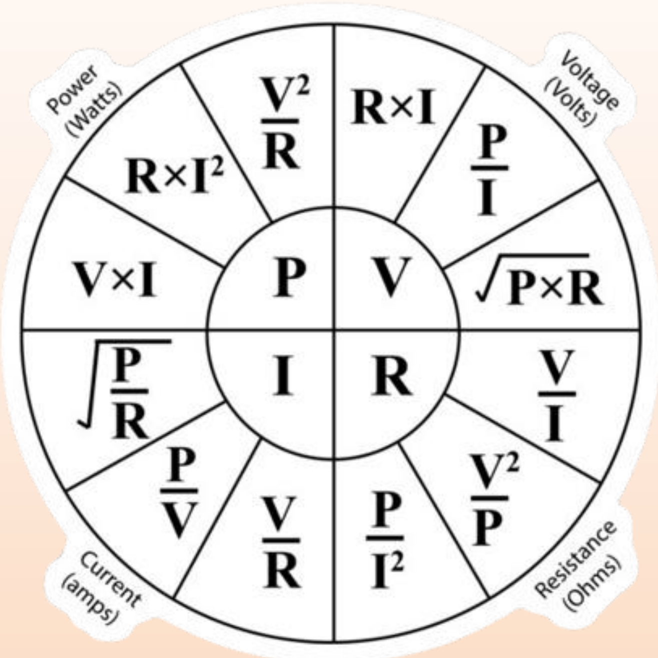
VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

Hand Book of formulas for 1st Year EEE



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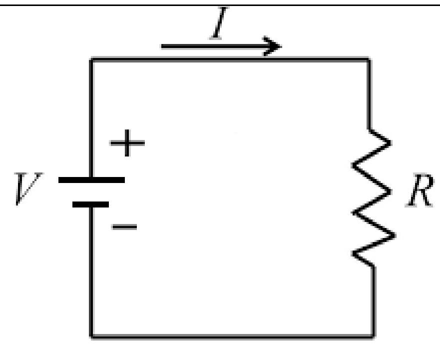
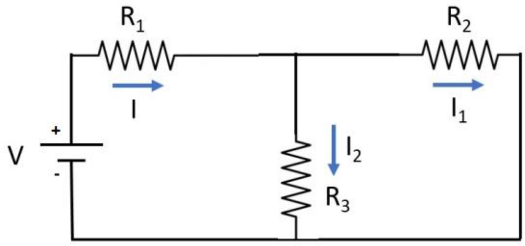
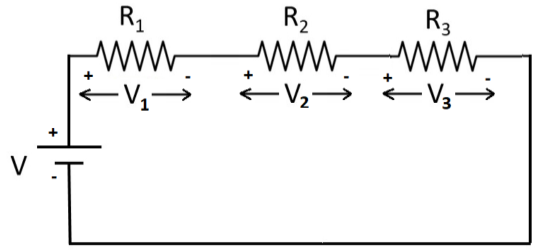
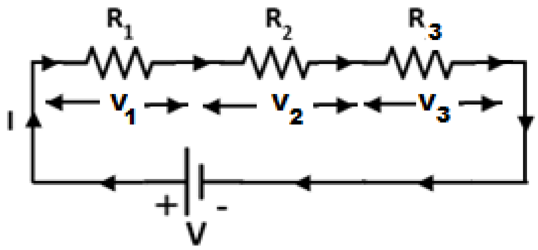
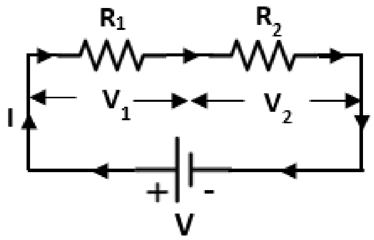
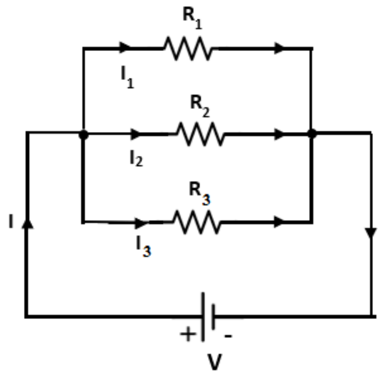
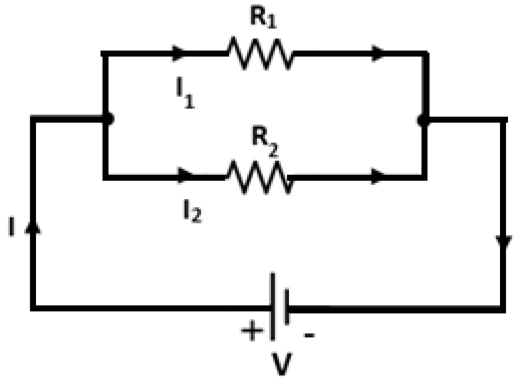
Module-1 (DC-Circuits)	
Ohm's Law **Statement:** The voltage across a conductor is directly proportional to the current flowing through it, provided all physical conditions and temperature, remain constant. $V= I \times R$ volt $I= V/R$ ampere $R=V/I$ ohm	
KCL **Statement:** The algebraic sum of all currents entering and exiting a node must equal zero. $I= I_1+ I_2$ ampere	
KVL **Statement:** The algebraic sum of all voltage drops around any closed loop is zero. $V= V_1 +V_2 + V_3$ volt	
Resistors in series: $V = (V_1+ V_2+ V_3)$ volt $R_{eq}= (R_1+R_2+R_3)$ ohm $I=\frac{V}{R_{eq}}$ ampere	
Voltage division in series circuit: $V_1 = \frac{R_1}{R_1+R_2} V \, volt$ $V_2 = \frac{R_2}{R_1+R_2} V$	
Resistors in parallel $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ $I= (I_1+ I_2+ I_3) \, ampere$ $I=\frac{V}{R_{eq}} \, ampere$	

Current division in parallel circuit

$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) \times I \, ampere$$

$$I_2 = \left(\frac{R_1}{R_1 + R_2}\right) \times I \, ampere$$



Power dissipated in the circuit

P = (V I) *watt* or P = (I^2 R) *watt* or $(P = \frac{V^2}{R})$*watt*

Energy

Energy = (Power×Time) *joule* or Energy =((Voltage×Current×Time) *joule*

Electromagnetism

Magnetic Flux Density B= $\frac{\phi}{a}$ Wb/m^2 or T

where B = Magnetic Flux Density

ϕ = Magnetic Flux

a = area of cross section

MMF = N I

where N = Number of turns in the coil

I= Current through the coil

MMF = Flux x Reluctance = ϕ x R

Reluctance R= $\frac{l}{\mu 0\ \mu r\ a}$

where μ_0 = Permeability of free space or air ($4\pi \times 10^{-7}$ H/m)

μ_r = Relative Permeability

a = area of cross section

Magnetic Force H = $\frac{N\,I}{l}$ AT /m

where N = Number of turns in the coil

I = Current

l= Coil length

EMF induced in the coil e = -N $\frac{d\phi}{dt}$

where e= induced emf in volts,

N= Number of turns in the coil

$\frac{d\phi}{dt}$ = rate of change of flux

Statically induced emf e= -L $\frac{di}{dt}$

Where, L = self-inductance of the coil

$\frac{di}{dt}$ = rate of change of current

Dynamically induced emf e=B l v sin θ

where B = flux density

l = length

v = conductor velocity

Self Inductance L= $\frac{N\phi}{I} = \frac{\mu 0\ \mu r\ a\ N^2}{l}$

Where N = Number of turns in the coil

I = Current

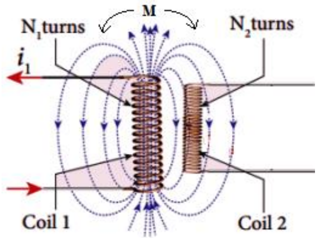
ϕ = Magnetic Flux

μ_0 = Permeability of free space or air ($4\pi \times 10^{-7}$ H/m)

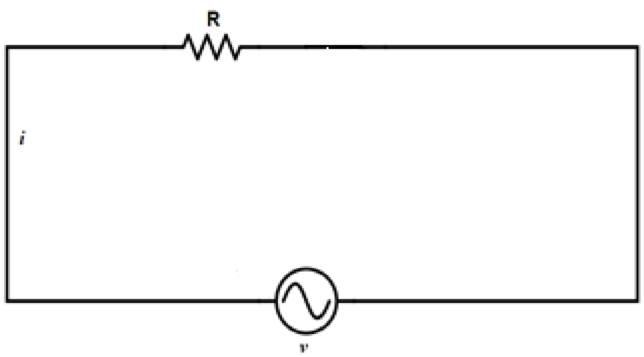
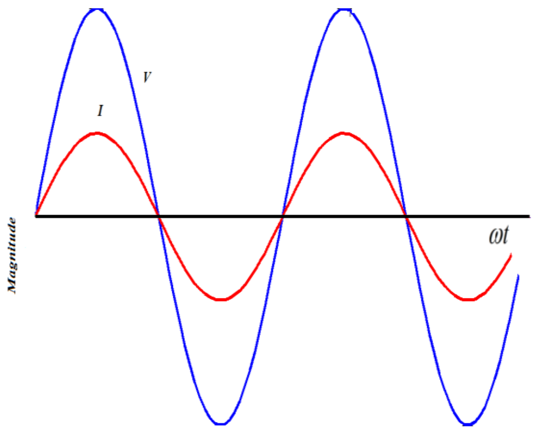
μ_r = Relative Permeability

a = area of cross section of the electromagnet

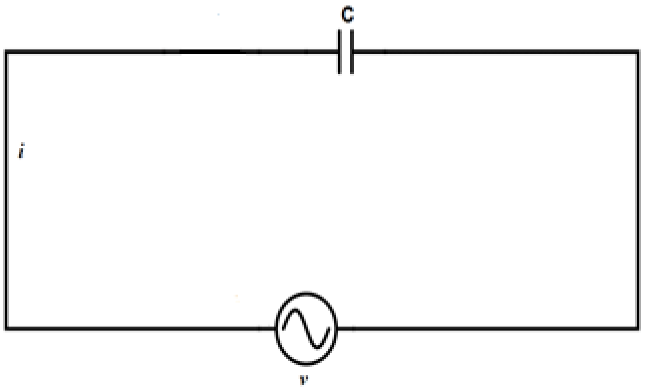
l = length of the electromagnet

<table>
<tr>
<td>Mutual Inductance $M = \frac{\mu_0 \mu_r N_1 N_2\, a}{l}$
where μ_0 = Permeability of free space or air ($4\pi \times 10^{-7}$ H/m)
μ_r = Relative Permeability
N_1 = number of turns in coil 1
N_2 = number of turns in coil 2
a = cross-sectional area
l = coil length</td>
<td>
</td>
</tr>
<tr>
<td colspan="2">Co-efficient of Coupling $K = \frac{M}{\sqrt{L_1 L_2}}$
where M = Mutual Inductance
L_1= Self inductance of coil 1
L_2= Self inductance of coil 2</td>
</tr>
<tr>
<td colspan="2">Energy stored in Magnetic field = $\frac{1}{2} L I^2$
where L= Self Inductance of a coil
I = Current flowing through the coil</td>
</tr>
</table>

Module-2 (A.C. Fundamentals & Single Phase AC Circuits)
Instantaneous value of alternating voltage $v = V_m \sin \omega t$
Instantaneous value of alternating current $i = I_m \sin \omega t$
Angular frequency $\omega = 2\pi f$, f -frequency in Hz
RMS value of voltage $V_{rms} = \frac{V_m}{\sqrt{2}}$, V_m - Peak voltage
RMS value of current, $I_{rms} = \frac{I_m}{\sqrt{2}}$, I_m - Peak current
Average voltage $V_{av} = \frac{2V_m}{\pi}$
Average current $I_{av} = \frac{2I_m}{\pi}$
$Form\ factor = \frac{rms\ value}{average\ value} = \frac{0.707\ I_m}{0.637\ I_m}$ =1.11
$Peak\ factor = \frac{Maximum\ value}{rms\ value}$

Pure Resistive Circuit	
	$v = V_m \sin \omega t = V\angle 0$ $i = I_m \sin \omega t = I\angle 0$ $Z = R = \frac{V}{I}$ $Cos\phi = 1$
	 Average Power $P = VI$ in Watts

Purely Capacitive circuit

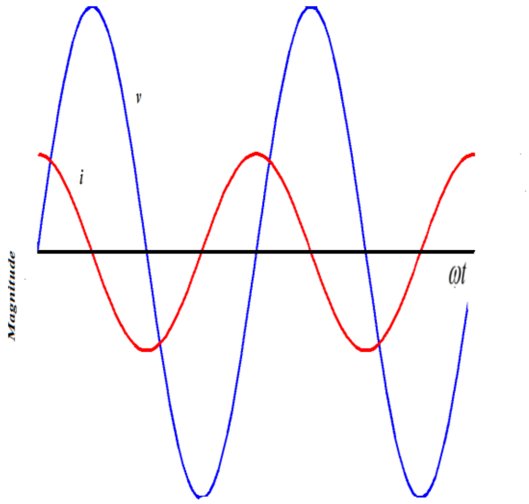


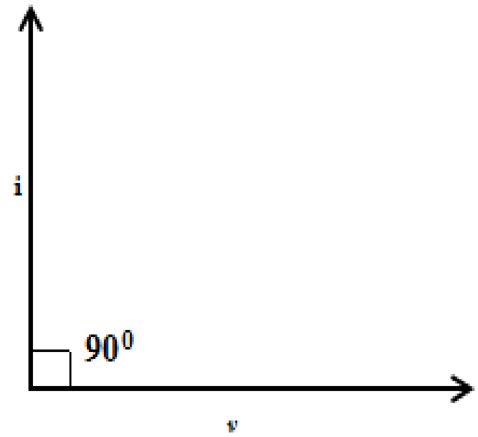
$$v = V_m \sin \omega t = V\angle 0$$

$$i = I_m \sin(\omega t + 90^0) = I\angle 90^0$$

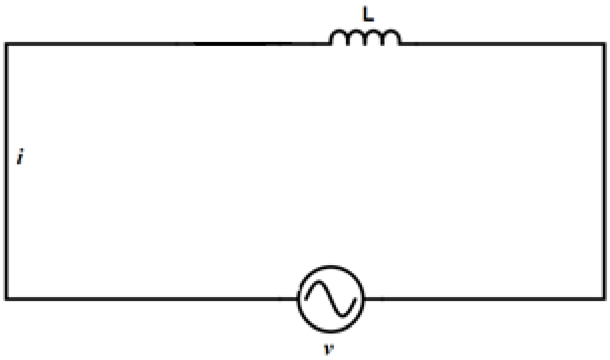
$$Z = R - jX_c = \frac{V\angle 0}{I\angle +\phi}$$

$P_{av} = 0$





Purely Inductive circuit

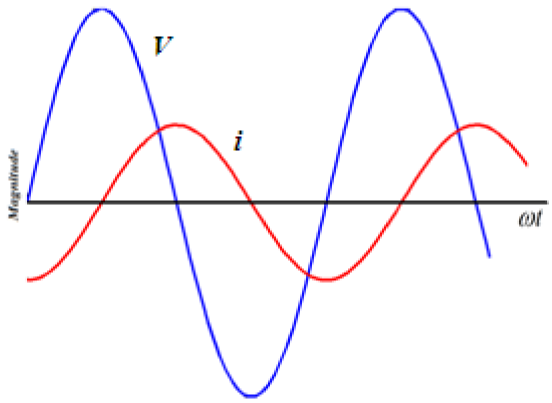


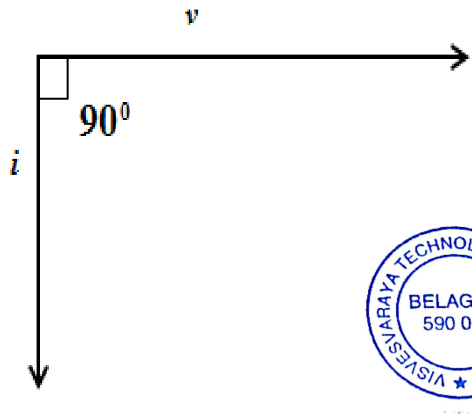
$$v = V_m \sin \omega t = V\angle 0$$

$$i = I_m \sin(\omega t - 90^0) = I\angle -90^0$$

$$Z = R + jX_c = \frac{V\angle 0}{I\angle -\phi}$$

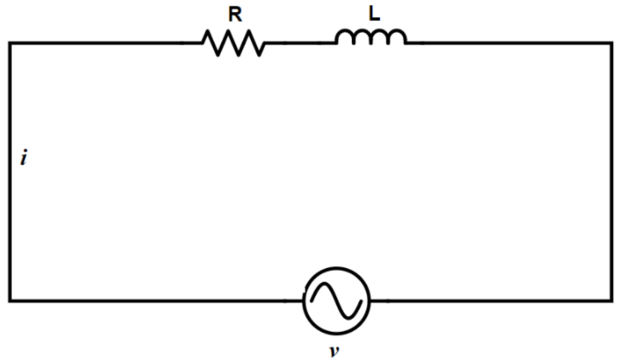
$P_{av} = 0$



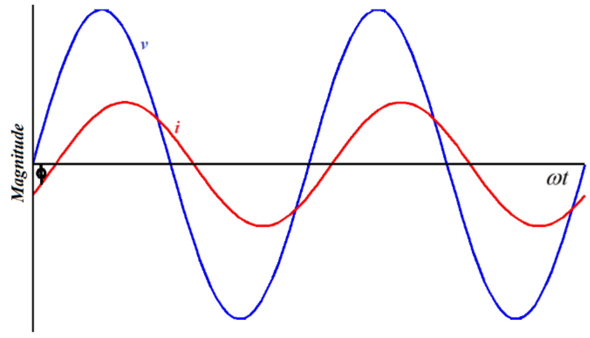


Single Phase Circuits

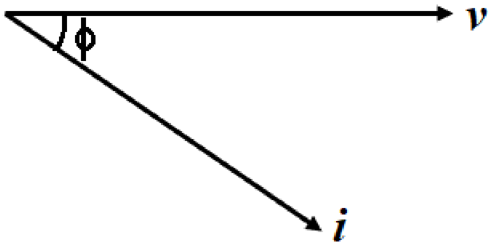
Series RL circuit:



$$v = V_m \sin \omega t = V\angle 0$$



$$i = I_m \sin(\omega t - \phi) = I\angle -\phi$$



$$\phi = \tan^{-1}\frac{X_L}{R}$$

Impedance

$$Z = R + jX_L = \frac{V\angle 0}{I\angle -\phi}$$

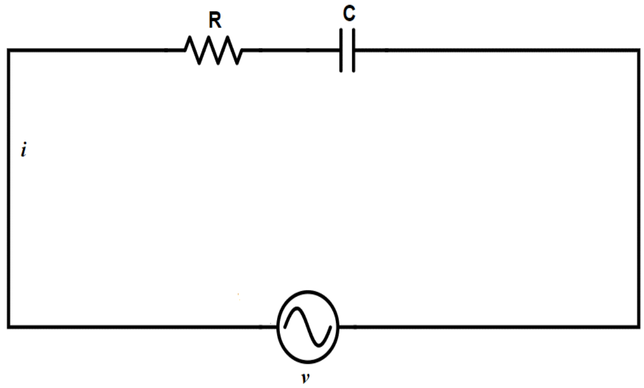
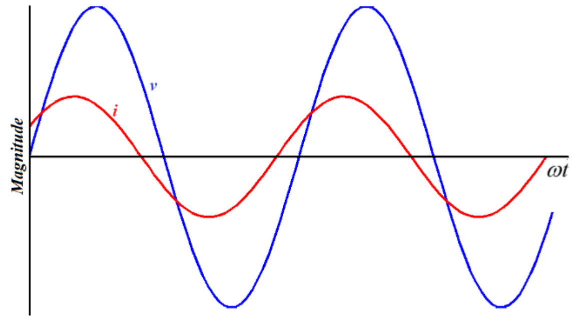
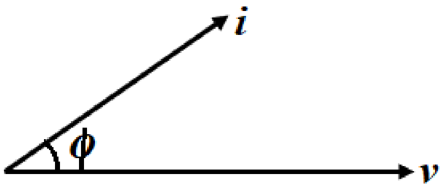
$$V = IZ$$

Active power (Watts) $P = VI\cos\phi = I^2 R$

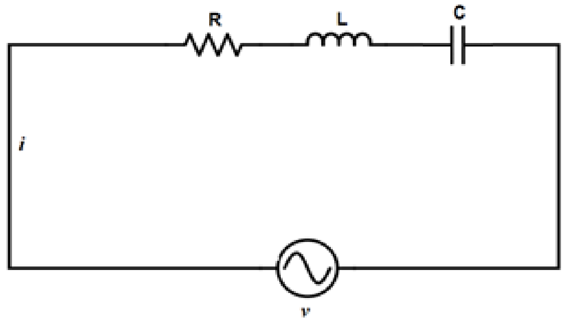
Reactive power (VAr) $Q = VI\sin\phi = I^2 X_L$

Apparent power (VA) $S = VI = I^2 Z$

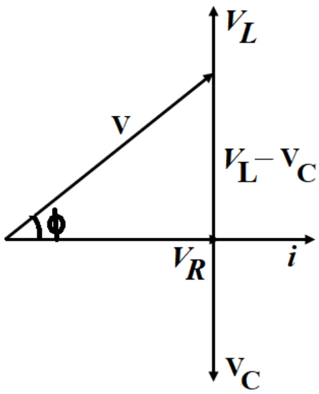
Power factor $\cos\phi = \dfrac{R}{Z}$

Series RC circuit:	
 $v = V_m \sin \omega t = V\angle 0$	 $i = I_m \sin(\omega t + \phi) = I\angle\phi$
	Impedance $Z = R - jX_C = \dfrac{V\angle 0}{I\angle\phi}$
$V = IZ$	
Active power(Watts) $P = VI\cos\phi = I^2 R$	
Reactive power(VAr) $Q = VI\sin\phi = I^2 X_C$	
Apparent power (VA) $S = VI = I^2 Z$	
Power factor $\cos\phi = \dfrac{R}{Z}$	

Series RLC Circuit:



If $X_L > X_C$



$$v = V_m \sin \omega t = V\angle 0$$

$$i = I_m \sin(\omega t - \phi) = I\angle -\phi$$

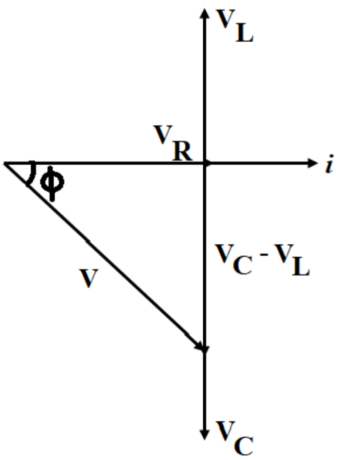
$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$Z = R + jX_L - jX_C$$

$$V = IZ$$

$$\cos\phi = \frac{R}{Z}$$

If $X_C > X_L$



$$v = V_m \sin \omega t = V\angle 0$$

$$i = I_m \sin(\omega t + \phi) = I\angle \phi$$

$$Z = R + jX_L - jX_C$$

$$V = IZ$$

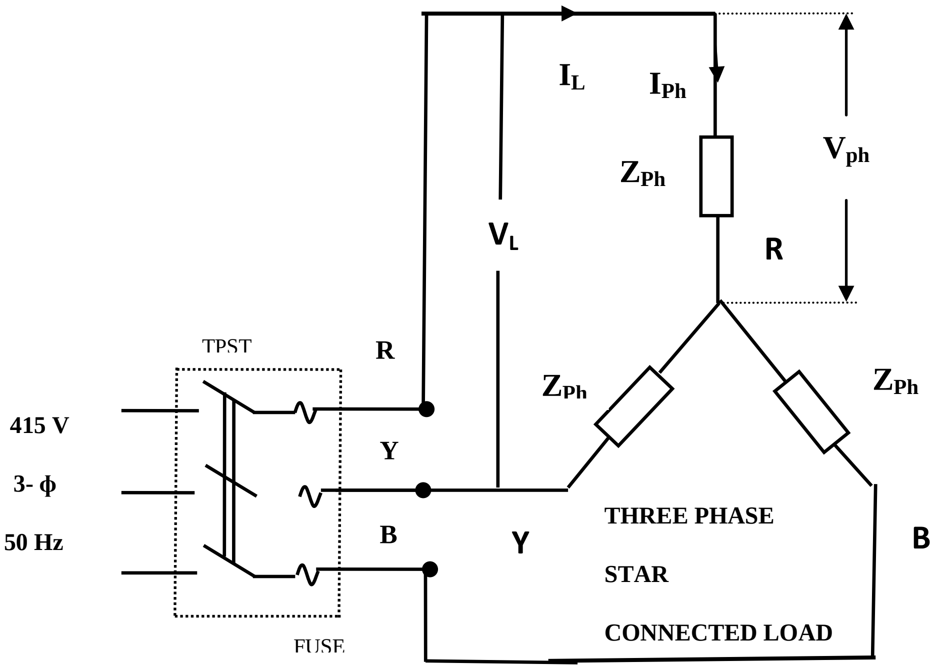
$$\cos\phi = \frac{R}{Z}$$

Three Phase AC Circuits:

Nomenclature:

V_L = line voltage,	$\emptyset$ = phase angle between phase voltage and phase current
I_L = line current,	W_1, W_2 =Two wattmeters reading
V_{Ph} = phase voltage,	P_{Ph} =Active power per phase
I_{Ph} = phase current,	Q_{Ph} =Reactive power per phase
Z_{ph} =Impedance per phase	S_{Ph} =Apparent power per phase

1. For star connected three phase AC circuit:

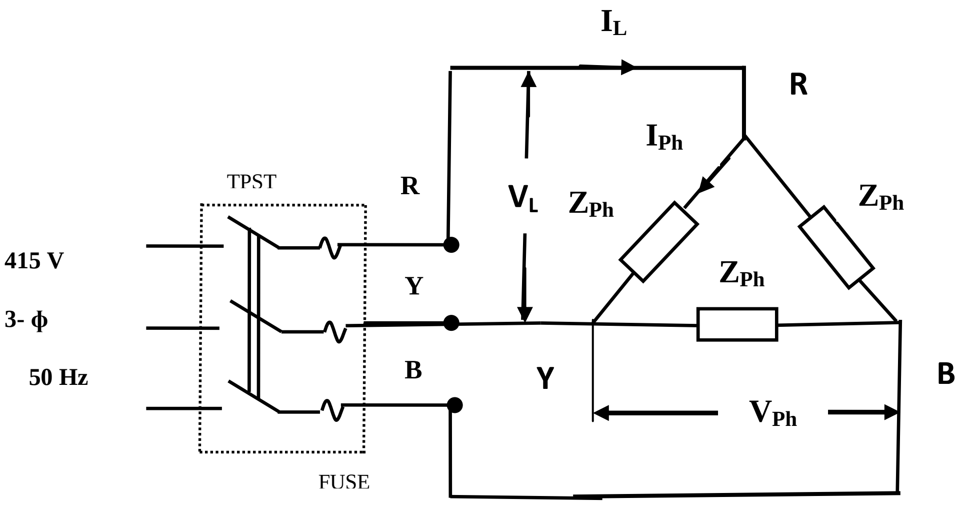


$$\mathbf{V_L = \sqrt{3} V_{Ph}} \text{ Volts}$$

$$\mathbf{I_L = I_{Ph}} \text{ Amps}$$

$$\mathbf{Z_{ph} = \frac{V_{ph}}{I_{ph}}} \, \Omega$$

2. For delta connected three phase AC circuit:



DELTA

CONNECTED LOAD

$\mathbf{V_L = V_{Ph}}$ Volts

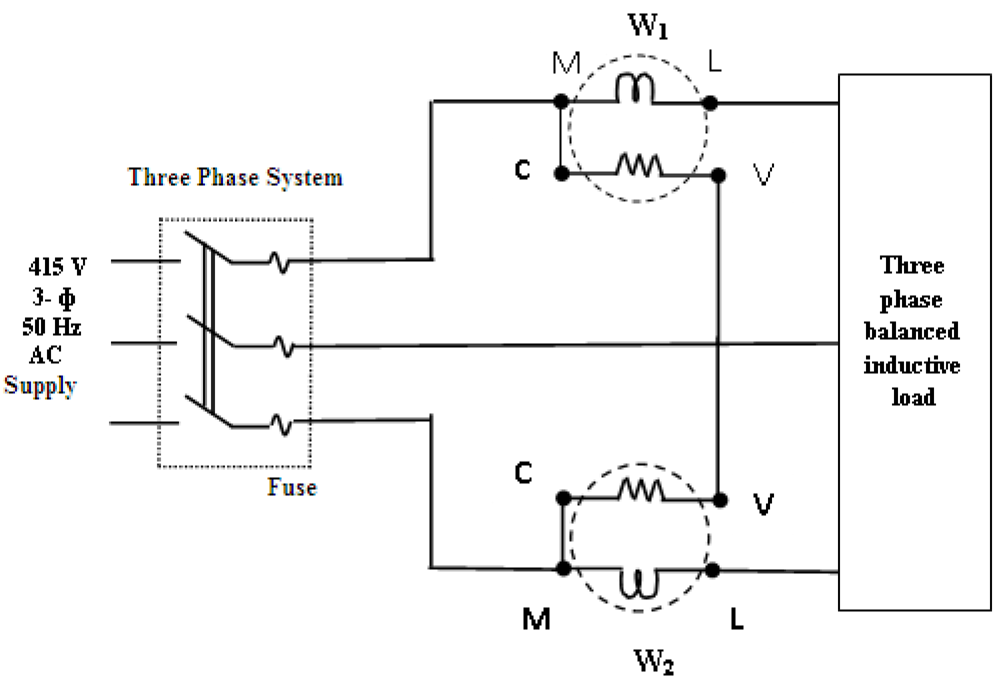
$\mathbf{I_L = \sqrt{3} I_{Ph}}$ Amps

$\mathbf{Z_{ph} = \frac{V_{ph}}{I_{ph}} \Omega}$

3. Power in a three phase AC circuit:

1. $\mathbf{P_{Ph} = V_{Ph} I_{Ph} \cos \emptyset}$ Watts
2. $\mathbf{Q_{Ph} = V_{Ph} I_{Ph} \sin \emptyset}$ VAR
3. $\mathbf{S_{Ph} = V_{Ph} I_{Ph}}$ VA
4. $\mathbf{P = \sqrt{3} V_L I_L \cos \emptyset}$ Watts
5. $\mathbf{Q = \sqrt{3} V_L I_L \sin \emptyset}$ VAR
6. $\mathbf{S = \sqrt{3} V_L I_L}$ VA

4. Measurement of power using two wattmeter:



$$\mathbf{W_1 = V_L I_L \cos(30 - \emptyset)} \text{ Watts}$$

$$\mathbf{W_2 = V_L I_L \cos(30 + \emptyset)} \text{ Watts}$$

$$\mathbf{W_1 + W_2 = \sqrt{3} V_L I_L \cos\emptyset} \text{ ....three phase power}$$

$$\mathbf{W_1 - W_2 = V_L I_L \sin\emptyset}$$

Power factor,

$$\mathbf{\cos\emptyset = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}\right]\right\}}$$

Module 3 (DC Generator)

EMF Equation:

$$E_g = \frac{\emptyset ZNP}{60A}\ volts$$

$\boldsymbol{E_g}$= generated emf in *volts*

$\boldsymbol{P}$ = number of poles

$\emptyset$ = flux per pole in *wb*

$\boldsymbol{Z}$ = number of slots× number of conductors per slot

$\boldsymbol{N}$ = speed of the armature in *rpm*

$\boldsymbol{A}$ = number of parallel paths

$\boldsymbol{A = P}$ for lap winding ; $\boldsymbol{A = 2}$ for wave winding

Nomenclature Used:

$\boldsymbol{E_g}$ = generated emf in *volts*

$\boldsymbol{V}$ = terminal voltage in *volts*

$\boldsymbol{R_a}$=armature resistance in *ohms*

$\boldsymbol{R_{se}}$=series field winding resistance in *ohms*

$\boldsymbol{R_{sh}}$=shunt field winding resistance in *ohms*

$\boldsymbol{I_a}$=armature current in *amperes*

$\boldsymbol{I_{se}}$=series field current in *amperes*

$\boldsymbol{I_{sh}}$= shunt field current in *amperes*

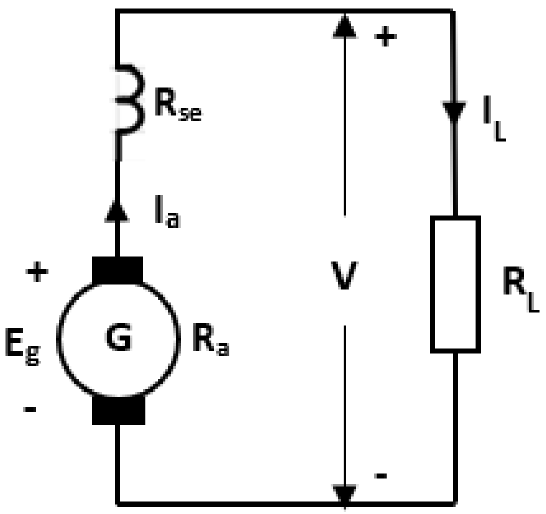
$\boldsymbol{I_L}$ = load current in *amperes*

$\boldsymbol{R_L}$ = load resistance in *ohms*

$\boldsymbol{BCD}$=Brush Contact Drop

Types of DC Generators:

1. DC SERIES GENERATOR

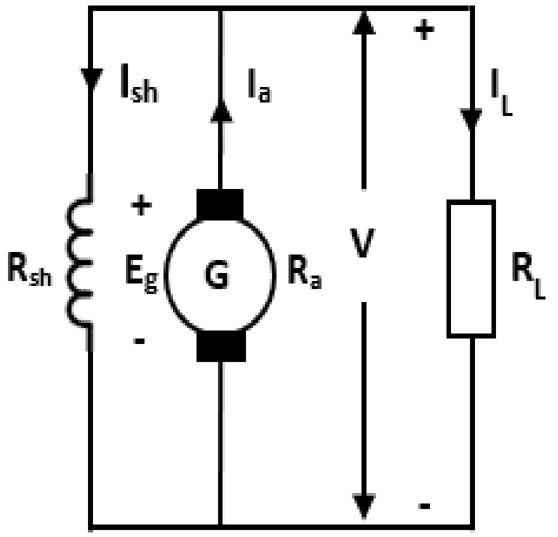


$I_a = I_L = I_{se}\ amps$

$V = E_g - I_a(R_a + R_{se}) - BCD\ volts$

$V = I_L R_L\ volts$

2. DC SHUNT GENERATOR

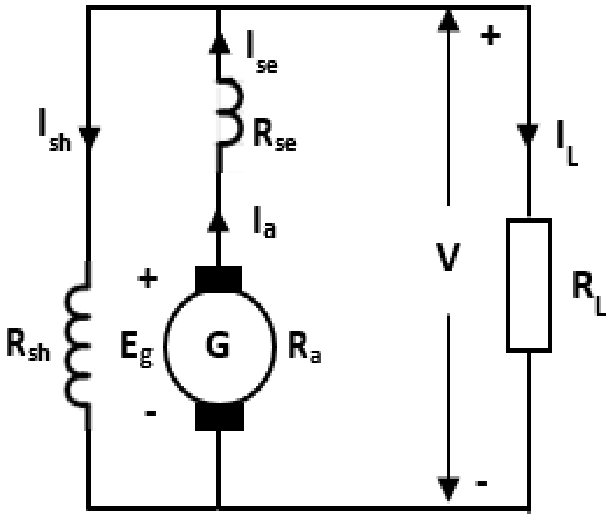


$I_a = I_L + I_{sh}$ *amps*

$V = E_g - I_a R_a - BCD$ *volts*

$V = I_L R_L = I_{sh} R_{sh}$ *volts*

3. DC LONG SHUNT COMPOUND GENERATOR



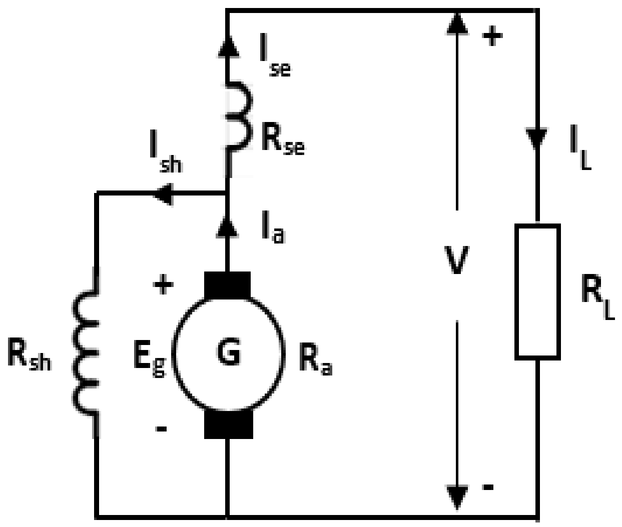
$I_a = I_{se}$ *amps*

$I_a = I_L + I_{sh}$ *amps*

$V = I_{sh} R_{sh} = I_L R_L$ *volts*

$V = E_g - I_a (R_a + R_{se}) - BCD$ *volts*

4. DC SHORT SHUNT COMPOUND GENERATOR



$I_a = I_{se} + I_{sh}$ *amps*

$I_{se} = I_L$ *amps*

$V = I_L R_L$ *volts*

$E_g - I_a R_a - BCD = I_{sh} R_{sh}$ *volts*

$V = E_g - I_a (R_a + R_{se}) - BCD$ *volts*

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Module 3 (DC Motor)

Nomenclature Used:

V	= DC input voltage in volts	I_{se}	= Series Field Current in amps
I_L	= Line Current in amps	I_{sh}	= Shunt Field Current in amps
P	= Number of poles	I_a	= Armature Current in amps
N	= Speed in rpm	BCD	= Brush Contact Drop in volts
Φ	= Flux in wb	R_a	= Armature Resistance in ohm
T_{sh}	= Shaft Torque in N-m	R_{sh}	= Shunt field Resistance in ohm
T_a	= Armature Torque in N-m	R_{se}	= Series field Resistance in ohm
E_b	= Back EMF in volts	I_a	= Armature current in Amps
A	= Number of parallel paths		
ω	= Angular Velocity in radians per second		

Back EMF

$$E_b = \frac{\emptyset \times Z \times N \times P}{60 \times A} \text{ volts}$$

Armature Torque

$$T_a = \frac{\emptyset \times Z \times I_a \times P}{2 \times \pi \times A} \text{ N-m}$$

Angular velocity

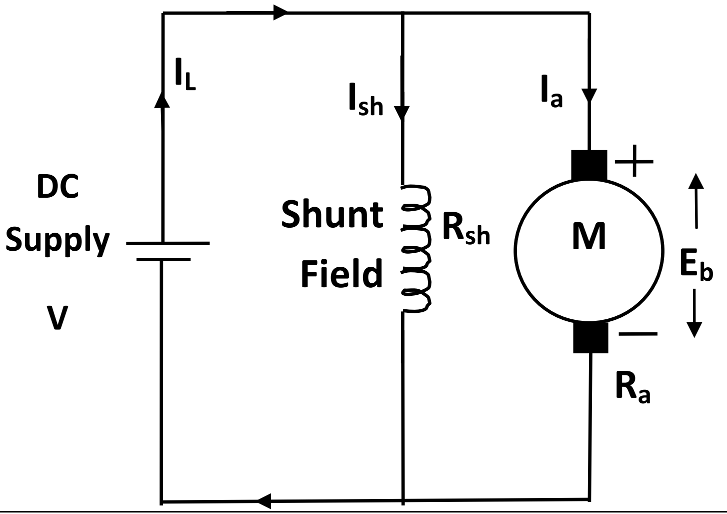
$$\omega = \frac{2 \times \pi \times N}{60} \text{ radians/second}$$

Shaft Torque

$$T_{sh} = \frac{\text{Output of motor in HP} \times 746}{\omega} \text{ N-m}$$

Types of DC Motor

DC SHUNT MOTOR

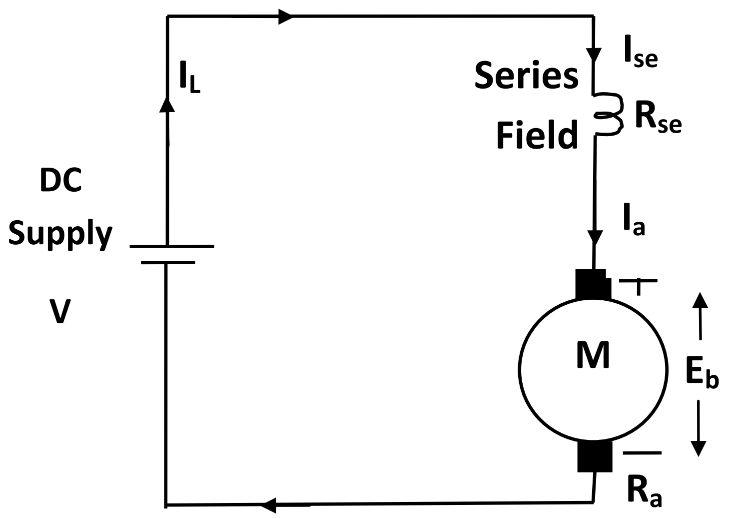


$$I_{sh} = \frac{V}{R_{sh}} \text{ amps}$$

$$I_L = I_a + I_{sh} \text{ amps}$$

$$E_b = V - I_a R_a - BCD \text{ volts}$$

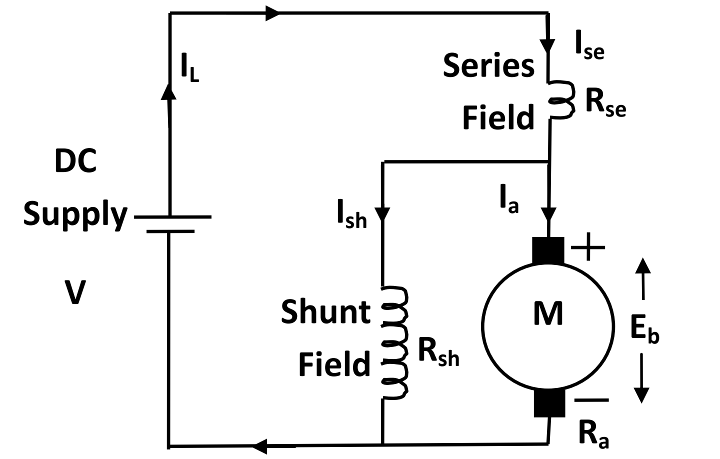
DC SERIES MOTOR



$I_L = I_a = I_{se}$ **amps**

$E_b = V - I_a(R_a + R_{se}) - BCD$ **volts**

DC SHORT SHUNT COMPOUND MOTOR

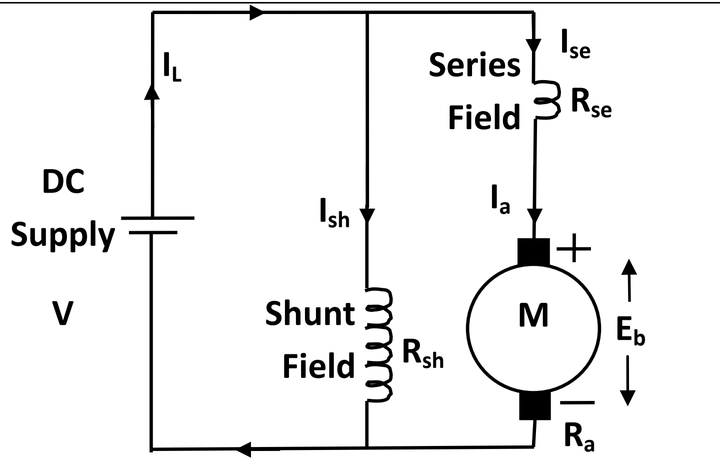


$I_{sh} = \frac{V - I_{se}R_{se}}{R_{sh}}$ **amps**

$I_L = I_{se} = I_a + I_{sh}$ **amps**

$E_b = V - I_{se}R_{se} - I_aR_a - BCD$ **volts**

DC LONG SHUNT COMPOUND MOTOR



$I_{sh} = \frac{V}{R_{sh}}$ **amps**

$I_L = I_a + I_{sh}$ **amps**

$I_a = I_{se}$ **amps**

$E_b = V - I_a(R_a + R_{se}) - BCD$ **volts**

Module 4 (Transformers)

Nomenclature:

E_1 = emf induced in primary winding in volts

E_2 = emf induced in secondary winding in volts

f = Frequency of supply voltage in Hertz

N_1 = number of primary windings

N_2 = number of secondary windings

ϕ_m = Maximum flux linking the windings in webers

V_1 = supply voltage given to the primary windings in volts

V_2 = output voltage across secondary windings in volts

I_1 = current flowing through primary windings

I_2 = current flowing through secondary windings

W_i = Iron loss

W_{cu} = Full load Copper loss

x = fractional load

V= volume of the core

B_{max} = maximum value of flux density in the core

η = a constant, whose value depends on the quality of the magnetic material used for making the core

β = a constant, whose value depends on the quality of the magnetic material used for making the core

t = thickness of the laminations

Emf equation:

$$E_1 = 4.44 f \phi_m N_1 \text{ Volts}$$

$$E_2 = 4.44 f \phi_m N_2 \text{ Volts}$$

Transformation ratio:

$$K = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

Condition for maximum efficiency:

$$W_i = W_{cu}$$

Full load currents:

$$I_1 = \frac{\text{Volt Ampere Rating of a transformer}}{V_1} \text{Amps}$$

$$I_2 = \frac{\text{Volt Ampere Rating of a transformer}}{V_2} \text{Amps}$$

Efficiency of a transformer:

$$\%\eta = \frac{x \times KVA \times 1000 \times Cos\emptyset}{x \times KVA \times 1000 \times Cos\emptyset + W_i + x^2 W_{cu\,(FL)}} \times 100$$

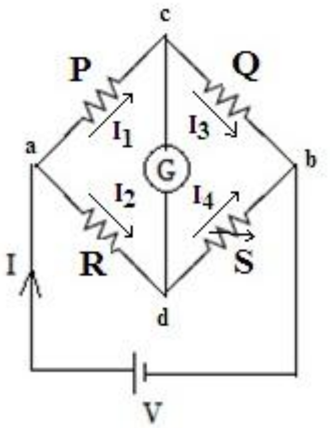
Hysteresis loss in transformer:

$W_h = \eta\, B^{1.6}_{max}\, f\, V$ Watt

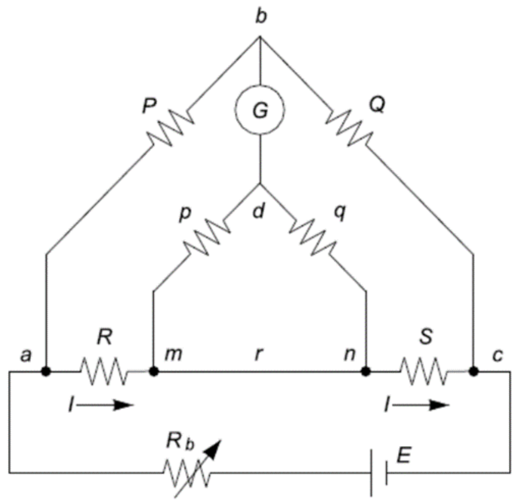
Eddy current loss in transformer:

$W_e = \beta\, B_{max}\, f^2\, t^2\, V$ Watt

Module 4 (Three-phase induction Motors)
Synchronous speed of rotating magnetic field $Ns = \frac{120\ f}{P}$ Where f= frequency in Hz, P= Number of poles
Percentage slip $s = \frac{Ns-N}{Ns}$ Where N = rotor speed, N_S = Synchronous speed
f'=sf Where ***f'*** frequency of rotor induced emf in Hz
Rotor speed $N = N_S(1-s)$

<table>
<tr><th colspan="2">Measuring instruments</th></tr>
<tr><td>Whetstone's Bridge


</td><td>The balance equation of the bridge is given by

therefore unknown resistance R $=S\frac{P}{Q}$</td></tr>
<tr><td>Kelvin's Double bridge


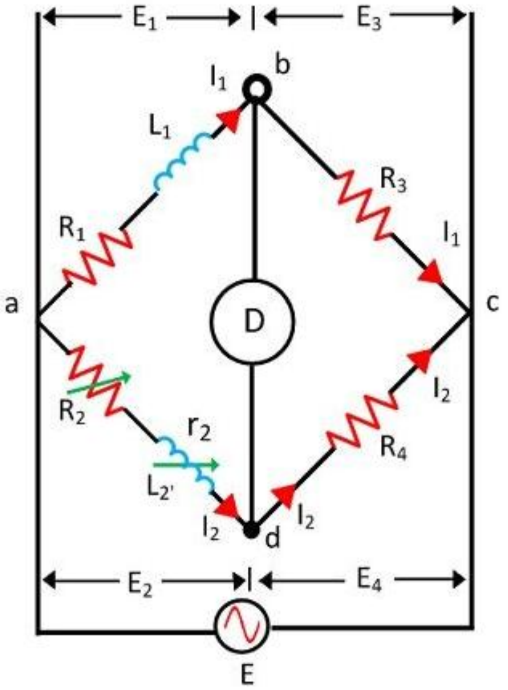
</td><td>The balance equation of the bridge is given by

$$R = \frac{P}{Q}S + \frac{qr}{(p+q+r)}\left[\frac{P}{Q} - \left(\frac{p}{q}\right)\right]$$

As per the design P/Q = p/q, the value of unknown resistance is given by

$$R = \frac{P}{Q}S$$</td></tr>
</table>

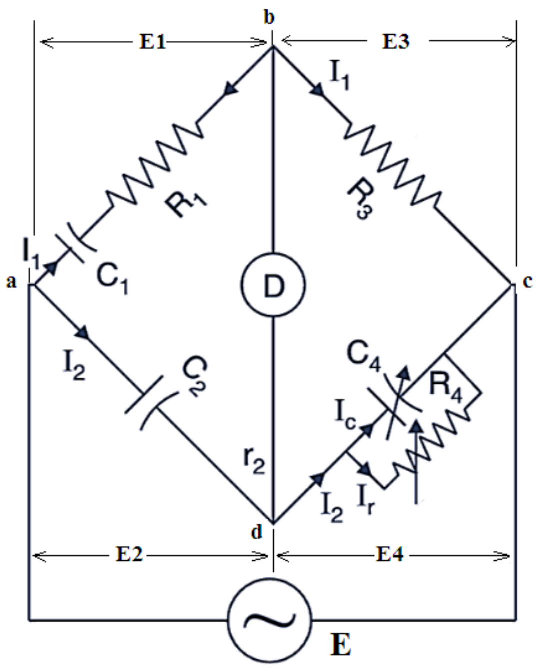
Maxwell's bridge for inductance



The balance equation of the bridge is given by

$$L1 = \frac{R_3}{R_4}\, L2 \quad \text{and} \quad R1 = \frac{R_3}{R_4}\,(R_2 + r_2)$$

Schering's bridge for capacitance

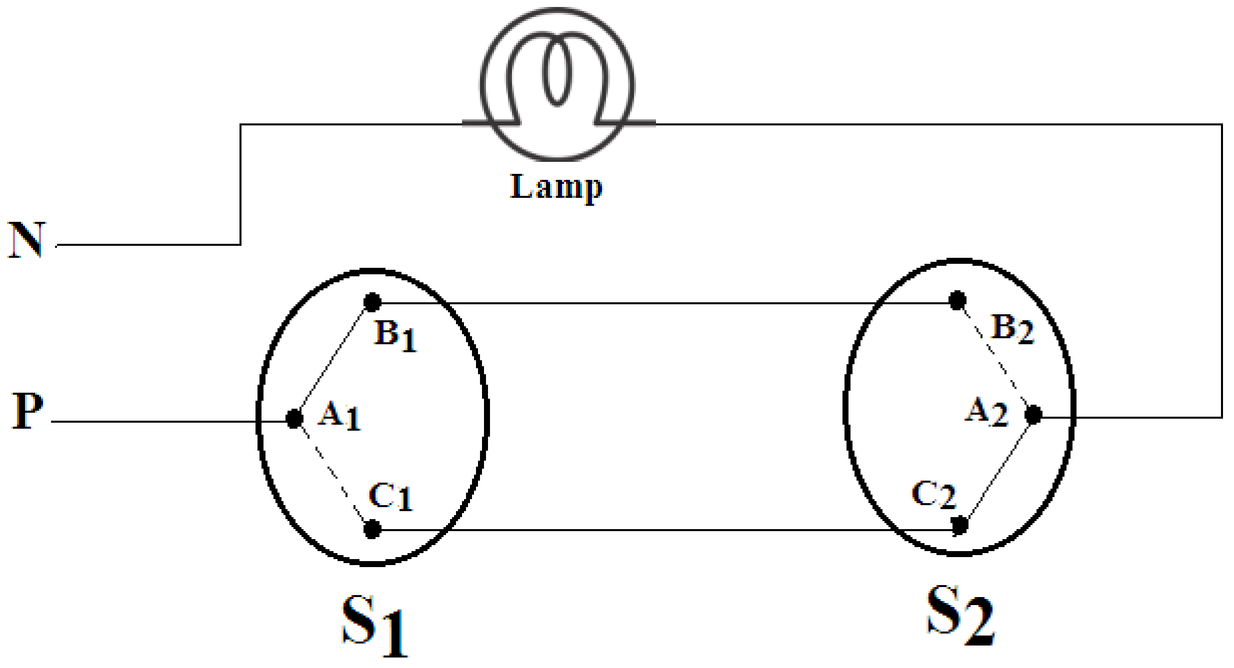


The balance equation of the bridge is given by

$$R_1 = \frac{R_3\, C_4}{C_2} \quad \text{and} \quad C_1 = \frac{R_4\, C_2}{R_3}$$

Module 5

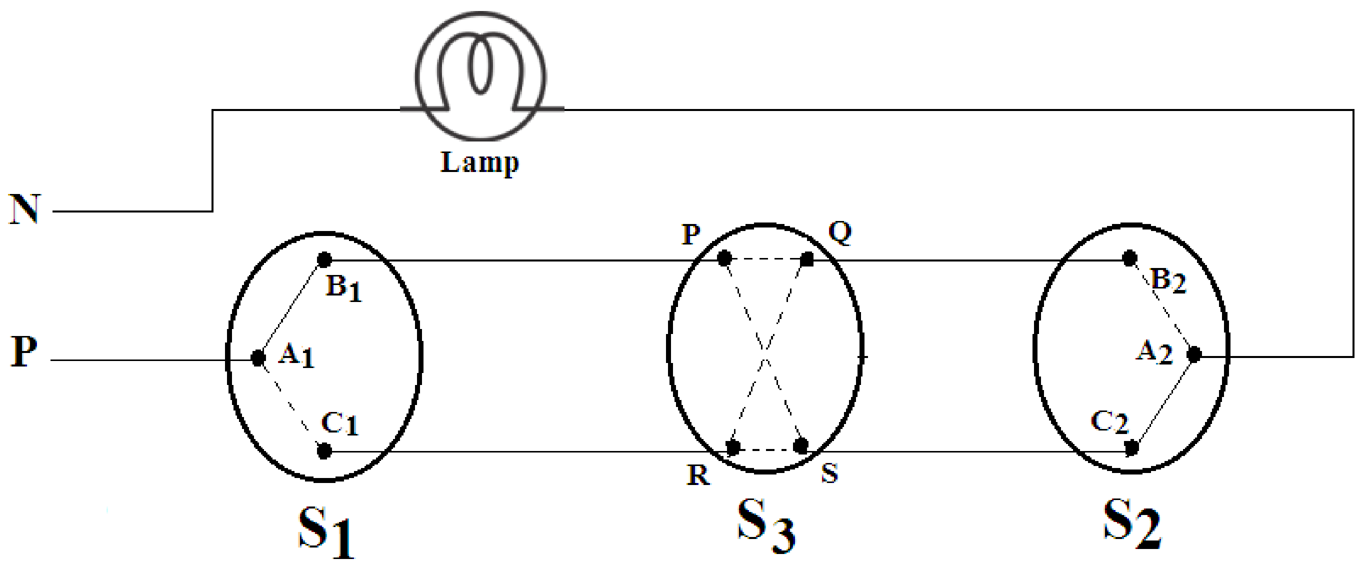
Two way Control of Lamp



Truth Table

Sl. No.	Switch S1	Switch S2	Lamp
1	$A_1 - B_1$	$A_2 - B_2$	ON
2	$A_1 - B_1$	$A_2 - C_2$	OFF
3	$A_1 - C_1$	$A_2 - B_2$	OFF
4	$A_1 - C_1$	$A_2 - C_2$	ON

Three way Control of Lamp



Truth Table

Sl. No.	Switch S1	Intermediate Switch S3	Position of S3	Switch S2	Lamp
1	$A_1 - B_1$	P – S & Q – R	Cross Connection	$A_2 - B_2$	OFF
2	$A_1 - B_1$	P – S & Q – R		$A_2 - C_2$	ON
3	$A_1 - C_1$	P – S & Q – R		$A_2 - B_2$	ON
4	$A_1 - C_1$	P – S & Q – R		$A_2 - C_2$	OFF
5	$A_1 - B_1$	P – Q & R – S	Straight Connection	$A_2 - B_2$	ON
6	$A_1 - B_1$	P – Q & R – S		$A_2 - C_2$	OFF
7	$A_1 - C_1$	P – Q & R – S		$A_2 - B_2$	OFF
8	$A_1 - C_1$	P – Q & R – S		$A_2 - C_2$	ON

Two-Part Electricity Tariff

Total charges = Rs (b x kW + c x kWh)

= Fixed charges + Running charges

Where b= charge per kW of maximum demand

c= charge per kWh of energy consumed