electrical circuit consisting of a resistor, an inductor, and a capacitor connected in series or in parallel. The circuit forms a harmonic oscillator for current and resonates similarly to an LC circuit.

There are many applications of this circuit. It is used in many different types of oscillator circuits. An important application is for tuning, such as in radio receivers or television sets, where

2

they are used to select a narrow range of frequencies from the ambient radio waves. In this role the circuit is often refered to as a tuned circuit. An RLC circuit canbe used as a passive filters.

passive Filters:-

~~The~~ passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (~~tr~~ transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.

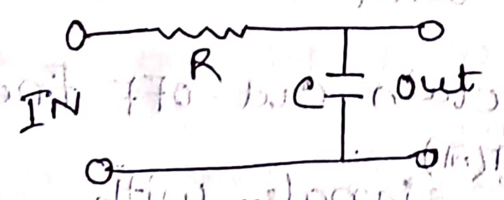
Types of passive filters :-

1) Low pass filters:-

A low-pass filter is a filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cut-off frequency.

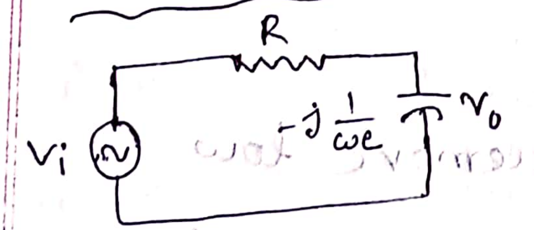
The frequency between the pass-and-stop bands is called the cut-off frequency.

It is used to remove high frequency signals and allow through low frequency signals.

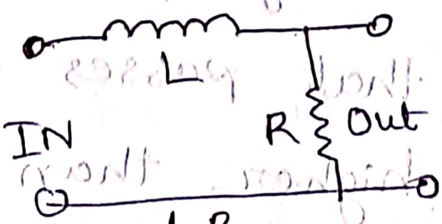


CR

RC-Low pass Filter

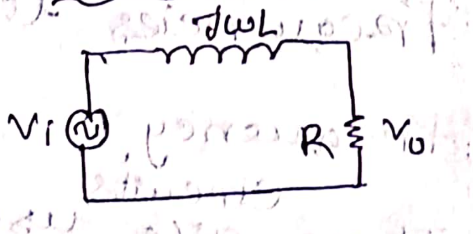


$$\frac{V_0}{V_i} = \frac{1}{1+j\omega RC}$$



LR

RL - Low pass Filter



$$\frac{V_0}{V_i} = \frac{1}{1+j\omega L/R}$$

$$\frac{|V_o|}{|V_i|} = \frac{1}{[1+(\omega RC)^2]^{1/2}}$$

$$\theta = -\tan^{-1}\omega RC$$

At cutoff frequency gain $= 1/\sqrt{2}$

$$\omega_c = \frac{1}{RC}$$

$$\frac{|V_o|}{|V_i|} = \frac{1}{\left[1+\left(\omega \cdot \frac{L}{R}\right)^2\right]^{1/2}}$$

$$\theta = -\tan^{-1}\omega\frac{L}{R}$$

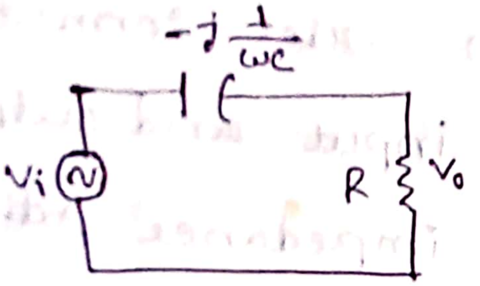
$$\omega_c = \frac{R}{L}$$

High pass Filters :-

A high pass filter is a electronic filter that passes signals with a frequency higher than a certain cut-off frequency and attenuates (কমায়(না)) signals with frequencies lower than the cut-off frequency.

These circuits are used to remove low frequency signals and allow high frequency signals.

RC - High pass Filter

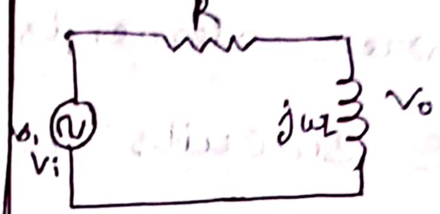


$$\frac{V_o}{V_i} = \frac{\omega RC}{\omega RC - j1}$$

$$\theta = \tan^{-1}\frac{1}{\omega RC}$$

$$\omega_c = \frac{1}{RC}$$

RL - High pass Filter



$$\frac{V_o}{V_i} = \frac{\omega L/R}{\omega L/R - j1}$$

$$\theta = \tan^{-1}\frac{R}{\omega L}$$

A cutoff gain $= 1/\sqrt{2}$

$$\omega_c = \frac{R}{L}$$

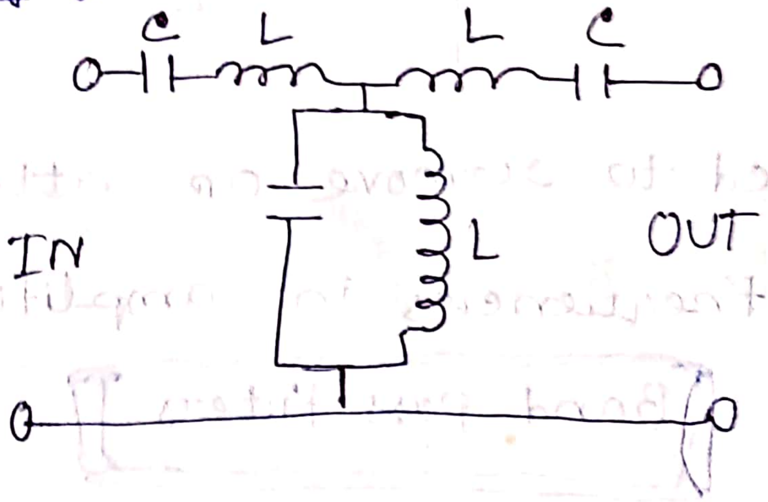
• Are used to remove or attenuate the lower frequencies in amplifiers.

Band pass Filters

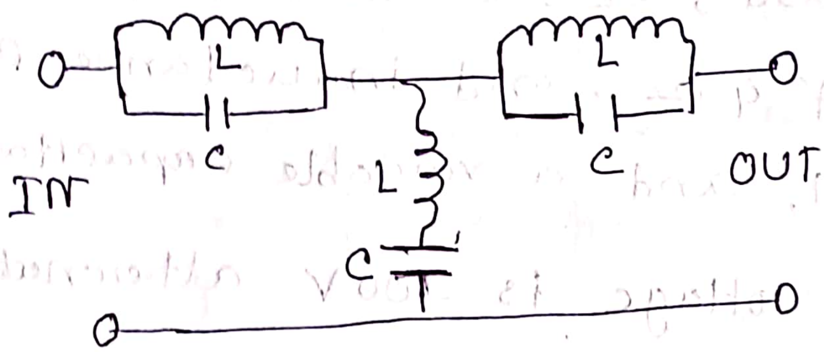
Band pass filters allow only a required band of frequencies to pass, while rejecting signals at all frequencies above and below this band. It is also

Called as a T Filter. It consists three elements, two series-connected LC circuits between input and output which form a low impedance path to signals of the required frequency but have a high impedance to all other frequencies.

~~Bus~~ ~~Stop~~



Band Stop Filters



=) These Filters have the opposite effect to band pass Filters.
There are two parallel LC circuits in the signals path to form high impedance at the unwanted signals frequency, and a series circuit forming a low impedance path to ground at the same frequency, to add the rejection.

Math

A series RLC circuit has resistance of 4 Ω, and inductance of 500 mH, and a variable capacitance. Supply voltage is 100 V alternating at 50 Hz. At resonance $X_L = X_C$. The capacitance required to give series resonance is calculated as:

Here,

$$X_C = X_L = 2\pi f L = 2\pi \times 50 \times 0.5H$$

$$= 157.1\ \Omega$$

$$\therefore C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi f \times 157.1}$$

$$= 2.03 \times 10^{-5}\ F.$$

Resonance voltages across the inductor and the capacitor, V_L and V_C will be,

$V_L =$ $I = \frac{V}{Z} = \frac{100\,V}{4\,\Omega} = 25\,A.$

NOW,

$V_{L} = V_C = IX_L = 25\,A \times 157.1\,\Omega$

$= 3.93 \times 10^3$

$= 3927.5\,V$

(Ans)

From this math,
when the series RLC circuit is at resonance, the magnitudes of the voltages across the inductor and Capacitor can become many times larger than the supply voltage.

Tuned circuit:-

An LC circuit also called a resonant circuit, tank circuit, or tuned circuit, is an electric circuit consisting of an inductor, represented by the letter C, connected together.

Lesson

Polyphase System

A polyphase system is a means of distributing alternating-current electrical power where the power transfer is constant during each electrical cycle.

Polyphase systems have three or more energized electrical conductors carrying alternating currents with a defined phase angle between the voltage waves in each conductor.

This system is useful for transmitting power to electric motors which rely alternating current to rotate.

Three phase power system is the most common example used for industrial applications and for power transmission.

Three phase balanced System

The electrical system is of two types, the single-phase system and the three phase system.

The single-phase system has only one phase wire and one return wire thus it is used for Low ~~pr.~~ power transmission. The three-phase system has three live wire and one returns the path. The three-phase system is used for transmitting a large amount of of power.

This 3 phased system is divided mainly into two types.

1) ~~One~~ Balanced three-phase system.

2) unbalanced three-phase system.

Balanced 3-phase Circuit.

The balance system is one in which the load are equally distributed in all the three phases of the system.

Analysis of Balanced 3 phase circuit:-

It is always better to solve the balanced three phase circuits on the basis of each phase.

To solve the balanced three-phase circuits:-

1. Draw the circuit Diagram.
2. Determine $X_{LP} = X_L / \text{phase} = 2\pi F_L$
3. Determine $X_{cp} = X_c / \text{phase} = 1/2\pi F_c$
4. Determine $X_p = X/\text{phase} = X_L - X_c$
5. Determine $Z_p = Z/\text{phase} = \sqrt{R_p^2 + X_p^2}$
6. Determine, $\cos\phi = R_p / Z_p$

[the power factor is lagging when $X_{LP} > X_{cp}$
the power factor is leading when $X_{cp} > X_{LP}$

7) Determine V_{phase},
[For star connection, $V_P = V_L/\sqrt{3}$ and for delta connection, $V_P = V_L$]

8) Determine $I_P = V_P/Z_P$

9) Determine the line current I_L

For star connection,

$$I_L = I_P$$

For Delta connection,

$$I_L = \sqrt{3}\, I_P$$

10) Determine the Active, Reactive and Apparent power.

Unbalanced 3-phase System

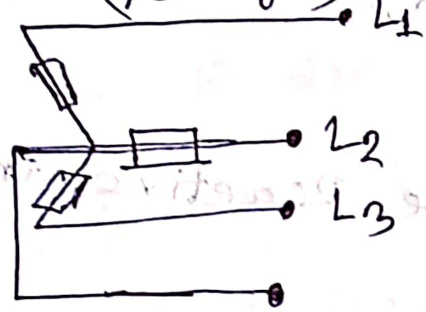
The load is connected either as star or Delta. In a three-phase AC generator, there are three windings. Each winding has two terminals. (Start & Finish)

⊛ An unbalanced system is due to unbalanced voltage sources or an unbalanced load.

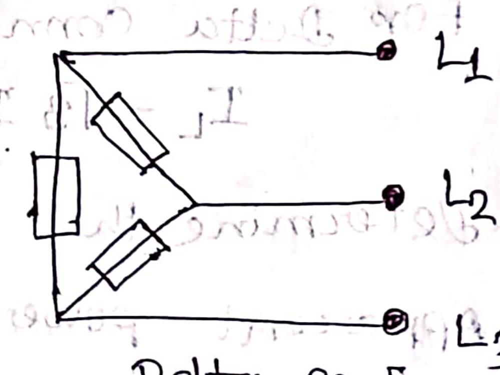
There are two basic three-phase configurations: wye (Y) and delta (Δ).

A delta (Δ) configuration requires only three wires for transmission but a wye (star) configuration may have a fourth wire. The fourth wire, is provided as a neutral and is normally grounded.

(Y configure)



Neutral (optional)



Delta confure

Generally, there are four different types of three-phase transformer winding connections for transmissions and distribution ~~pr~~ purposes

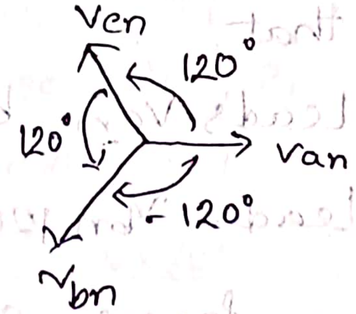
- Wye(Y) - wye(Y) is used for small current and high voltage. (It is a three phase system with a balanced Y-connected source and balanced Y-connected load)
- Delta(Δ) - Delta(Δ) is used for large currents and low voltages. (Both balanced source and balanced load are Δ-connected)
- Delta(Δ) - wye(Y) is used for step-up transformers at generating stations.

It consists of a balanced Δ-connected source feeding a balance Y-connected source

- Wye(Y) - Delta(Δ) is used for step-down transformers, at the end of the transmission.

Y-connected source feeding a balanced Δ-connected load

~~Y-Y System~~ :-



$$V_{an} + V_{bn} + V_{cn} = 0$$

$$|V_{an}| = |V_{bn}| = |V_{cn}|$$

Balanced phase voltages are equal in magnitude and are out of phase with each other by 120°.

$$V_{an} = V_p \angle 0^\circ$$
$$V_{cn} = V_p \angle -120^\circ$$
$$V_{bn} = V_p \angle -240^\circ = V_p \angle +120^\circ$$

(*) Determine the phase sequence of the set o[f] voltages, $v_{an} = 200\cos(\omega t + 10^\circ)$

$v_{bn} = 200\cos(\omega t - \cancel{23}\,230^\circ)$

$v_{cn} = 200\cos(\omega t - 110^\circ)$

=> The voltages can be expressed in phasor form as,

$V_{an} = 200\angle 10^\circ$ V; $V_{bn} = 200\angle -230^\circ$ V ; $V_{cn} = 200\angle -110^\circ$

we notice that,

V_{an} Leads V_{cn} by 120° and V_{cn} in turn leads V_{bn} 120°.

Hence, we have acb sequence.

Summary of phase and line voltages / currents for balanced three-phase systems :-

Connection	Phase voltages / currents	Line voltages / currents
~~1] Y-Y~~		
1] Y-Y	$V_{an} = V_p\angle 0^\circ$	$V_{ab} = \sqrt{3}V_p\angle 30^\circ$
	$V_{bn} = V_p\angle -120^\circ$	$V_{bc} = V_{ab}\angle -120^\circ$
	$V_{cn} = V_p\angle +120^\circ$	$V_{ca} = V_{ab}\angle +120^\circ$
	Same as line current	$I_a = V_a/Z_Y$
		$I_b = I_a\angle -120^\circ$
		$I_c = I_a\angle +120^\circ$
2] Y-Δ	$V_{an} = V_p\angle 0^\circ$	$V_{ab} = V_{AB} = \sqrt{3}V_p\angle 30^\circ$
	$V_{bn} = V_p\angle -120^\circ$	$V_{bc} = V_{BC} = V_{ab}\angle -120^\circ$
	$V_{cn} = V_p\angle +120^\circ$	$V_{ca} = V_{CA} = V_{ab}\angle +120^\circ$
	$I_{AB} = V_{AB}/Z_\Delta$	$I_a = I_{AB}\sqrt{3}\angle -30^\circ$
	$I_{BC} = V_{BC}/Z_\Delta$	$I_b = I_a\angle -120^\circ$
	$I_{CA} = V_{CA}/Z_\Delta$	$I_c = I_a\angle +120^\circ$
		(~~Same as phase~~ voltages)
3] Δ-Δ	$V_{ab} = V_p\angle 0^\circ$	~~$I_a = I_{ab}\sqrt{3}\angle$~~
	$V_{bc} = V_p\angle -120^\circ$	Same as phase voltage,
	$V_{ca} = V_p\angle +120^\circ$	$I_a = I_{AB}\sqrt{3}\angle -30^\circ$
	$I_{AB} = V_{ab}/Z_\Delta$	$I_b = I_a\angle -120^\circ$
	$I_{BC} = V_{bc}/Z_\Delta$	$I_c = I_a\angle +120^\circ$
	$I_{CA} = V_{ca}/Z_\Delta$	

4) $\Delta - Y$ $\rightarrow$ $V_{ab} = V_p \angle 0°$

$V_{bc} = V_p \angle -120°$

$V_{ca} = V_p \angle +120°$

Same as line current

Same as phase voltages

$I_a = \frac{V_p \angle -30°}{\sqrt{3} Z_y}$

$I_b = I_a \angle -120°$

$I_c = I_a \angle +120°$

Lesson -

Machine Basics

⇒ An electrical machine is a device that can convert either mechanical energy to electrical energy (generator) or electrical energy to mechanical energy (motor). Since any electrical machine can convert power in either direction, any machine can be used as either a generator or a motor.

Principle of generator and motor:-

Generator is a machine that converts mechanical energy into electrical energy. Based on the principle of Faraday law of ~~electo~~ electromagnetic induction.

The principle of an electrical motor is based on the magnetic effect of electric current. A current carrying loop experiences a force and rotates when placed in a magnetic field. The direction of rotation of the loop is according to the Fleming's left-hand rule.

Significance of back e.m.f:-

When something like a refrigerator or an air conditioner (anything with a motor)

First turns on, & the light often dim momentarily.
To understand this, realize that a spinning motor also acts like a generator. A motor has coils turning inside a magnetic fields, and a coil turning inside a magnetic field induces an emf.
This emf, known as the back emf, acts against the applied voltage that's causing the motor to spin in the first place, and reduces the current flowing through the coils of the motors.
At the motor's operating system, enough current flows to overcome any losses due to friction and other sources and to provide the necessary energy required for the motor to do work.

This is generally much less current than is required to get the motor spinning in the first place.

Here,

$$I = \frac{DV}{R}$$

I = Initial current
DV = Applied voltage
R = Resistance.

[A device drawing that much current reduces the voltage and current provided to other electrical equipment in your house, causing lights to dim.]

When the motor is spinning and generating a back emf e, the current is reduced to:-

$$I = \frac{(DV - e)}{R}$$

Back emf = e

[It takes very little time for the motor to reach operating speed and for the current to drop from its high initial value. This is why the lights dim only briefly.]

- Motors
  - Electric Motors
    - DC Motors
      - DC Shunt motor
      - Separately Excited Motor
      - Series motor
      - PMDC Motor
      - Compound Motor
    - AC Motors
      - Induction motor
      - Synchronous motor
    - Other motors
      - Stepper motor
      - Brushless motor
      - Hysteresis Motor
      - Reluctance Motor
      - Universal Motor

DC current motors

DC motors can be powered by batteries, motor vehicles or rectifiers.

Series motors:-

In DC series motor, rotor windings are connected in series. The operation principle of this electric motor mainly depends on a simple electromagnetic law.

The law is, whenever a magnetic field can be formed around conductor & interacts with an external field to generate the rotational motion. These motors are mainly used in starter motors which are used in elevators and cars.

Dc Compound motor :-

Dc motor is a hybrid component of Dc series and shunt motors. In this type of motor, both the Fields like series and shunt are present.

In this type of electric motor, the stator and rotor can be ~~Con~~ connected to each other through a series & shunt windings compounds.

This series winding can be designed with Few windings of wide copper wires, which gives a small resistance path.

~~This~~ ~~[illegible]~~ The shunt winding can be designed with multiple windings of copper wire to get the full i/p votage.

AC motors

AC motors are powered by power grid, inverters, electrical generators.

Synchronous motor:-

The working of the synchronous motor mainly depends on the 3-phase supply. The stator in the electric motor generates the field current which rotates in a stable speed based on the AC frequency. As well as the rotor depends on the similar speed of the stator current. There is no air gap among the speed of stator current and rotor.

When the rotation accuracy level is high, then these motors are applicable in automation, robotics etc.

2) Induction Motor:-

The electric motor which runs asynchronous speed is known as induction motor, and an alternate name of this motor is the asynchronous motor.

Induction motor mainly uses electromagnetic induction for changing the energy from electric to mechanical.

Based on the rotor construction, these motors are classified into two types namely squirrel cage & phase wound.

Special purpose motors.

Stepper Motor:-

The stepper motor can be used to offer step angle revolution, as an alternative to stable revolution. We know that for any rotor, the whole revolution angle is 180 degrees. However, in a stepper motor, the complete revolution angle can be separated in numerous steps like 10 degree × 18 steps. This means, in a total revolution cycle the rotor will go stepwise eighteen times, every time 10 degree.

It is used in plotters, circuit fabrication, process control tools, usual movement generators etc.

5 Universal Motor :-

This is a special kind of motor and this motor works on single AC supply otherwise DC supply.

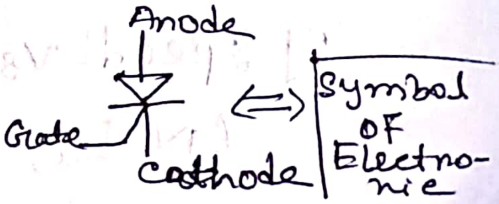
Universal motors are series wound where the field and armature windings are connected in series and thus generates high starting torque. These motors are mainly designed for operating at high-speed above 3500 rpm.

They utilize AC supply at low-speed and DC supply of similar voltage.

Thyristor :-

A Thyristor is a solid-state semiconductor device with four layers of alternating p- and N- type materials.

Thyristors are mainly used where high currents and voltages are involved, and are often used to control alternating currents, where the change of polarity of the current causes the device to switch off automatically, referred to as zero cross operation. It also used as the control elements for phase angle triggered controllers. This ~~is~~ ~~use~~ is being used for decades as light dimmers in TV, motion pictures, theater,



Torque - speed characteristics OF Shunt

Shunt motor:-

A DC Shunt motor (also known as a Shunt wound DC motor) is a type of self excited DC motor where the field windings are shunted to or are connected in parallel in armature winding of the motor.

Since, they are connected in parallel, the armature and field windings are exposed to the same supply voltage.

The three important shunt characteristic curves are:-

1| Torque Vs Armature current Characteristic (T_a/I_a)

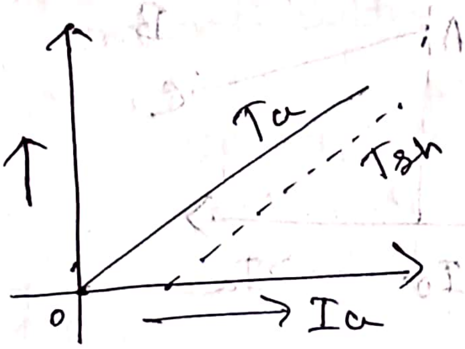
2| Speed Vs Armature current characteristic (N/I_a)

3] Speed Vs Torque characteristic (N/Ta)

=>

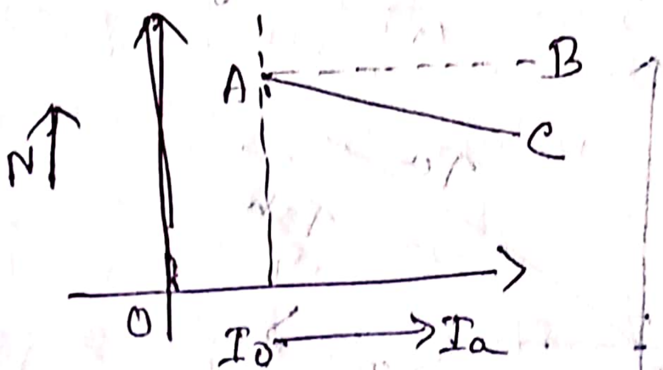
1] Torque Vs Armature current Characteristic :-

we know that in DC motor $Ta \propto \phi Ia$.
In this, the Flux ϕ is continuous by ignoring the ~~arm~~ armature reaction, since the motor is working from a continual source voltage



This graph between Torque Vs armature current is a straight line transitory through the origin which is shown in figure. The shaft torque (Tsh) is a smaller amount than armature torque and ~~a~~ is shown in the figure by ~~d~~ a dotted line. From this curve it is proved that to start a heavy load very large current is requisite. Hence, the shunt DC motor shouldn't be started at full load.

Speed vs Armature current characteristics

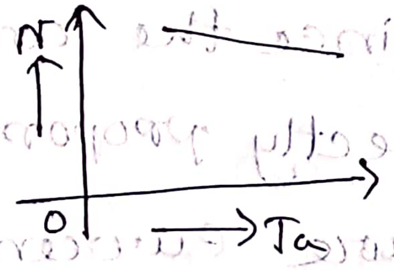


At normal condition the back emf E_b and flux ϕ both are constant in a DC shunt motor. Hence, the armature current differs and the speed of a

DC shunt motor will continue ~~continue~~ constant which is shown in Figure (line AB). Whenever, the shunt motor load is ~~__~~ increased $E_b = V - I_a R_a$ and flux reduces as a result drop in the armature resistance and armature reaction.

On the other hand, back emf reduces marginally more than that the speed of the shunt motor decreases to some extent with load.

<u>Speed vs Armature Torque</u>



This curve is drawn between the speed of the motor and armature current

with various amps as shown in figure.
From the curve it is understood that the speed reduces when the load torque increases.

So, we can say from all three characteristics that,
when the shunt motor runs from no loads to full load there is slight change in speed.
Thus, it is essentially a constant speed motor. ~~runs from no load to full load~~ Since the armature torque is directly proportional to the armature current, the starting torque is not high.

Extra

Rotor :-

Rotor is a moving component of an electromagnetic system in the electric motor, electric generator, or alternator. Its rotation is due to the interaction between the windings and magnetic fields which produces a torque around rotor's axis.

Fig :- Rotor

Armature :-

An armature is the component of an electric machine which carries alternating current. The armature winding conduct AC even on DC machines, due to the commutator action (which periodically reverses current direction) or due to electronic commutation, as in Brushless DC motor.

Armature.

Difference between Rotor & Armature:-

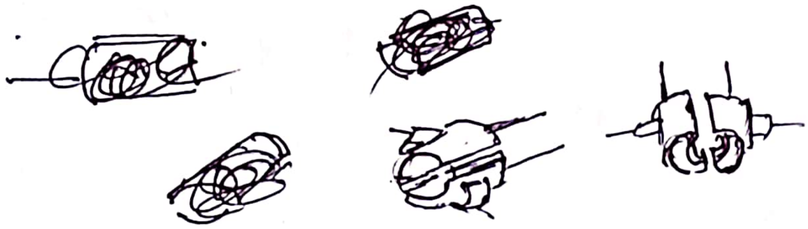
A rotor is the rotating part in AC motors whilst an armature is the rotating part in DC motors.

A rotor has no Commutator bars but an armature has commutator bars which carry current from the supplier to the windings.

Commutator:-

A Commutator is a rotary electrical switch in certain types of electrical motors and electrical generators that periodically reverses the current direction between the rotor and the external circuit.

It also used for insure that the current flowing through the rotor windings is always in the same direction. And the proper coil on the rotor is energized in respect to the field coils.



→ Commutator

windings in electrical motors :-

The ~~electring~~ electric motor winding definition is windings in electric motors are wires that are placed within coils, generally enclosed around a coated flexible ~~iron~~ iron magnetic core to shape magnetic poles while strengthened

with the current.
Generally, these are power driven with electromagnetic induction.

→ Coil windings