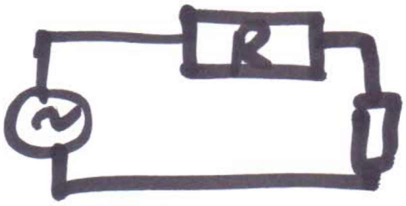
① Energy Source 

2 ①

"Provide the Voltage needed to force Current (electrons) through circuit."

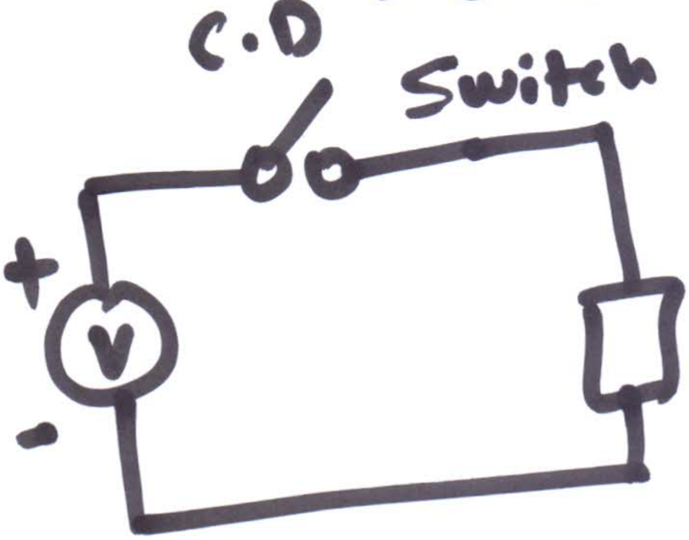
② Conductors
"Through which the Current can travel"

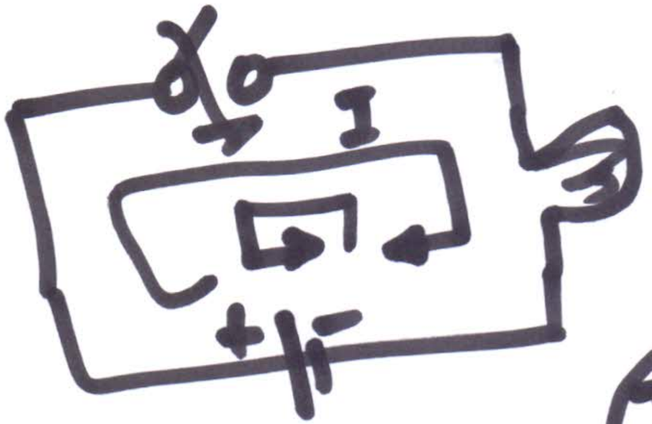
③ Insulators
"Confine the Current and convert the EE taken from the Energy Source."

④ Control device, "often a Switch, to start/stop the flow of I.

⑤ Protection device, "To interrupt the circuit in case of circuit malfunction

Simple circuit

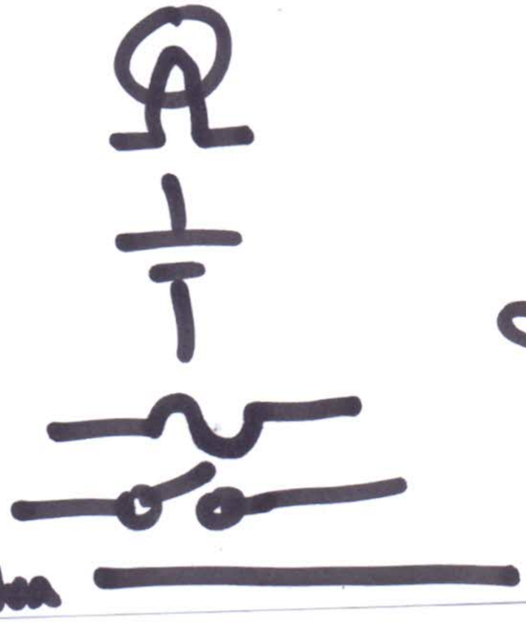




C.D.C
E.F.D.C

Symbol

Bulb.
Cell
Fuse
switch
wire/Conductor



Ampere: (A)

"It is the constant current which when maintained in two // straight conductors of ∞ length and negligible x-section separated by a distance of one meter in vaccum, produced between these conductors a force equal to 2×10^{-7} Newtons/meter length."

Coulomb (Q):

~~It is the quantity of Electricity conveyed by a current of one Amp flowing through a solid conductor at constant temperature is proportional to~~

Coulomb (Q)

$Q = It$, $I = Q/t$

1 Coulom = 1 Ampere - Second

1 Amp = 1 Coulom/sec

Quantity of electricity conveyed by a current of one ampere flowing for one second

ampere - hour = Ah

1 amp-hour = 3600 Coulombs

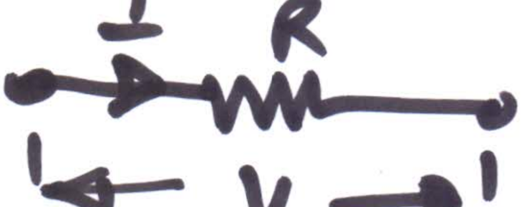
Difference of Potential (V)

Voltage / Electrical pressure required to drive the current between them is called Difference of Potential.

Ohm's Law

The relationship between current (I), Voltage (V) and resistance (R) was discovered by a German Scientist named, Georg Ohm. This relationship is named Ohm's Law in his honour.

Ohm found that the current in a circuit varies directly with the Voltage when the resistance is kept constant



$I \propto V$ (R – Constant)

Ohm's Law States

"The Current is directly Proportional to the Voltage and Inversely Proportional to the resistance".

(R- Const.)

$$I \propto V$$

$$I \propto \frac{1}{R}$$

$$I = V/R \times \text{Constat}$$

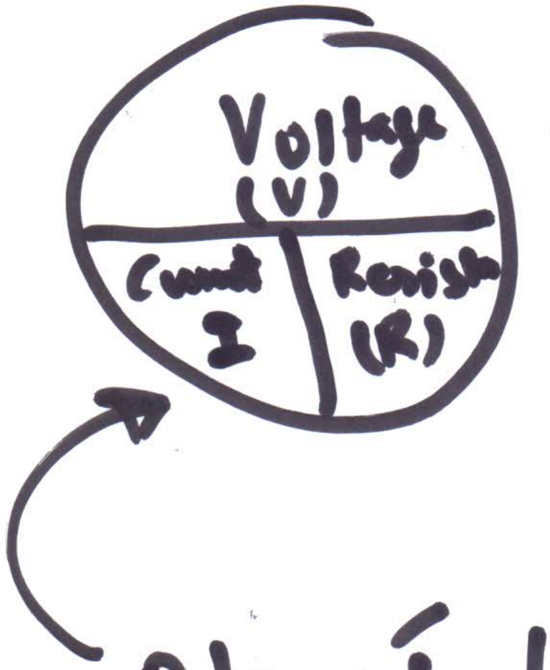
$$\boxed{V = IR}$$

Constant = 1

Ohm's Law equation

$$\boxed{I = V/R}$$

V = Vollts
R = Ohms
I = Amperes.



$V = IR$

$I = \frac{V}{R}$.

$R = \frac{V}{I}$.

Ohm's law circle

Unit of Potential Difference (p.d) and Electromotive Force (e.m.f)

e.m.f / P.d ⇒ Volt.

1 Volt = 1 joule/Coulomb

The p.d between two Points is one Volt if one joule of energy is used in sending one Coulomb between them.

The Volt is therefore defined as the P.D across a resistance of one Ohm carrying a current of one Ampere

$$\text{Current} = \frac{\text{P.D}}{\text{Resistance}} = \frac{V}{R}$$

$$\text{P.D} = \text{Current} \times \text{Resistance} = IR$$

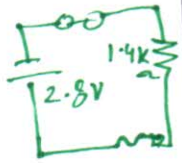
$$\text{Resistance} = \frac{\text{P.D}}{\text{Current}} = \frac{V}{I}.$$

V - Volt - KV - MV, mV

I = Ampere = A - KA -

R = ohm = Ω, - KΩ, - MΩ - mΩ

Example: 3.1



V = 2.8 Volts

R = 1.4 KΩ

$I = V/R = \frac{2.8}{1400}$

$I = 0.002\,A$

Exp. 3.2

R = 96 Ω

V = 120 V

$I = \frac{120}{96} = 1.25\,A$

$I = 1.25\,A$

Do yourself - 3.3, 3.4, 3.5.

Power = Current (I) × Voltage (V)

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

if

P = watts, V = Volts, I = Ampere.

Exp 3.6

Current (I) = 3 A

Voltage (V) = 120 V

Power (P) = VI.

= 3 × 120

= 360 (Watts)

Exp 3.7

V = 120 V

P = 500 W

$$I = \frac{P}{V} = \frac{500W}{120V} = 4.17A.$$

Do Exp 3.8, ... 3.13

Calculating cost.

The cost of E.E can be determined from the amount of energy used and the cost rate.

The cost rate is usually specified in Rs: per kilowatt hour.

The cost of Electric Energy is:

Cost = Rate × Energy

= Rupees per kilowatt hour × kilowatt hours

Exp: 3.14: Energy cost = ?

Energy = 120 KWh

Rate = Rs: 6/KWh

Cost = 6 × 120 = 720 Rupees.

Exp: 3.15

$P = 100W$ (Lamp)

$t = 3h$

Rate = Rs: 6/Kwh

Q = Cost of operating Lamp for 3-hours.

Sol:

$P = 100W$

$t = 3h$

Cost = rate × energy

$$\text{Energy} = P \times t$$

$$= 100 \times 3$$

$$= 300\,Wh$$

$$= 0.3\,Kwh$$

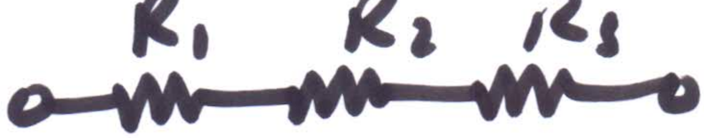
$$\text{Cost} = 0.3 \times 6$$

$$= Rs: 1.8$$

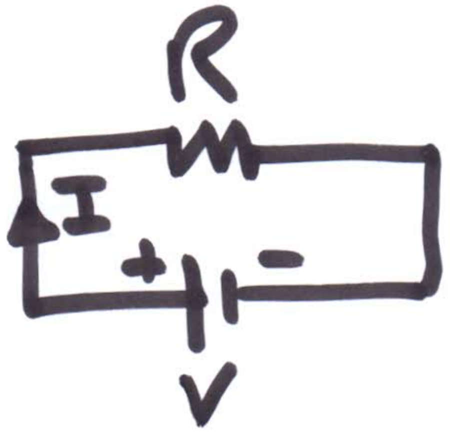
Solve: 3.16.

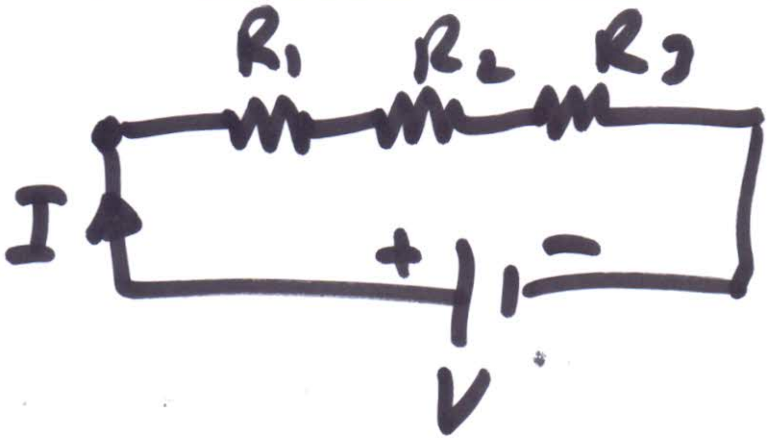
Arrangement of Resistors

Series Arrangement



$$\boxed{R = R_1 + R_2 + R_3}$$

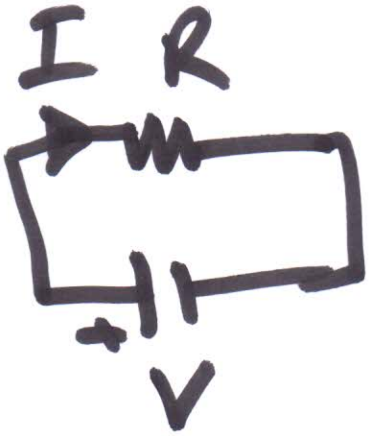


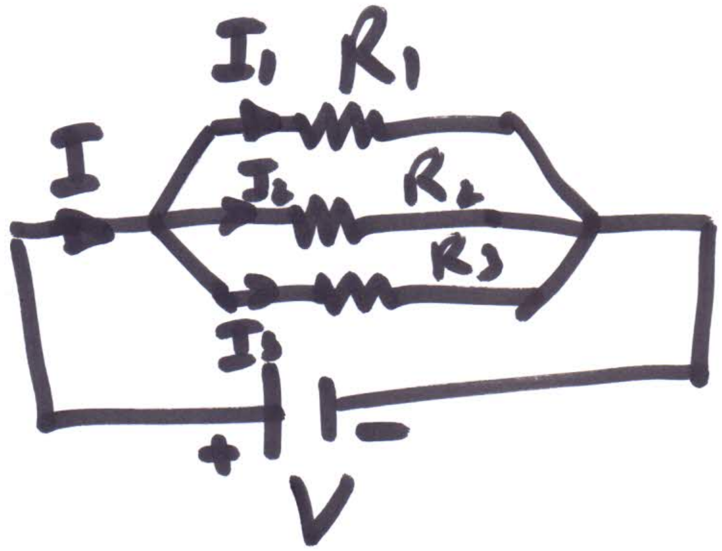


$$V = IR \qquad V = IR_1 + IR_2 + IR_3$$

$$IR = I(R_1 + R_2 + R_3)$$

$$\boxed{R = R_1 + R_2 + R_3}$$





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

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

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

$$I = I_1 + I_2 + I_3$$

$$=$$

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

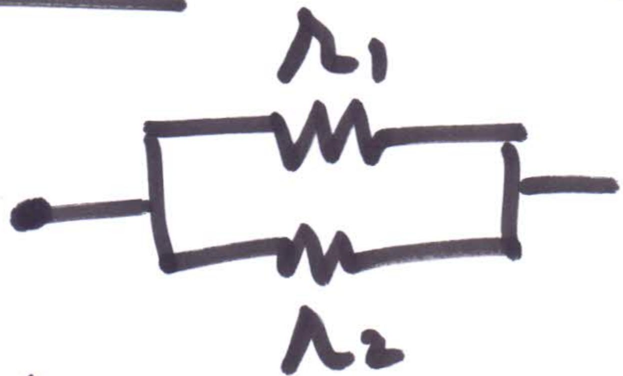
$$\boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$\boxed{R = \frac{1}{3} R_0}$$

$$R_1 = R_2 = R_3 = R_0$$

$$\frac{1}{R} = 3\,\frac{1}{R_0}$$

Two Equal Resistors



$r_1 = r_2 = r$

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{r} + \frac{1}{r}.$$

$$\boxed{r_{eq} = \frac{r}{2}}$$

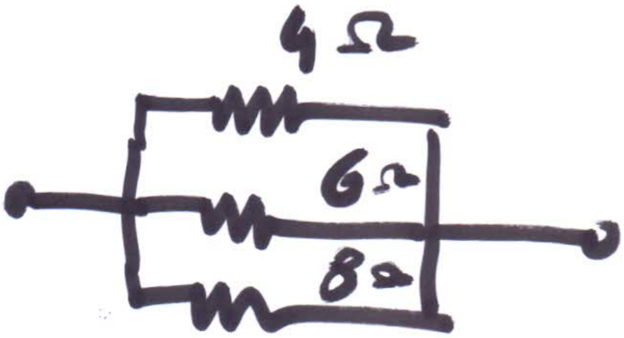
Unequal Resistors

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

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

$$\boxed{R = \frac{R_1 . R_2}{R_1 + R_2}}$$

Example: A



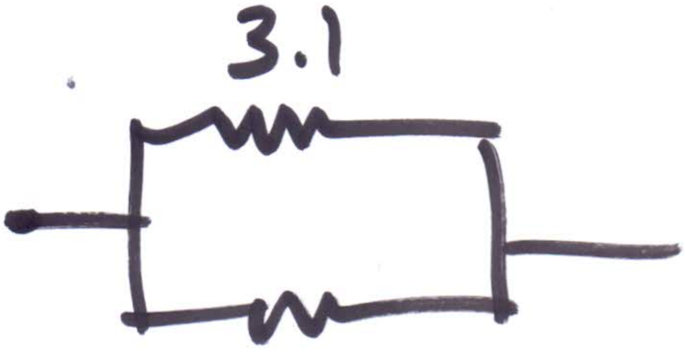
$$\frac{1}{R} = \frac{1}{4} + \frac{1}{6} + \frac{1}{8}$$

Req = ?

$$\frac{1}{R} = \frac{6+4+3}{24} = \frac{13}{24}$$

$$R = \frac{24}{13} = 1.846\ \Omega$$

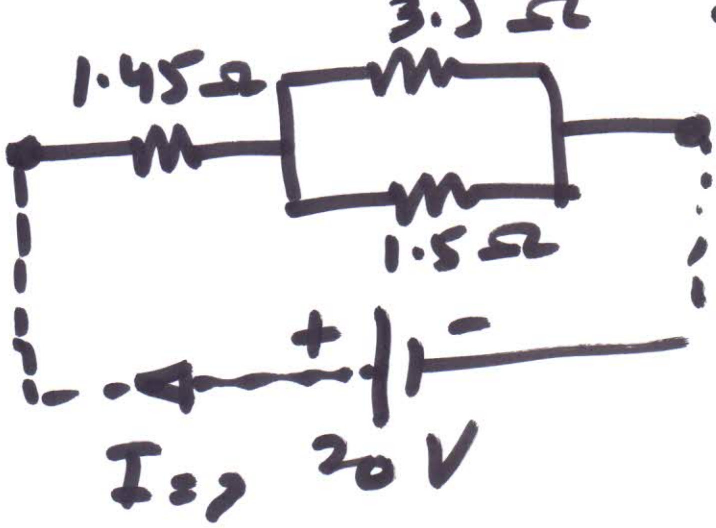
Example - B



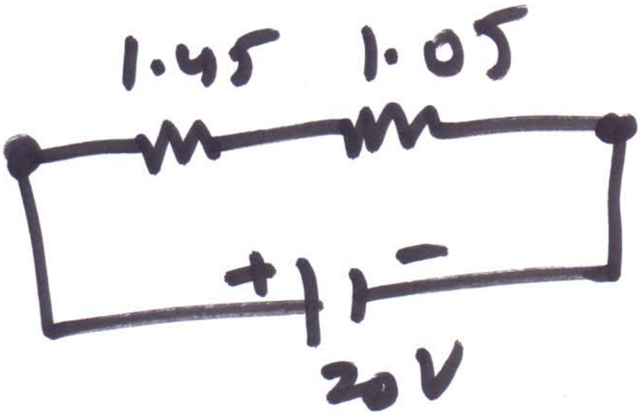
Equivalent Resistor = $\dfrac{\text{Product}}{\text{Sum}}$

$$R_{eq} = \frac{3.1 \times 7.2}{3.1 + 7.2} = 2.16\ \Omega$$

Exp- C

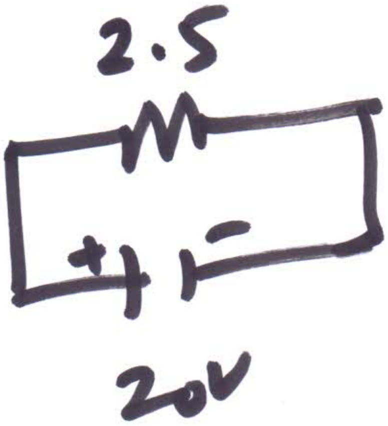


Parallel $R_p = \frac{3.5 \times 1.5}{3.5 + 1.5} = 1.05\,\Omega$



$R_t = 1.45 + 1.05$

$= 2.5\,\Omega$

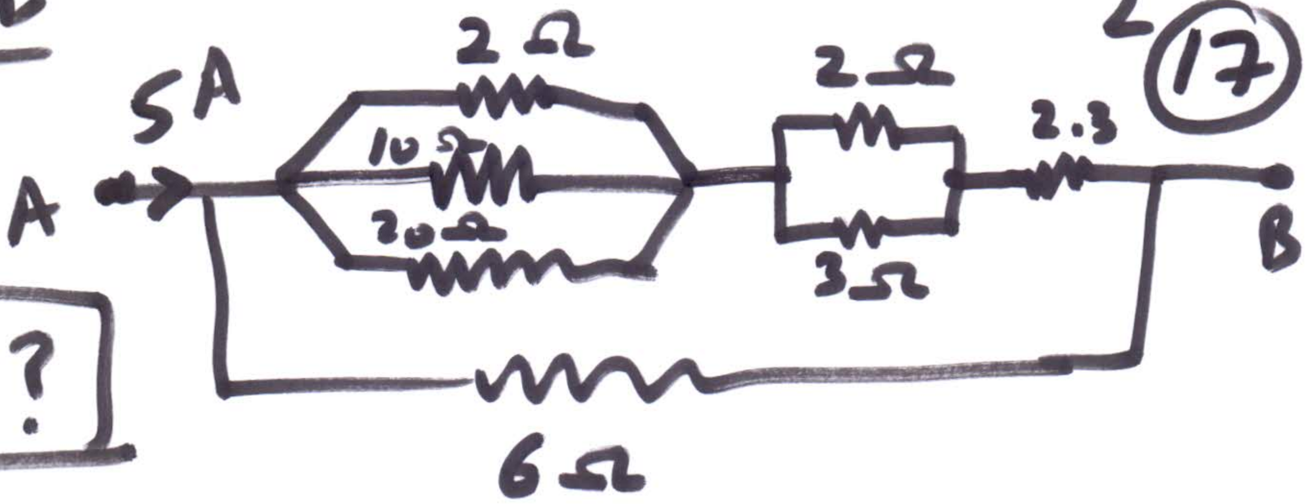


$I = \frac{20}{2.5} = \frac{V}{R}$

$\boxed{I = 8 \text{ Ampere}}$

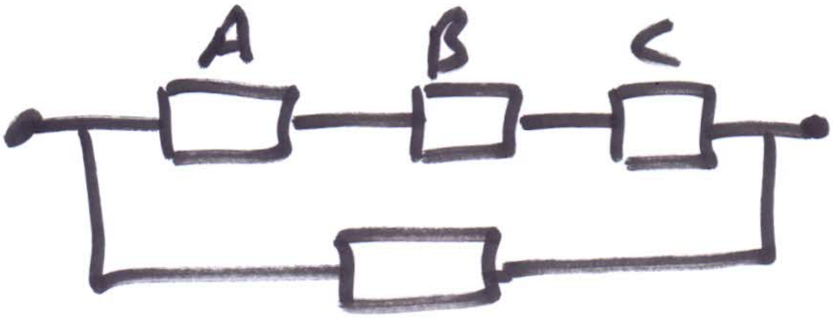
Exp-D

2 17



$\boxed{V_{AB} = ?}$

$R_{eq} = ?$



$\boxed{V_{AB}\ 5 \times 3 = 15\text{-Volt}}$

$R_A = ?$

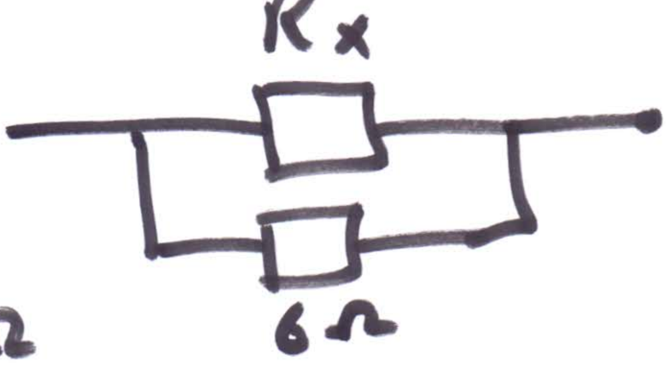
$$\frac{1}{R_A} = \frac{1}{4} + \frac{1}{10} + \frac{1}{20} = \frac{8}{20}$$

$$R_A = 2\tfrac{1}{2}\ \Omega$$

$R_B = ?$

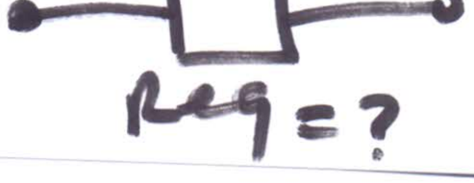
$$R_B = \frac{2 \times 3}{2 + 3} = \frac{6}{5} = 1.2\ \Omega$$

$R_c = 2.3$



$$R_x = R_A + R_B + R_c$$
$$= 2.5 + 1.2 + 2.3 = 6\ \Omega$$

$$R_{eq} = \frac{6 \times 6}{6 + 6} = \frac{36}{12} = 3\ \Omega$$



Exp-E

A searchlight takes 100 A at 80 V. It is to be operated from 220 V supply.

Find the value of $R = ?$

Ans:

P.d across Bulb is 80 V then P.d across $R = 220 - 80$

$$V_R = 140\,V$$

$$R = \frac{V}{I} = \frac{140}{100} = 1.4\,\Omega$$

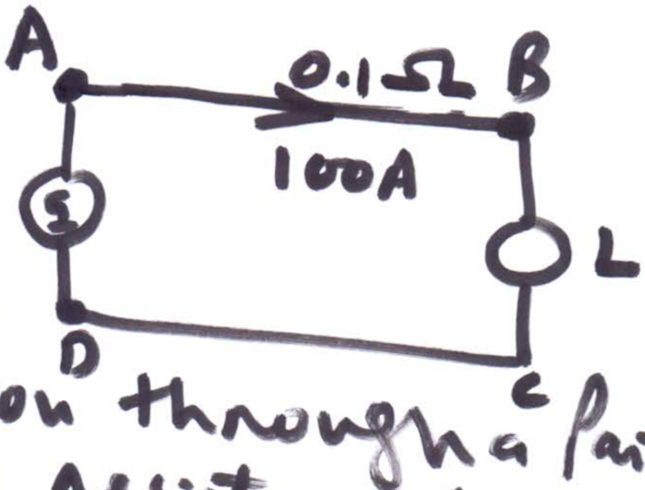
Exp. F

Load taking 100 A

110 Volts is supplied

a generating station through a pair cable each having resistance of 0.1 Ω

age at Generating station = ?



Loss of Voltage
due to resistance
of the cable.

$V_{AB} = IR = 100 \times 0.1 = 10$ Volt

Similarly

$V_{CD} = IR = 100 \times 0.1 = 10$ Volt

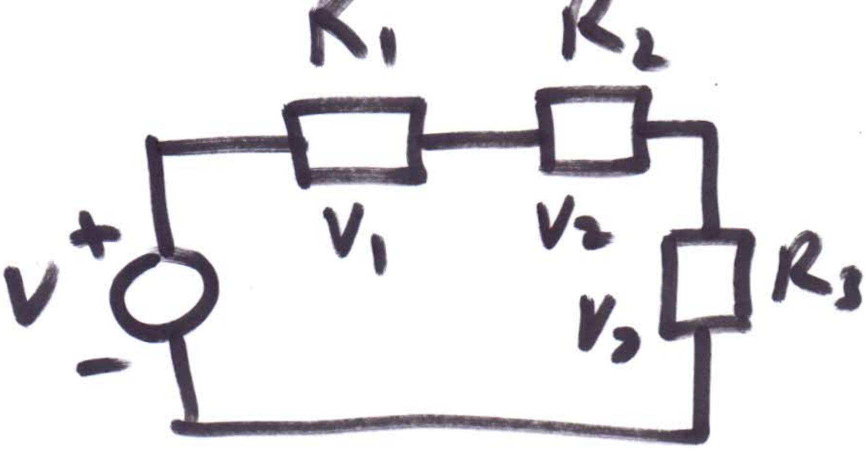
There is total Loss of Voltage 20V,
Called the Volt drop in the Lead.

Voltage at generating
Station $= 110 + 20$
$= 130V$

Kirchhoff's Law

1. Kirchhoff's Voltage Law (KVL)
2. Kirchhoff's Current Law (KCL)

KVL



Version-1

Sum of the Voltage rises are equal to Sum of Voltage drops in a closed Loop:

$$V = V_1 + V_2 + V_3 \rightarrow (A)$$

Version-2

$$\sum V = 0$$

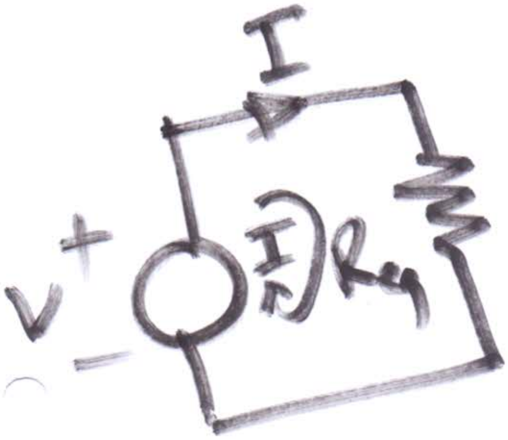
Algebraic Sum of the voltages in a close Loop is equal to zero.

Voltage Rise = +ive
Voltage Drops = -ive

$$V + (-V_1) + (-V_2) + (-V_3) = 0 \;\hookrightarrow \text{B}$$

Equation A is Same to Equation B

Series Combination of ~~Series~~ Resistors Can be proved using KVL.



$$V = \overset{V_1}{IR_1} + \overset{V_2}{IR_2} + \overset{V_3}{IR_3}$$

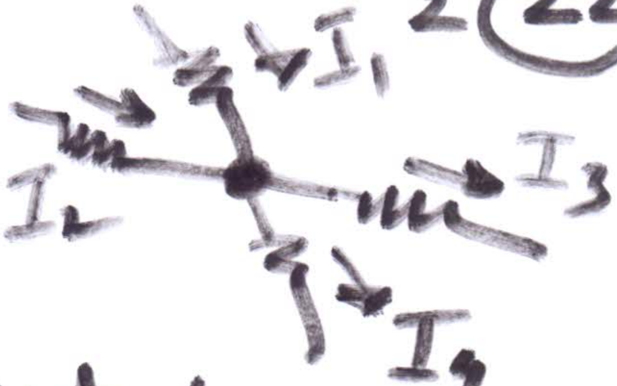
$$V = I.R_{eq}$$

$$I R_{eq} = I(R_1 + R_2 + R_3)$$

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

KCL

Version-1



Sum of the current to a node must be equal to sum of the currents going away from the node.

$$I_1 + I_2 = I_3 + I_4 \longrightarrow \text{(A)}$$

Version-2

Algebraic sum of all currents at a node must be equal to zero.

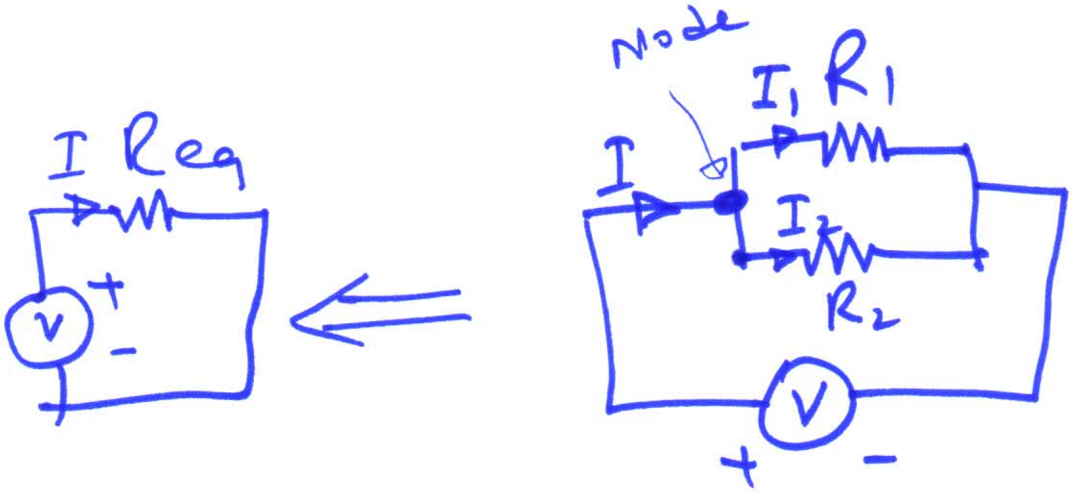
$$\Sigma I = 0$$

$I \xrightarrow{to}$ node +ive

$I \xleftarrow{away}$ from node −ive

$$I_1 + I_2 + (-I_3) + (-I_4) = 0 \longrightarrow \text{(B)}$$

Eq: (A) and (B) are same.



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

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

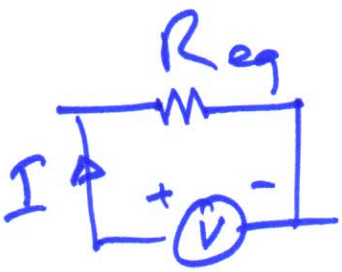
According to K.C.L

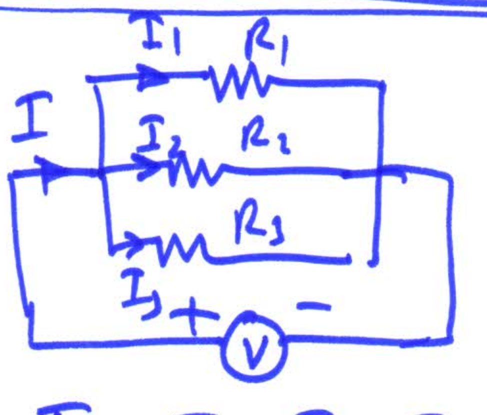
$$I = I_1 + I_2$$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2}.$$

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

$$\boxed{R_{eq} = \frac{R_1 . R_2}{R_1 + R_2}}$$





$$I = I_1 + I_2 + I_3 \quad (KCL)$$

$$I = \frac{V}{R_{eq}}.$$

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

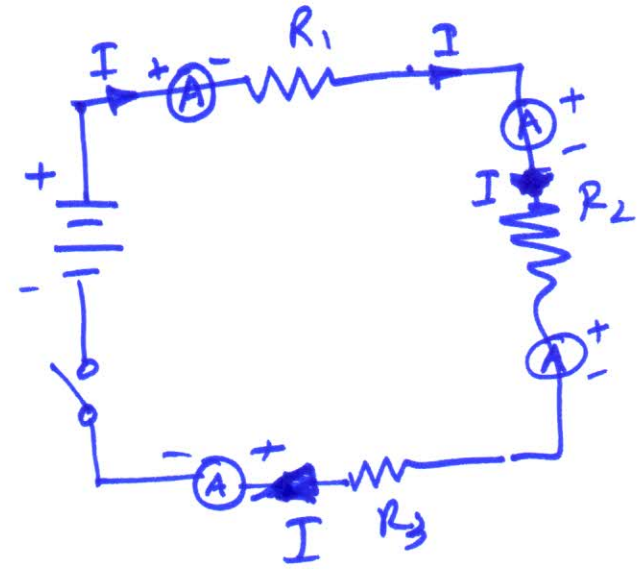
$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Ch. 5 Multiple-Load Circuit

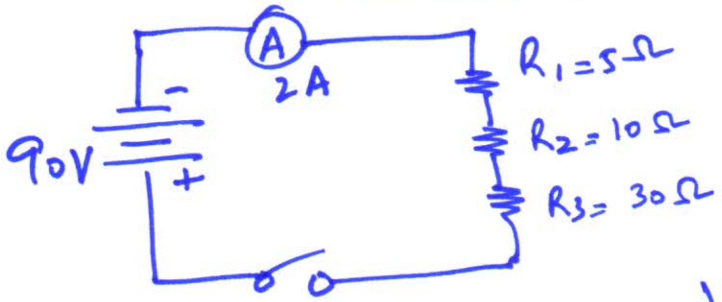
Series circuits.

Current in series circuits:

Current is same everywhere in Series circuit



$$I_T = I_{R_1} = I_{R_2} = I_{R_3}$$



$$R_T = R_1 + R_2 + R_3 = 45\,\Omega$$

$$R_T = \frac{V}{I} = \frac{90}{2} = 45\,\Omega$$

Voltage in Series circuit

The battery voltage in above circuit divides up across the three load resistors. It always divides up so that the sum of the individual load voltages equal the source voltage

$$V_T = V_{R_1} + V_{R_2} + V_{R_3} + \dots$$

$$= 10V + 20V + 60V$$

$$\boxed{V_T = 90V}$$

$$V_{R_1} = I_{R_1} \times R_1 = 2A \times 5\Omega = 10V$$

$$V_{R_2} = I_{R_2} \times R_2 = 2A \times 10\Omega = 20V$$

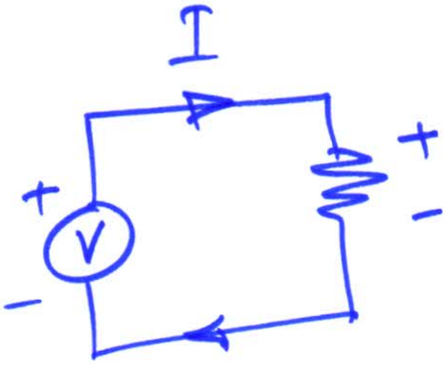
$$V_{R_3} = I_{R_3} + R_3 = 2A \times 30\Omega = 60V$$

Voltage drop + Polarity

→ According to conventional Direction of Current

Voltage Rise, Voltage source

Voltage drops



V. Rise

V. drops

$V_{rise} = V_{drop.}$ = K.V.L.

Go through page 102, 103, for open circuit and short circuit

Also go through Examples: 5.1, 5.2

Maximum Power Transfer

Maximum power transfer referes to getting max possible amount of power from a source to its load. The source may be bettery, and load a lamp, or the source could be a guitar Amplifier and load a speaker.

Maximum power transfer occurs when the source's Internal opposition to the current equals the Load's opposition to the current.

Resistance (R) is one form of opposition to current.

Impedance (Z) is another form of opposition to current.

R → in A.C/D.C and Z → in AC

In d.c circuits, Maximum Power Transfer occurs when resistances are Matched.

Example of ~~MPT~~ (Maximum Power Transfer)

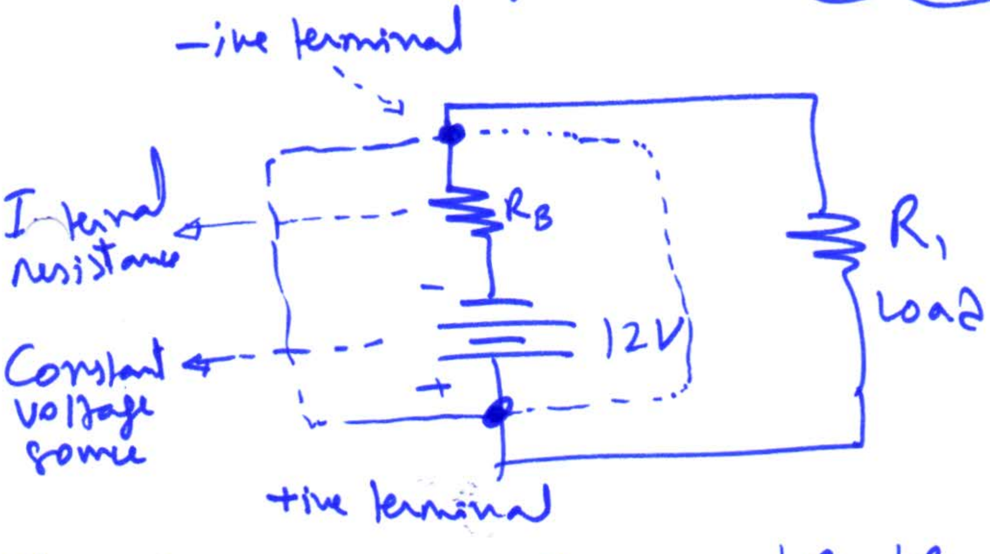


Fig: 5.16

Maximum Power Transfer occurs when R_B and R_1 are equal.

Fix $R_B = 3$, Vary R_1, 1, 2, 3, 4 6

R_1 (Ω)	R_T (Ω)	I_T A	P_{R_1} W	P_{R_B} W	P_T W
1	4	3.0	9.0	27.0	36
2	5	2.4	11.52	17.28	28
3	6	2.0	12.0	12.0	24
4	7	1.71	11.76	8.82	20
5	8	1.50	11.25	6.75	18
6	9	1.33	10.67	5.33	16

Let us calculate: let $R_1 = 9$, $R_B = 3$

$R_T = R_1 + R_B = 9\Omega + 3\Omega = 12\Omega$

$I_T = \frac{V_T}{R_T} = \frac{12V}{12\Omega} = 1A$,

$P_{R_1} = I_{R_1}^2 \cdot R_1 = (1A)^2 \times 9\Omega = 9W$

$P_{RB} = I_{RB}^2 \cdot R_B = (1A)^2 \times 3 = 3W$

$PT = 9W + 3W = 12W$

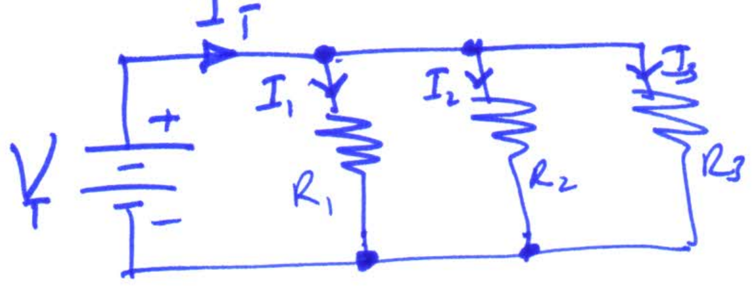
Notice that the maximum power dissipation occurs when $R_1 = 3\Omega$.

From the table:

- We will observe the power dissipated within the source and the total power taken from the source.
- when Maximum power transfer occurs, the efficiency is only 50%.
- Of the 24W furnished by source only 12W is used by the load.
- As the load gets larger, the efficiency improves and the power transferred decreases.

Parallel circuits

- Same Voltage
- Different currents

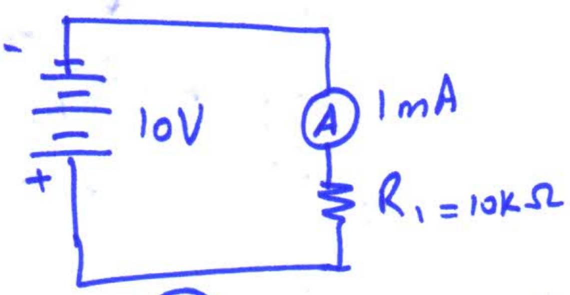


$$V_T = V_{R_1} = V_{R_2} = V_{R_3} = \cdots$$

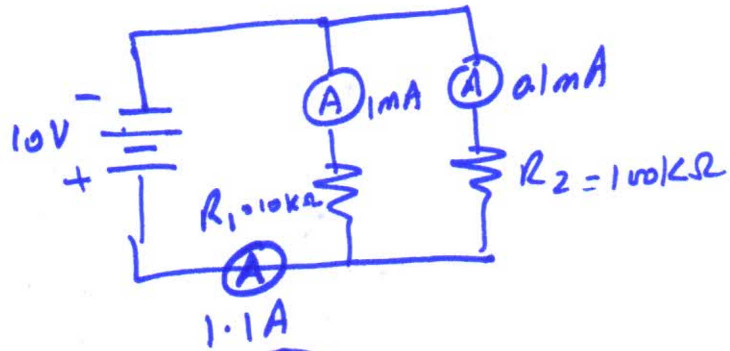
$$I_T = I_1 + I_2 + I_3$$

$$I_T = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

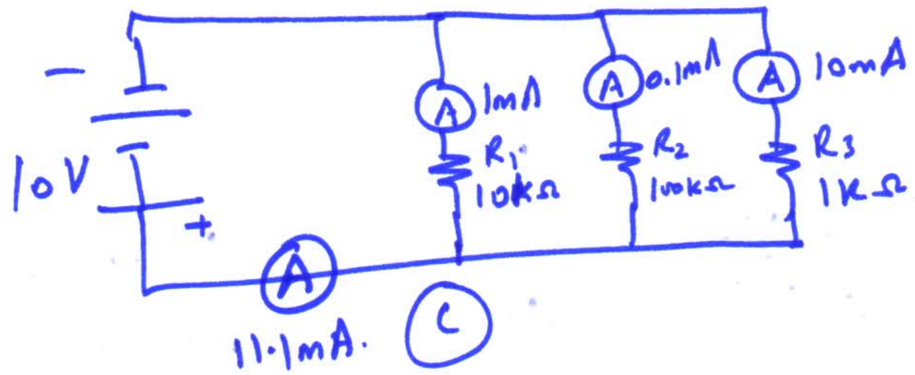
Resistance in Parallel



(a)



(b)



(c)

→ Total resistance in parallel circuits.
Adding resistors in parallel increases total current and decreases total resistance.

$$I_{R_1} = \frac{V}{R_1} = \frac{10V}{10{,}000} = 0.001A = 1mA$$

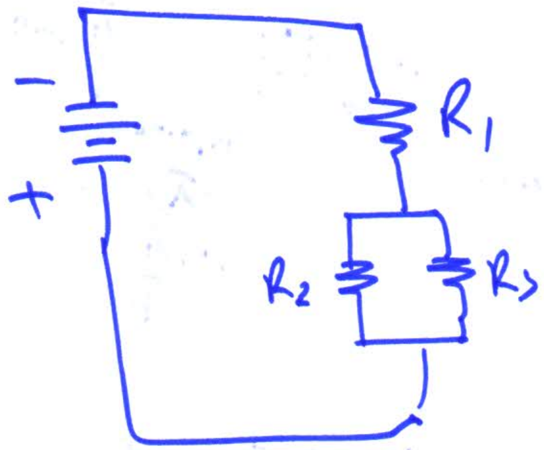
$$I_{R_2} = \frac{V_2}{R_2} = \frac{10V}{100{,}000\Omega} = 0.0001A = 0.1mA.$$

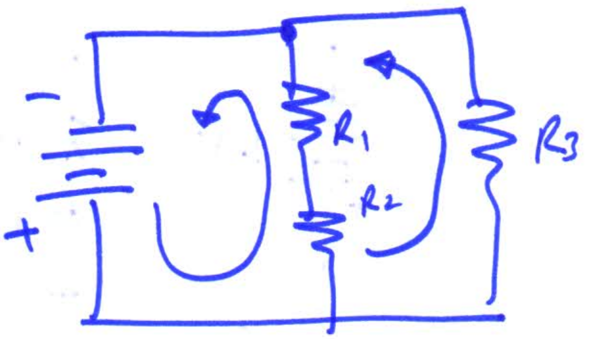
$$I_{R_3} = \frac{10V}{1000\Omega} = 0.01A = 10mA.$$

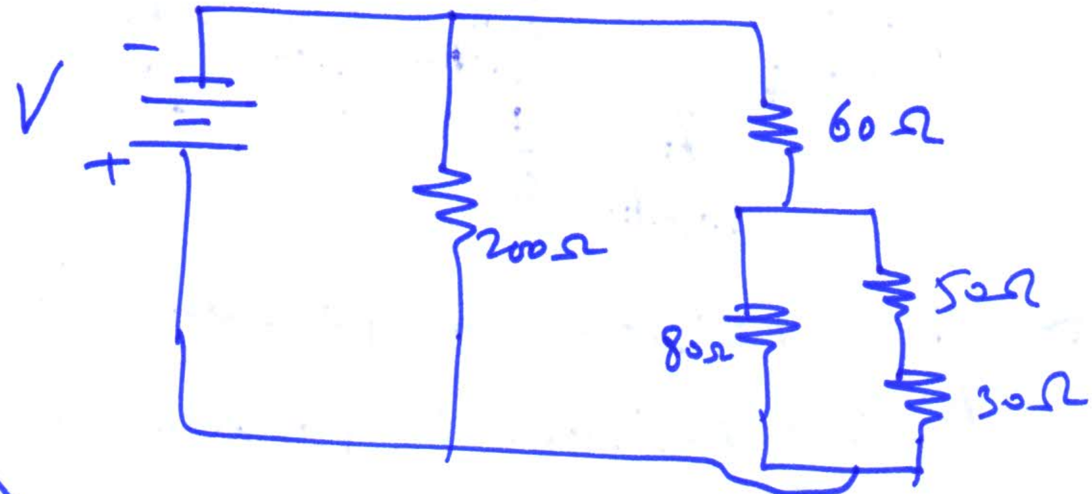
Solve Example, 5.3, 5.4, 5.5, 5.6

(P.T.O)

Series Parallel circuit

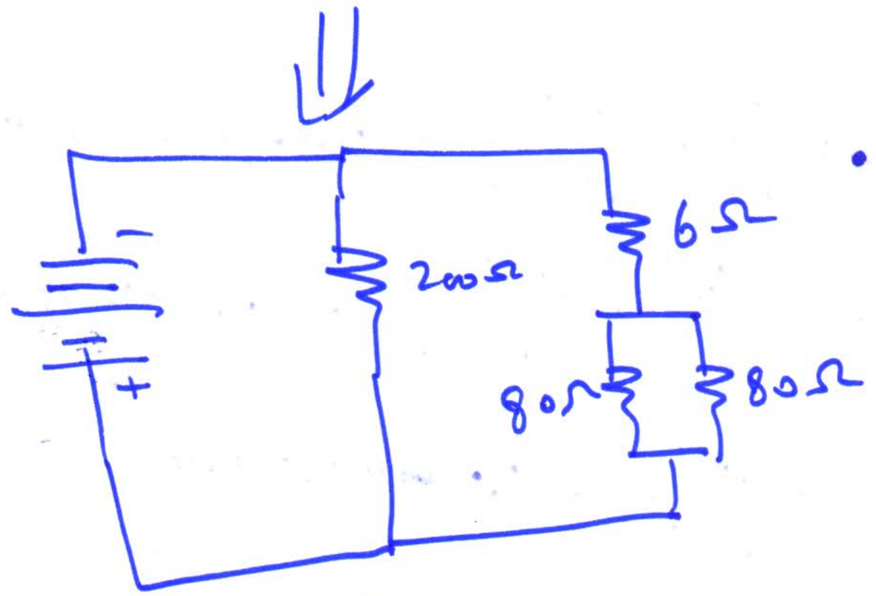


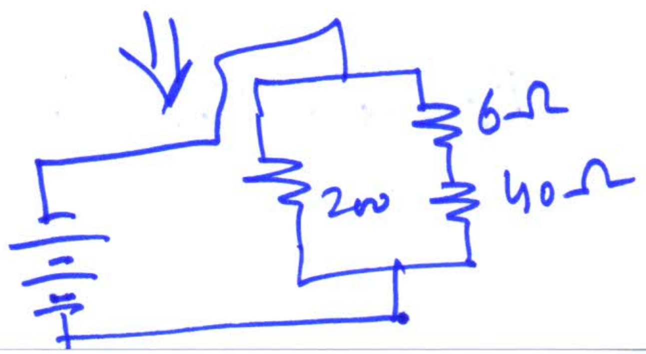


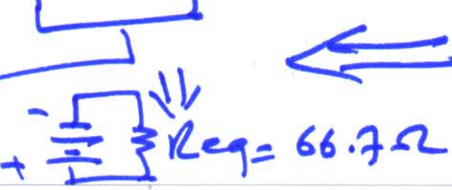


Note.

Solve example: 5.10, 5.11





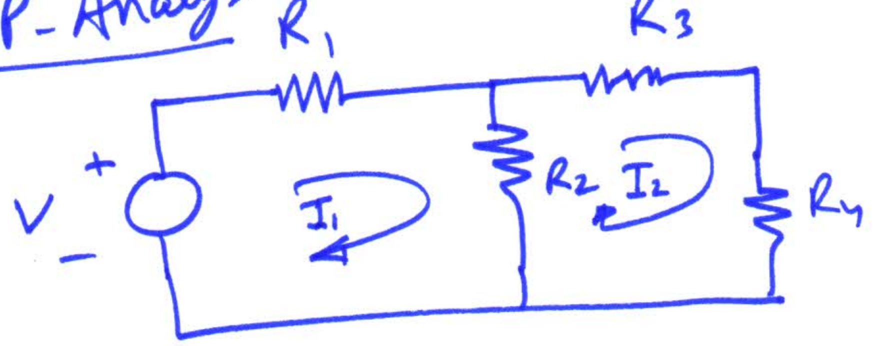


Further Application of Kirchhoff's Laws

KVL — Loop Analysis/Mesh Analysis

KCL — Node Analysis.

Loop-Analysis



Loop-I.

Voltage rises = Voltage drops

$$V = I_1 R_1 + (I_1 - I_2) R_2$$

$$V = I_1 (R_1 + R_2) + I_2 (-R_2) \rightarrow ①$$

Loop-II

$$0 = I_2 R_3 + I_2 \cdot R_4 + (I_2 - I_1) R_2$$

$$0 = I_1 (-R_2) + I_2 (R_2 + R_3 + R_4) \rightarrow ②$$

$$\begin{bmatrix} (R_1 + R_2) & (-R_2) \\ (-R_2) & (R_2 + R_3 + R_4) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V \\ 0 \end{bmatrix}$$

General equation

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Cramer Rule Solution

$$\Delta_R I = V$$

$$I_1 = \frac{\begin{vmatrix} V_1 & R_{12} \\ V_2 & R_{22} \end{vmatrix}}{\Delta_R}$$

$$I_2 = \frac{\begin{vmatrix} R_{11} & V_1 \\ R_{21} & V_2 \end{vmatrix}}{\Delta R}$$

$$\Delta = \begin{vmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{vmatrix} = R_{11} R_{22} - R_{12} R_{21}$$

) R_{11} = Sum of All Resistance in Loop 1

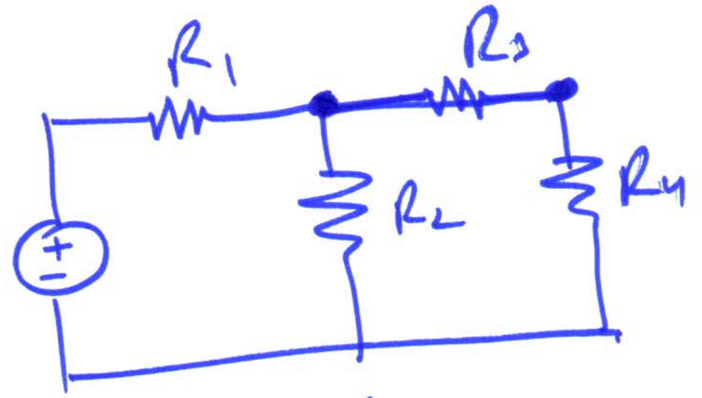
+) R_{22} = Sum of All Resistance in Loop 2

-) $R_{12} = R_{21}$ = Resistance common between Loop 1 and Loop 2.

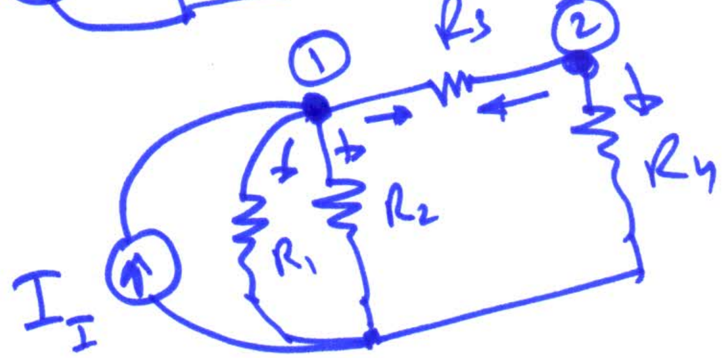
V_1 = Sum of the Voltage rises in Loop_1

V_2 = Sum of the Voltage rises in Loop-2.

Node Analysis



OR



K.C.L

$$I_I = \frac{V_1}{R_1} + \frac{V_1}{R_2} + \frac{V_1 - V_2}{R_3}$$

Node 1

1 ⟵ $$I_I = V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) + V_2\left(-\frac{1}{R_3}\right)$$

$$0 = \frac{V_2 - V_1}{R_3} + \frac{V_2}{R_4}$$

$$0 = V_1\left(-\frac{1}{R_3}\right) + V_2\left(\frac{1}{R_4} + \frac{1}{R_3}\right)$$

$$\begin{bmatrix} \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right) & \left(-\frac{1}{R_3}\right) \\ \left(-\frac{1}{R_3}\right) & \left(\frac{1}{R_3}+\frac{1}{R_4}\right) \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} I_I \\ 0 \end{bmatrix}$$

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

$$\begin{bmatrix} (G_1+G_2+G_3) & (-G_3) \\ (-G_3) & (G_3+G_4) \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} I_1 \\ 0 \end{bmatrix}$$

Generalized Equation:

$$\begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

+ G_{11} = Sum of all conductance connected to node-1

+ G_{22} = Sum of all conductance connected to node-2

− $G_{12} = G_{21}$ = Conductance common between node-1 and node-2

⊕ if towards node-1 I_1 = Current source connected to node-1

⊕ if towards node-2 I_2 = Current source connected to node-2

and (-ive) if away from the node-(2)

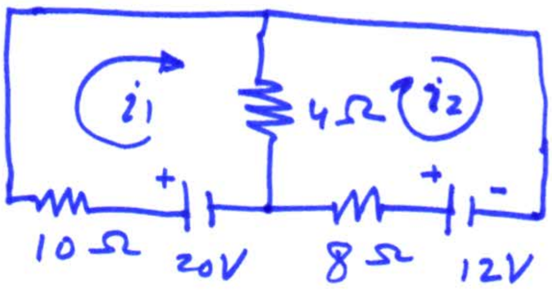
$$[G][V] = [I]$$

Solution is cramer's rules or straight method.

Chapter (VIII)

Admittance. Kirchhoff's Law

Exp. 1 (Page-64)



$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 12 \end{bmatrix}$$

$R_{11} = 10 + 4 = 14$

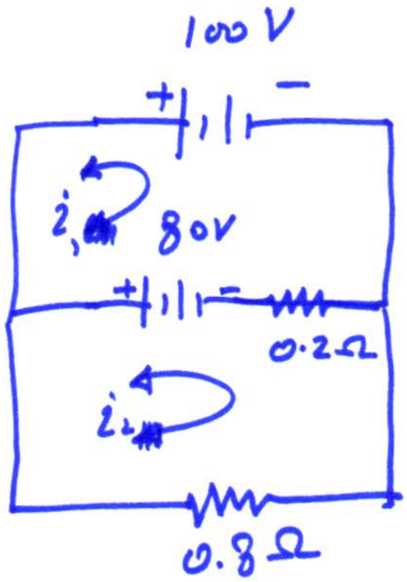
$R_{22} = 8 + 4 = 12$

$R_{12} = R_{21} = -4$

$$\begin{bmatrix} 14 & -4 \\ -4 & 12 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 12 \end{bmatrix}$$

$i_1 = ?$ $i_2 = ?$

EXP-2



$R_{11} = 0.2\ \Omega$

$R_{22} = 1.0\ \Omega$

$R_{12} = R_{21} = -0.2\ \Omega$

$V_1 = 100 - 80 = 20V$

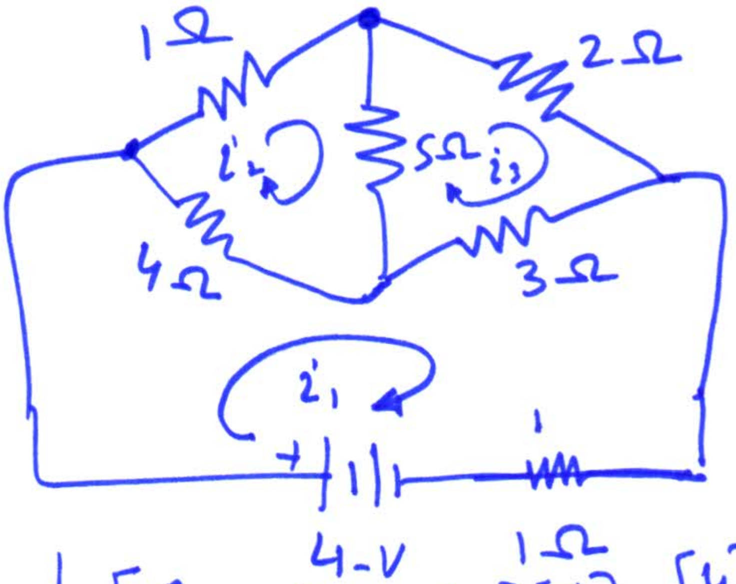
$V_2 = 80$

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} 0.2 & -0.2 \\ -0.2 & 1.0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 80 \end{bmatrix}$$

$i_1, i_2 = ?$

EXP-4



$R_{11} = 4 + 3 + 1 = 8\ \Omega$

$R_{22} = 5 + 4 + 1 = 10\ \Omega$

$R_{33} = 3 + 5 + 2 = 10\ \Omega$

$R_{12} = -4\ \Omega = R_{21}$

$R_{13} = R_{31} = -3$

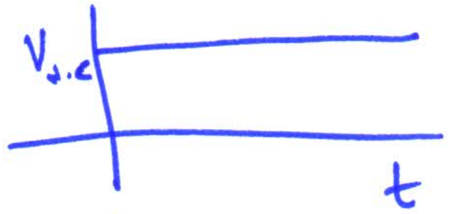
$R_{23} = R_{32} = -5$

$V_1 = 4,\ V_2 = 0,\ V_3 = 0$

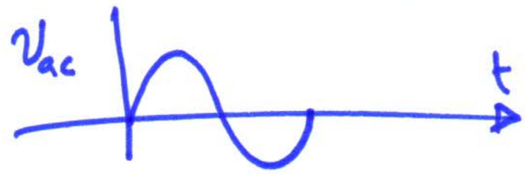
$$\begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 0 \\ 0 \end{bmatrix}$$

Complex Circuit Analysis

D.C → Direct current



A.C → Alternating current



frequency of D.C, $f = 0$

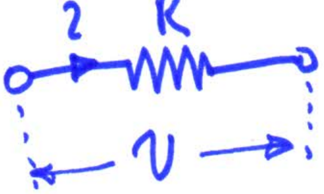
frequency of A.C, $f = 50$ Hz (cps)

$= 60$ Hz (America)

Three Basic element in Power System

① Resistor, ② Inductor ③ Capacitor.

① Resistor



ohms Law

$v = iR$

$i = v/R$

$R =$ ohms

$P = i^2 . R$

$P = Vi$

D.C/A.C

$P = vi \cos\phi$

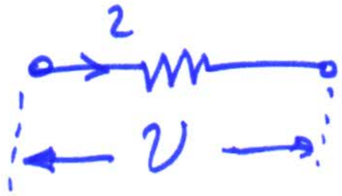
$\phi =$ Angle between V/i is zero

$\cos\phi = \cos 0 = 1.0$

$P = vi$

No Energy is stored in Resistor.
All Energy is consumed in Resistor.

$$\boxed{E = i^2 \cdot R \times t}$$

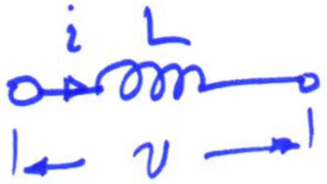


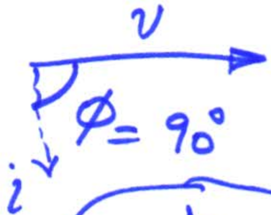
Instantaneously change voltage changes the instantaneous change in current.

$\phi = 0$
$\cos\phi = 1$

$$\boxed{P = vi}$$

② Inductor





Current Lagging behind voltage by 90°

Normally used formulae

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

Original formulae: Faradays law

$$v = \frac{d\psi}{dt}$$

ψ = flux linkages $= Li$

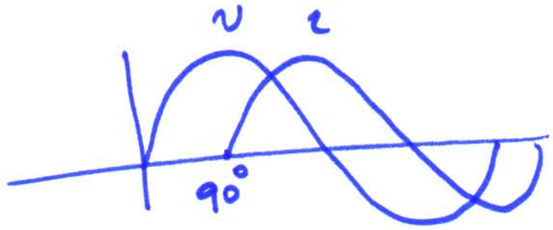
$$v = \frac{d(Li)}{dt} = L\frac{di}{dt} + i\frac{dL}{dt}.$$

$$\boxed{v = L\frac{di}{dt}}$$ (if L = Constant, which is normally the case)

$X_L = 2\pi f L$ (Inductive reactance) in ohms Ω

$X_L = 0$ D.C

$X_L = 2\pi f L$ A.C



$$\boxed{\text{Current does not change instantaneously. Always a delay in inductive circuit}}$$

Energy consumed is ideally zero.
Practically yes, but negligibly small

Actual inductor.

Energy is stored in inductor.

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

$$P = V_L . i$$

$$dW = P . dt$$

$$dW = V_L . i . dt$$

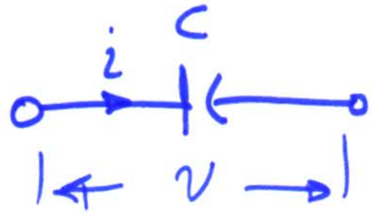
$$= L\frac{di}{dt} . i . dt$$

$$dW = L\, i\, di$$

$$W = L\int_0^I i . di = \frac{1}{2} L I^2$$

$$\boxed{W = \frac{1}{2} L I^2}$$

Capacitor



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

orignal formulae $\Rightarrow$ $i = \frac{dq}{dt}$.

$$q = CV$$

$$i = \frac{dq}{dt} = \frac{d}{dt}(CV) = C\frac{dv}{dt} + v\frac{dc}{dt}.$$

$$\boxed{i = C\frac{dv}{dt}}$$ only if $C = \text{Constant}$

Energy stored in a capacitor

$$P = vi = v.\frac{dq}{dt}.$$

$$\cancel{\frac{dW}{dt}} = \cancel{\frac{dP}{dt}} =$$

$$dE = P \times dt.$$

$$dE = v.\frac{dq}{dt}.dt$$

$$dE = v.dq$$

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

$$dE = \frac{q}{c}.dq$$

$$Q = CV$$

$$V = \frac{Q}{c}$$

$$\Rightarrow E = \frac{1}{c}\int_0^Q q.dq$$

$$E = \frac{1}{C} q^2 \Big|_0^Q$$

$$E = \frac{Q^2}{2C}.$$

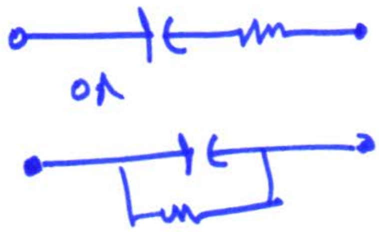
As $Q = CV$

hence

$$\boxed{E = \frac{1}{2} C V^2}$$

No Energy is consumed in a (ideal Capacitor)
However in a real capacitor only small energy is consumed.

Actual model of capacitor



AC/DC

$P = vi\cos\phi$

$P = vi \times 0$

$\boxed{P = 0}$

$\phi = 90^\circ$
current is Leading by 90°

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

$f = 0$ for D.C

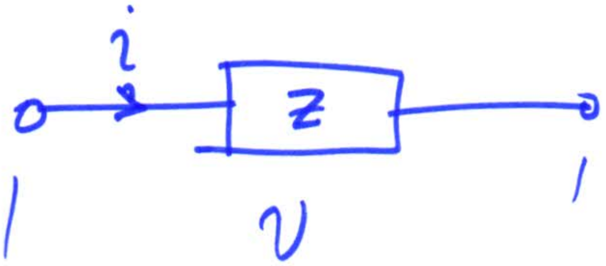
$X_C = \infty$ (open circuit) Ω

$X_C = \frac{1}{2\pi f c}$ (A.C, Capacitive reactance)
units are ohm

Complex circuit

Impedance (Combined affect of R, L, C to oppose Electric current is called impedance)

Combination of R, L and C is called a complex circuit.



$$\boxed{V = iZ}$$

R = ohms (Resistor) Ω

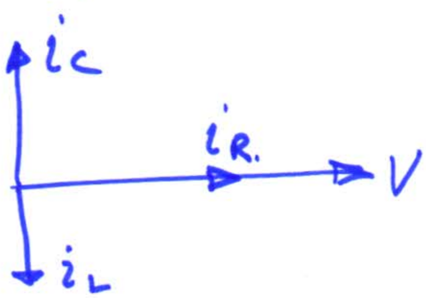
L = Inductance inductance in Henry (H)

C = Capacitance in Farads (F)

$R \rightarrow \Omega, m\Omega, M\Omega, k\Omega$

$L \rightarrow H, mH$

$C \rightarrow F\ \mu F, nF, \mu\mu F$

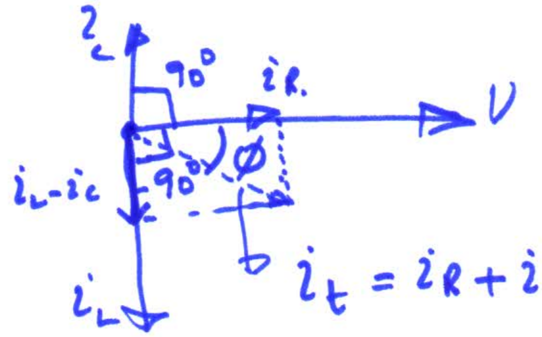


R = ohms

$X_L = 2\pi f L$ (ohms)

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

2 41



$i_t = i_R + i_L \angle 90^\circ$

$$\boxed{Z = R + jX_L - jX_C}$$

$j = 1\angle 90^\circ$

$$\phi = \tan^{-1}\frac{(X_L - X_C)}{R}.$$

ϕ is the angle between V and i

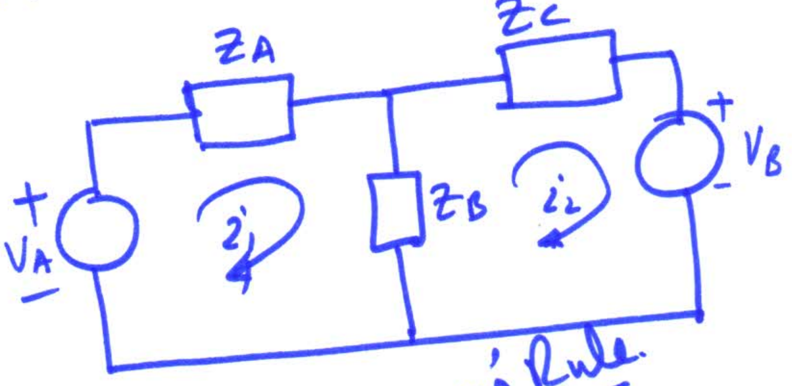
$\cos\phi$ = Power Factor → if $X_L > X_C$, the net reactance will be inductive

R → Resistance → if $X_C > X_C$ then the net ~~ind~~ reactance will be capacitive.

Z → Impedance

$\frac{1}{R} = G$ = Conductance (℧) (mho)

$\frac{1}{Z} = Y$ = ~~[illegible]~~ Admittance (℧) (mho)



$$\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Cramer's Rule.

$Z_{11} = Z_A + Z_B$
$Z_{22} = Z_B + Z_C$
$Z_{12} = Z_{21} = -Z_B$

$V_1 = V_A$
$V_2 = -V_B$