BEE(R-22) SUPPLY SCHEME OF EVALUATION

R22EE104ES   PART-A   I-I

Q1. a. voltage and current relation for capacitance & inductance (1M)

b. Statement of superposition theorem - (1M)

c. Power triangle diagram - (1M)

d. Resonant frequency definition - (1M)

e. Definition of auto transformer - (1M)

f. Types of 3-φ t/f connections - (1M)

g. Function of commutator - (1M)

h. Back emf - (1M)

i. Definition of slip - (1M)

(j) Finding frequency - (1M)

PART-B

2. Assuming direction of currents - (2M)
   Applying KCL at both nodes - (5M)
   Solving the equations and finding answers - (3M)

3. Statement of thevenins theorem - (2M)
   Finding thevenins voltage - (2M)
   Finding thevenins resistance - (2M)
   Drawing equivalent circuit - (2M)
   Finding load current - (2M)

4. (a) Definition and derivation - (4M)

(b) Finding f_r, X_L, X_C, Z - (6M)

5. Behaviour of series RLC circuit
case (i) $X_L > X_C$ (~~loss~~) waveforms, phasor diagrams) - [4M)
case (ii) $X_L < X_C$ [waveforms, phasor diagram - (4M)
case (iii) $X_L = X_C$ [waveforms, phasor diagrams - (2M)

6. (a) Definition of transformer, transformation ratio, KVA rating - (5M)
(b) Explaination - (5M)

7. Problem :-
Finding Cu loss, iron loss - (4M)
Finding η at 3/4 load - (2M)
Finding η at 1/2 load - (2M)
Finding η at 1.25 load - (2M)

8. Construction diagram - (4M)
Explaination of each part - (6M)

9. Characteristics of DC shunt motor - (4M)
" DC series motor - (4M)
" DC compound motor - (2M)

10. Comparison of squirrel cage and slip ring Induction motor - (10M)

11. Torque slip characteristics graph - (4M)
Explaination - (6M)

Basic Electrical Engineering [R-22 supply]

PART- A

Q1. a. Write voltage and current relations for capacitance and inductance.

Ans. Inductor :- $V = L\frac{di}{dt}$, $i = \frac{1}{L}\int V.dt$

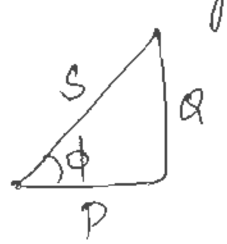
capacitor :- $i = C\frac{dv}{dt}$, $V = \frac{1}{C}\int i\,dt$

b. State Superposition theorem.

Ans. It states that "In any linear bilateral network consisting of n no. of voltage sources, current sources and resistors, the response in any element is equal to the algebraic response of responses when individual sources are acting alone while other sources are made inoperative.

(c) Draw power triangle.

Ans



P = real power

Q = reactive power

S = apparent power

(d) Define resonant frequency.

Ans. The frequency at which resonance occurs is called resonant frequency. (f_r)

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}\ Hz.}$$

(e) What is an autotransformer?

Ans. An autotransformer is a single winding electrical transformer where part of the same coil serves as both primary and secondary winding unlike conventional transformer with separate, isolated winding.

(f) List the three phase transformer connections.

Ans. (i) star - star

(ii) star - delta

(iii) delta - star

(iv) delta - delta

(g) What is the function of commutator in DC generator?

Ans. Commutator acts as mechanical rectifier which converts electrical energy into mechanical energy.

(h) What is back emf?

Ans. Back EMF is a voltage generated in a electric motor that opposes the supply voltage, acting as the self regulating mechanism.

(i) Define slip in 3-ϕ induction motor.

Ans. Slip is the difference between the rotating magnetic field's synchronous speed (N_s) and actual rotor speed (N_r), expressed as a fraction of N_s.

$$\boxed{\%S = \frac{N_s - N}{N_s} \times 100}$$

(j) Find the frequency, if the synchronous speed is 1500 rpm and poles are 4.

Ans.

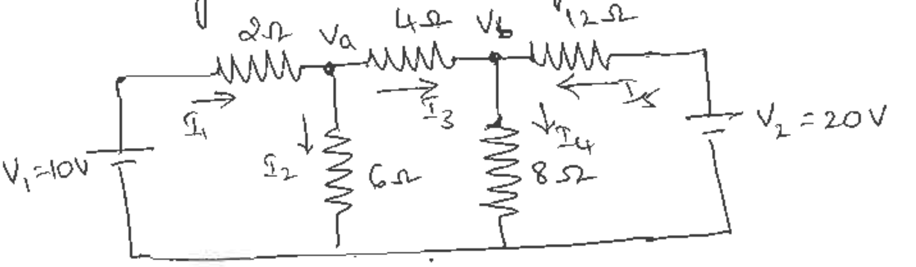
$$N_S = \frac{120 f}{P}$$

$$f = \frac{\overset{50}{\cancel{1500}} \times \cancel{4}}{\underset{\cancel{4}}{\cancel{120}}}$$

$$\boxed{f = 50 Hz}$$

PART-B

2. Find the node voltages V_a and V_b in the given network using nodal Analysis.



$$I_1 = I_2 + I_3$$

$$\frac{10 - V_a}{2} = \frac{V_a}{6} + \frac{V_a - V_b}{4}$$

$$5 = V_a\left[\frac{1}{6} + \frac{1}{4} + \frac{1}{2}\right] - V_b\left[\frac{1}{4}\right]$$

$$5 = V_a[0.16 + 0.25 + 0.5] - 0.25 V_b$$

$$5 = 0.91 V_a - 0.25 V_b \quad \text{---} (1)$$

$$I_3 + I_5 = I_4$$

$$\frac{V_a - V_b}{4} + \frac{20 - V_b}{12} = \frac{V_b}{8}$$

$$V_a\left[\frac{1}{4}\right] - V_b\left[\frac{1}{4}+\frac{1}{12}+\frac{1}{8}\right] = \frac{-20}{12}$$

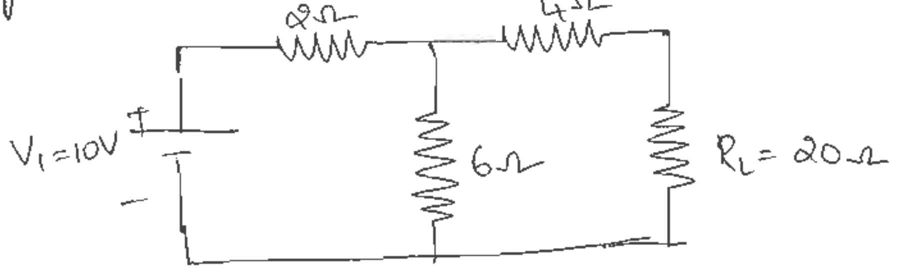
$$0.25V_a - V_b\left[0.25+0.08+0.125\right] = -1.66 \quad \text{②}$$

$$0.25V_a - 0.455V_b = -1.66 \quad \text{—②}$$

solving ① & ②

$$\boxed{V_a = 7.65V, \quad V_b = 7.85V}$$

3. State Thevenins theorem. Find the load current I_L using Thevenins theorem.



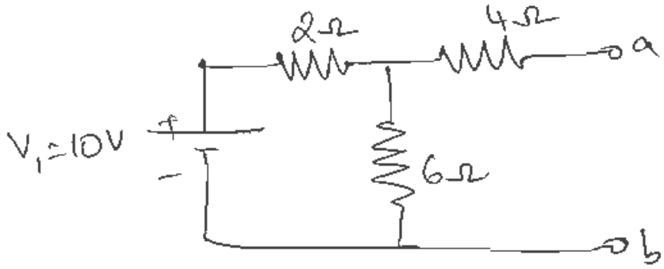
Ans. Thevenins theorem :-

It states that " In any linear bilateral network consisting of 'n' no. of voltage sources, current sources and resistors, can be replaced by a simple equivalent circuit having single voltage source in series with single resistor, where voltage source is called thevenins voltage (V_{th}) and resistance is called thevenins resistance (R_{th}).

$$\boxed{I_L = \frac{V_{th}}{R_{th}+R_L}}$$

Problem :-

Step 1 :- Remove load resistance R_L and open ckt the terminals a and b.



Step 2 :- Find V_{th} b/w (a) & (b)

$$V_{th} = V_{ab} = V_{6\Omega} = 6 \times I_{6\Omega}$$

$$I_{6\Omega} = \frac{V_1}{2+6} \Rightarrow \frac{10}{2+6}$$

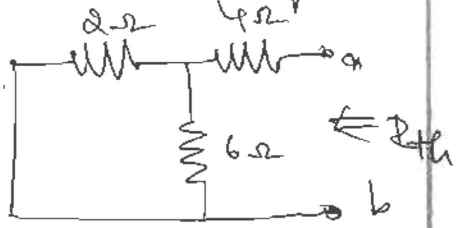
$$I_{6\Omega} = 1.25A.$$

$$V_{th} = 6 \times 1.25 \Rightarrow \boxed{V_{th} = 7.5V}$$

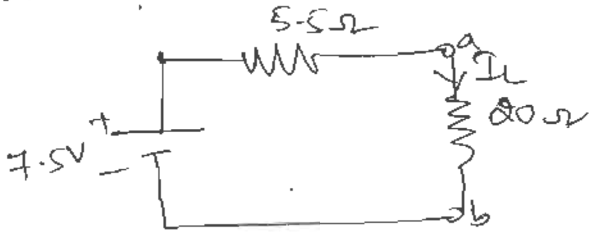
Step 3 :- Find R_{th} b/w a & b short circuiting V_1

$$R_{th} = (2 \parallel 6) + 4$$

$$\boxed{R_{th} = 5.5\Omega}$$



Step 4 :- Draw thevenins eq. ckt and add load resistance R_L b/w a & b.



Step 5 :- Find I_L.

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

$$I_L = \frac{7.5}{5.5 + 20}$$

$$\boxed{I_L = 0.29\ A}$$

Q4. (a) Define resonant frequency and derive the formula for it

Ans. Resonant frequency :-
It is defined as the frequency at which resonance occurs (f_r).

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

At resonance,

$$X_L = X_C$$

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

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

(b) A series RLC network consists of $R = 3\Omega$, $L = 2mH$, $C = 0.4mF$ with the supply frequency of 50Hz. Determine the resonant frequency, inductive reactance, capacitive reactance and impedance.

Sol. Given data :-

$R = 3\Omega$

$L = 2mH = 2\times10^{-3}H$

$C = 0.4mF = 0.4\times10^{-3}F$

$f = 50Hz.$

(i) $f_r = ?$ (ii) $X_L = ?$ (iii) $X_C = ?$ (iv) $Z = ?$

(i) $f_r = \dfrac{1}{2\pi\sqrt{LC}}$

$= \dfrac{1}{2\pi\sqrt{2\times10^{-3}\times 0.4\times10^{-3}}}$

$= \dfrac{1}{0.005617}$

$\boxed{f_r = 178.03 Hz}$

(ii) $X_L = 2\pi fL$

$= 2\times3.14\times50\times2\times10^{-3}$

$\boxed{X_L = 0.628\,\Omega}$

(iii) $X_C = \dfrac{1}{2\pi fC}$

$= \dfrac{1}{2\times3.14\times50\times0.4\times10^{-3}}$

$= \dfrac{1}{0.1256}$

$\boxed{X_C = 7.96\,\Omega}$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

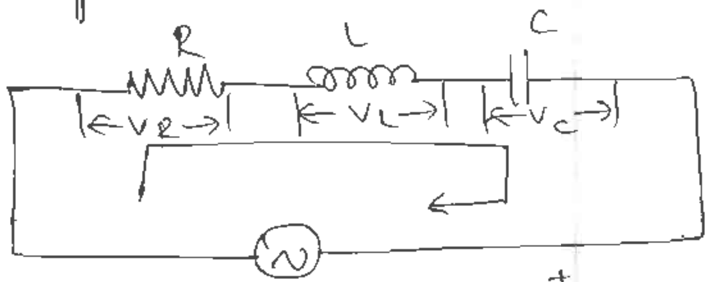
$$Z = \sqrt{3^2 + (0.628 - 7.96)^2}$$

$$Z = \sqrt{53.75}$$

$$\boxed{Z = 7.33\ \Omega}$$

Q5. Explain the behaviour of series RLC circuit excited by a AC supply with relevant waveforms and phasor diagrams.

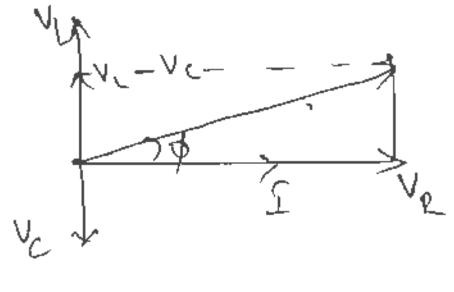
Ans.



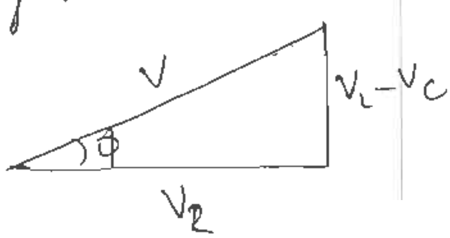
$V = V_m \sin \omega t$

case (i) when $X_L > X_C$, $V_L > V_C$

Phasor diagram:-

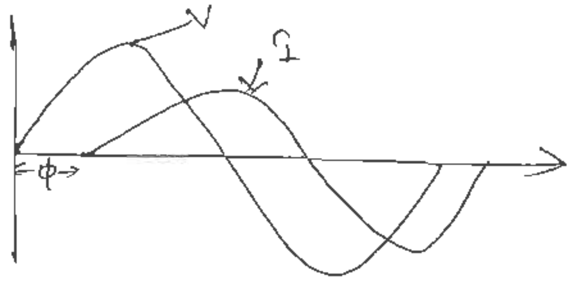


voltage triangle:-



waveform :-

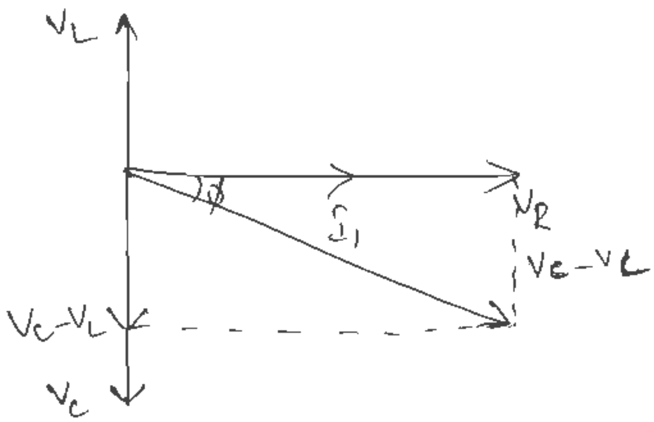
$Z = \sqrt{R^2 + (X_L - X_C)^2}$



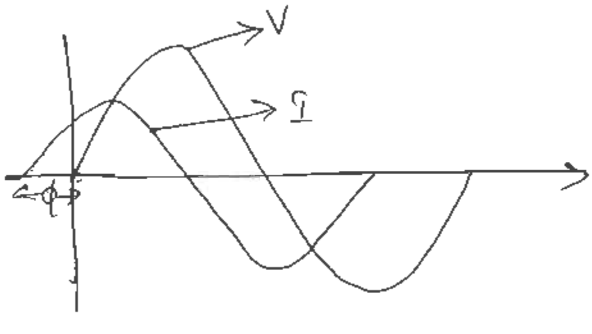
circuit behaves ~~xxx~~ as series RL circuit.

case(ii) :- $X_L < X_C$; $V_L < V_C$

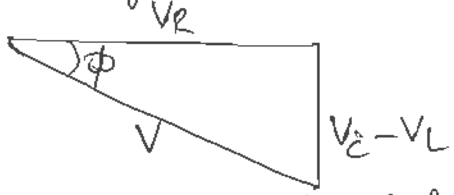
Phasor diagram :-



waveforms :-



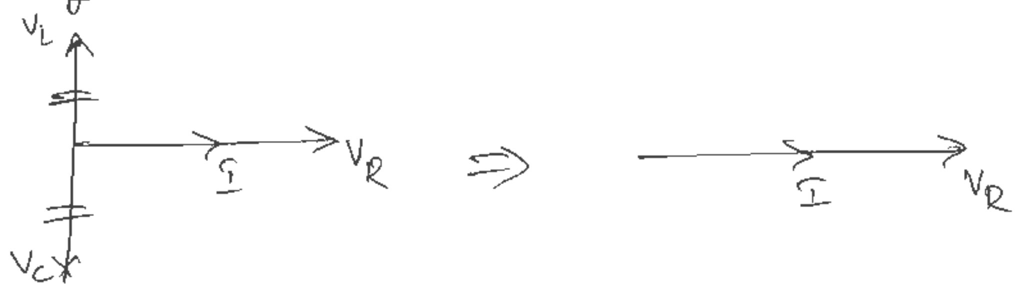
voltage ~~xxx~~ triangle :-



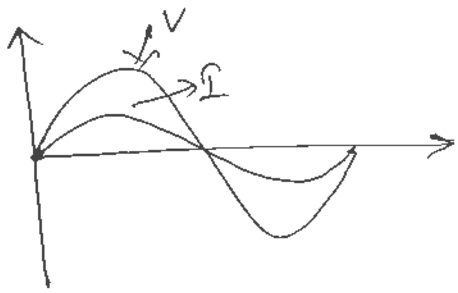
$Z = \sqrt{R^2 + (X_C - X_C)^2}$

~~xxx~~ series RLC circuit behaves as series RC circuit case(iii) $X_L = X_C$, $V_L = V_C$

Phasor diagram :-



waveform :-



$$\boxed{Z = R}$$

series RLC circuits behaves as pure resistive circuit

Q6. (a) Define the following terms :-
(i) Transformer (ii) transformation ratio (iii) KVA ratings.
(b) Why are transformers not working with DC supply.

Ans. (a) (i) Transformer :-
Transformer is a static device which transfers energy from one circuit to another circuit without change in the frequency with the desired change in the voltage and current.

(ii) Transformation ratio :-
It is defined as the output voltage V_2 to the input voltage V_1 or secondary turns N_2 to primary turns N_1

$$\boxed{K = \frac{V_2}{V_1} = \frac{N_2}{N_1}}$$

(iii) KVA ratings :-

KVA rating indicates its maximum apparent power capacity, showing how much total power (real + reactive) it can safely deliver, calculated as voltage × current/1000.

$$\boxed{\text{KVA rating} = \frac{V_1 I_1}{1000} = \frac{V_2 I_2}{1000}}$$

(b) Why are transformers not working with DC supply?

Ans. A transformer doesn't work on DC because it relies on a changing magnetic field (electromagnetic induction) to induce voltage, but DC provides a constant current, creating a steady magnetic field that doesn't induce voltage in the secondary coil and cause the primary winding to draw excessive current, leading to over heating and burnout. Transformers need alternating current (AC) for the flux to vary, enabling power transfer, DC's constant nature stops this process.

Transformer does not work on DC because

- No changing flux
- Zero Back EMF
- Low Resistance, High current
- Overheating & Burnout

Q7. A single phase 25KVA, 1000V/2000V, 50Hz transformer has maximum efficiency of 98% at full load upf. Determine the efficiency at (i) 3/4th full load upf, (ii) 1/2 load 0.8pf (iii) 1.25 full load 0.9pf

sol. Given data :-

KVA rating $= 25 \times 10^3$ VA.

$V_1 = 1000V$

$V_2 = 2000V$

$f = 50Hz$.

$\% \eta = 98\% \Rightarrow 0.98$

pf $\cos\phi = 1$

(i) $\% \eta$ at $n = 3/4$, pf = 1

(ii) $\% \eta$ at $n = 1/2$, pf = 0.8

(iii) $\% \eta$ at $n = 1.25$, pf = 0.9.

(i) $$\eta = \frac{(\text{KVA rating}) \times \cos\phi}{\text{KVA rating} \times \cos\phi + P_i + P_{cu}}$$

$$0.98 = \frac{25 \times 10^3 \times 1}{25 \times 10^3 \times 1 + \text{losses}}$$

$$25 \times 10^3 + \text{losses} = \frac{25 \times 10^3}{0.98}$$

losses = 0.51 kW.

At max η, $P_i = P_{cu} = 0.255$ kW.

(i) 3/4 full load, UPF

$n = 3/4$.

$$\% \eta = \frac{n \cdot (\text{KVA rating}) \times \cos\phi}{n \times \text{KVA rating} \times \cos\phi + P_i + P_{cu}} \times 100$$

$$\% \eta = \frac{0.75 \times 25 \times 1}{0.75 \times 25 \times 1 + 0.255 + (0.75)^2 \times 0.255} \times 100$$

$$\boxed{\% \eta = 97.9\%}$$

(ii) 1/2 load, $n = 1/2$,

$$\% \eta = \frac{1/2 \times 25 \times 0.8}{1/2 \times 25 \times 0.8 + 0.255 + (0.5)^2 0.255} \times 100$$

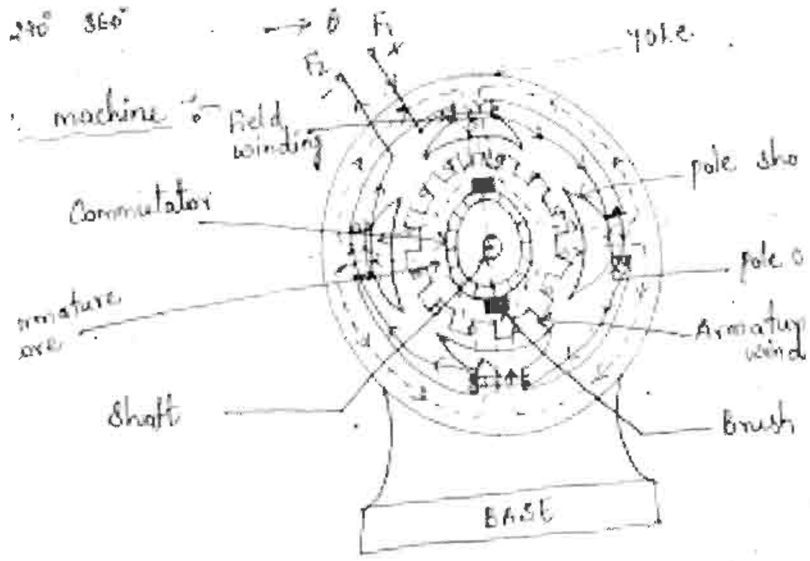
$$\boxed{\% \eta = 96.9\%}$$

(iii) 1.25 fullload, 0.9 pf

$$\% \eta = \frac{1.25 \times 25 \times 0.9}{1.25 \times 25 \times 0.9 + 0.255 + (1.25)^2 0.255} \times 100$$

$$\boxed{\% \eta = 97.7\%}$$

Q8. Briefly explain the constructional details of a DC machine



→ A DC generator has the following parts
1. yoke
2. poles
3. Field winding
4. Armature
5. Commutator
6. Brushes.
7. Bearing.

① yoke :- It is outer frame of DC Generator

Functions :-
→ It provides mechanical support to the poles.
→ It provides a path of low reluctance for magnetic flux.
→ It serves of outermost cover of d.c machine.

choice of material :
It is made up of cast iron for small machines. For large machines it is made up of cast steel.

② poles :-
Each pole is divided into two parts (i) pole core (ii) pole shoe.

Functions :-
→ pole core carries a field winding which is necessary to produce flux.
→ pole shoes spread out the magnetic flux uniformly in the airgap and reduce the reluctance of the magnetic path.

choice of material :
It is made up of cast iron or cast steel. The pole shoe is always laminated to avoid Eddy current loss.

(3) Field winding :-

The field winding is wound on the pole core.

Functions :-

It helps in producing the magnetic flux i.e. Exciting the pole as an Electromagnet. It is also called as Exciting

Choice of material : Copper or Aluminium.

(4) Armature :-

It is further divided into two parts (i) Armature core

(ii) Armature winding

(i) Armature core :-

Armature core is cylindrical in shape mounted on the shaft. It is build up of circular laminated sheet. It consis of slots on its periphery.

Functions :-

→ The purpose of armature core is to hold the armature winding.

→ provides low reluctance path to magnetic flux.

Choice of Material :-

It is assembled from steel laminations having a in order to reduce Eddy current losses, the laminations are insulated from each other

(ii) Armature winding :-

Armature winding is nothing but the interconnection of armature conductors, placed in the slots provided on the armatu core.

Functions :-

→ Generation of emf takes place in the armature winding in case of generators.

→ To carry the current supplied in case of d.c motors.

Choice of material :-

It is made up of conducting material, which is copper.

⑤ Commutator :-

The nature of emf induced in the armature conductors is alternating. The function of the commutator is to convert the ac voltages induced in the armature conductors to dc voltage in the external circuit in generator operation, whereas in dc motors it produces unidirectional torque.

choice of material :-

As it collects current from armature, it is also made up of copper segments. It is made up of high conductivity hard drawn copper.

⑥ Brushes :-

The rotating armature and external circuit are connected through brushes.

Function :

Brushes are employed to collect current from the commutator and deliver it to the load.

choice of material :-

These are rectangular and are made of carbon, carbon graphite.

Q.9. Draw the torque speed and torque armature characteristics of DC shunt, series and compound motor.

D.C Motor characteristics :-

(i) Torque - Armature current characteristics (T Vs Ia):

The graph showing the relationship between the torque and the armature current is called a torque - armature current characteristic. These are also called electrical characteristics.

(ii) Speed - Armature current characteristics (N Vs Ia) :

The graph showing the relationship between the speed and armature current characteristics.

(iii) Speed - Torque characteristics (N Vs T) :

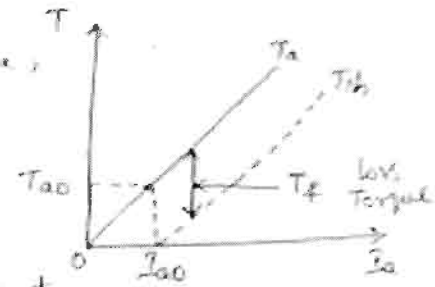
The graph showing the relationship between the speed and the torque of the motor is called speed - torque characteristics of the motor. These are also called mechanical characteristics.

→ characteristics of D.C Shunt Motor :-

(i) Torque - Armature current characteristics :

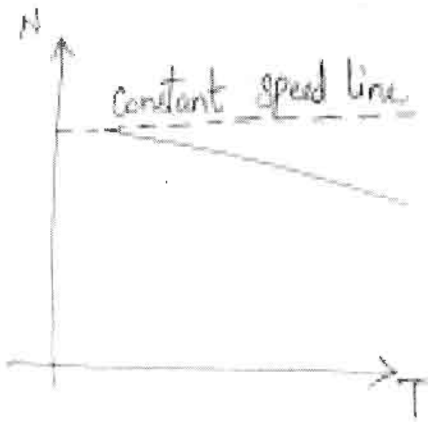
(for a d.c motor $T \propto \phi I_a$
For a constant values of R_{sh} and supply voltage V, I_{sh} is also constant and hence flux is also constant

$\boxed{T_a \propto I_a}$



The equation represents a straight line, passing through the origin, as shown. As load increases, armature current increases, increasing the torque developed linearly)
Now if shaft torque is plotted against armature current, it is known that shaft torque is less than the armature torque and the difference between the two is loss torque T_f as shown.
On no load $T_{sh} = 0$ but armature torque is present which is just enough to overcome stray losses shown as T_{ao}. The current required is I_{ao} on no load to produce T_{ao} and hence T_{sh} graph has an intercept of I_{ao} on the current axis.
To generate high starting torque, this type of motor requires a large value of armature current at start. This may damage the motor hence d.c shunt motors can develop moderate starting torque and hence suitable for such applications where starting torque requirement is moderate.

(iii) Speed - Torque characteristics :-



These characteristics can be derived from above two characteristics. This graph is similar to speed - armature current characteristics as torque is proportional to the armature current. This curve shows that the speed almost remains constant through torque changes from no load to full load conditions.

Characteristics of D.C Series Motor :-

(i) Torque – Armature current characteristics :-

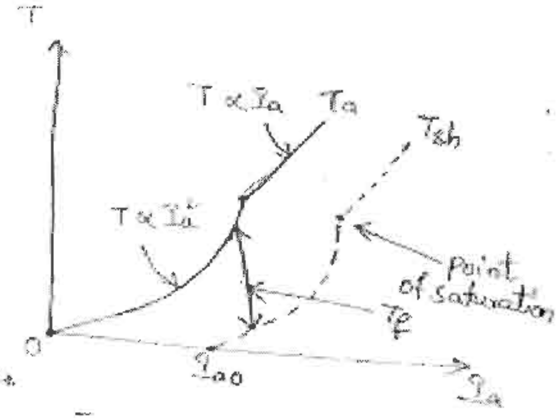
In case of series motor the series field winding is carrying the Entire armature current. So flux produced is proportional to the armature current

$$\therefore \phi \propto I_a$$

Hence $\boxed{T_a \propto \phi I_a \propto I_a^2}$

Thus torque in case of series motor is proportional to the square of the armature current. (This relation is parabolic in nature as shown.)

As load increases, armature current increases and torque produced increases.

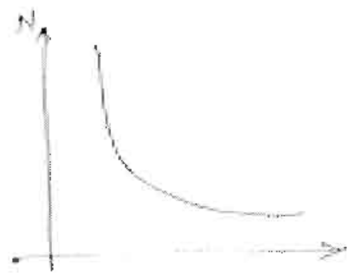


(iii) Speed – Torque characteristics :-

In case of series motors,

$T \propto I_a^2$ and $N \propto \frac{1}{I_a}$

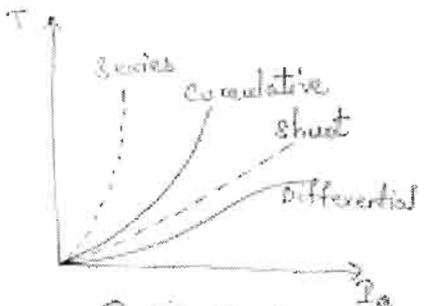
Hence we can write, $\boxed{N \propto \frac{1}{\sqrt{T}}}$



Thus as torque increases when load increases, the speed decreases. On no load, torque is very less and hence speed increases to dangerously high value. Thus the nature of the speed – torque characteristics is similar to the nature of the speed – armature current characteristics.

→ Characteristics of D.C Compound Motor :-

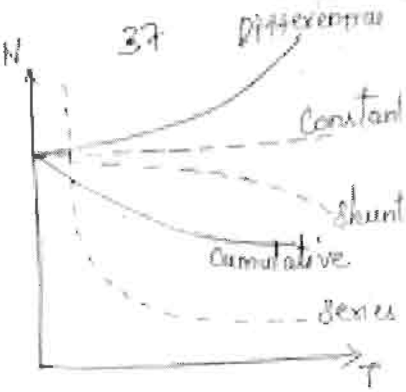
Compound motor characteristics basically depends on the fact whether the motor is Cumulatively compound or differential compound. All the characteristics of the compound motor are the combination of the shunt and series characteristics.



(i) T Vs I_a

Cumulative compound motor is capable of developing large amount of torque at

So cumulative compound motor can run at a reasonable speed and will not run with dangerously high speed like series motor, on light or no load condition.



(c) N Vs T

In differential compound motor, as two fluxes oppose each other, the resultant flux decreases as load increases, thus the machine runs at a higher speed with increase in the load. This property is dangerous as on full load, the motor may try to run with dangerously high speed. So differential compound motor is generally not used in practice.

The various characteristics of both the types of compound motors cumulative and the differential as shown in fig. (a), (b) and (c)

Q10. Compare squirrel cage and slip ring Induction motor.

COMPARISON OF SQUIRREL CAGE AND WOUND ROTOR

WOUND (OR) SLIP RING ROTOR	SQUIRREL CAGE ROTOR
1. Rotor consists of a three phase winding similar to stator winding	1. Rotor consists of bars which are shorted at the ends with the help of end rings
2. Construction is complicated	2. Construction is very simple
3. Resistance can be added externally	3. As permanently shorted, external resistance cannot be added
4. Slip rings and brushes are present to add external resistance	4. Slip rings and brushes are absent
5. The construction is delicate and due to brushes, frequent maintenance is necessary	5. The construction is robust and maintenance free
6. The rotors are very costly.	6. Due to simple construction, the rotors are cheap.
7. Only 5% of induction motors in industry use slip ring rotor.	7. Very common almost 95% induction motors are this type of rotor
8. High starting torque can be obtained	8. Moderate starting torque which cannot be controlled.
9. Rotor resistance starter can be used	9. Rotor resistance starter cannot be used
10. Rotor must be wound for the same number of poles as stator	10. The rotor automatically adjusts itself for same number of poles as stator.
11. Speed control by rotor resistance is possible.	11. Speed control by rotor resistance is not possible.
12. Rotor copper losses are high hence efficiency is less.	12. Rotor copper losses are less hence have higher efficiency
13. Used for lifts, hoists, cranes, elevators, compressors etc.	13. Used for lathes, drilling machines, fans, blowers, water pumps, grinders, printing machines etc.

Q11. Explain torque slip characteristics of three phase Induction motor with neat sketch.

TORQUE - SLIP CHARACTERISTICS :

As induction motor is loaded from no load to full load, its speed decreases hence slip increases. Due to the increased load, motor has to produce more torque to satisfy load demand. T depends on slip. The behaviour of motor can be judged by plotting curve on which torque produced against slip.

The curve obtained by plotting torque against slip from s = 1 (at start) to s = 0 (at synchronous speed) is called torque slip characteristics.

$$T \propto \frac{s R_2}{R_2^2 + (s X_2)^2}$$ [E_2 is constant as supply voltage const

To judge the torque-slip char, slip range is divided into two parts and analyse independently.

(i) LOW SLIP REGION :-

In this region, s is small so $(sX_2)^2$ is small compared to R_2^2 that can be neglected.

$$T \propto \frac{s R_2}{R_2^2} \propto s \Rightarrow \boxed{T \propto s}$$

So as load ↑, N ↓, s ↑. This increases torque which satisfies load demand. Hence graph is straight line in nature.

At $N = N_s$, s = 0 hence T = 0, as no torque is generated at $N = N_s$, motor stops if it tries to achieve N_s.

∴ Torque increases linearly in this region.

(ii) HIGH SLIP REGION :-

In this region slip is high i.e slip approaches to 1. Here R_2^2 is small as compared to $(s X_2)^2$. Hence neglecting R_2^2, we get

$$T \propto \frac{s R_2}{(sX_2)^2} \propto \frac{1}{s} \Rightarrow \boxed{T \propto \frac{1}{s}}$$

As T is inversely proportional to s, nature is like rectangular hyperbola.

Now when load ↑, load demand ↑ but N ↓, s ↑.

As $T \propto \frac{1}{s}$, T ↓ as s ↑. But torque must increase to satisfy load demand.

As T ↓ as loading effect, N ↓ further, s ↑, again T ↓

as $T \propto \frac{1}{s}$, hence same load acts as an extra load due to reduction in torque produced. Hence speed further drops to standstill condition.

Eventually motor comes to standstill at any point in the motor cannot continue to rotate at any point in this high slip region called unstable region of operation.

So torque slip characteristics has two parts.

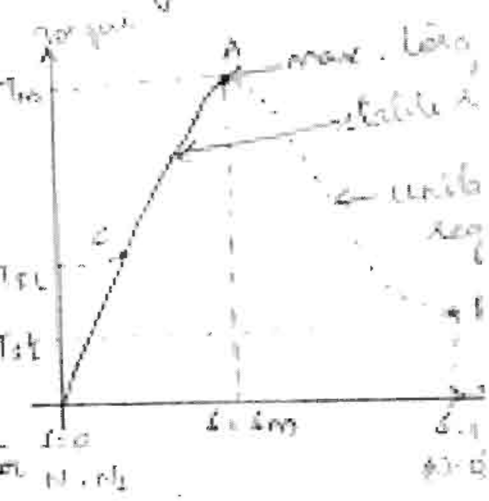
1. Straight line called stable region of operation.

2. Rectangular hyperbola called unstable region of operation.

In low slip region, s ↑, T ↑ linearly.

Every motor has its own limit to produce a torque. The max torque, the motor can produce as load increases is T_m which occurs at $s = s_m$. So linear behaviour continues till $s = s_m$. T ↑

If load is increased beyond the limit, motor slip acts dominantly pushing motor into high slip region. Due to unstable cond^n, motor comes to standstill cond^n at such a load.



OA - stable region

AB - unstable

B = standstill

A = max. torque

C = full load