BEE MODULE 3

PART A

@ Abhirami

1) State the principle of DC generator.

A) A DC generator operates on the principle of Faraday's laws of electromagnetic induction.
According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor.

---

2) List out the rotating parts and stationary parts in DC machine.

A) A DC machine is made out of two essential parts, one stationary and one rotating part. The parts are listed below:

- Stator
- Rotor
- Armature Windings
- Yoke
- Poles
- Pole Shoe
- Commutator
- Brushes

---

3) Explain why electro magnets are preferred over permanent magnets in large DC machines?

A) The main reason why an electromagnet is preferred over a permanent magnet is that the magnetic field can be quickly changed by controlling the amount of electric current in the winding. However, unlike a permanent magnet that needs no power, an electromagnet requires a continuous supply of current to maintain the magnetic field.

---

4) Explain why the armature core of a DC machine is laminated

A) To minimize the eddy current loss we increases the resistance in the path of eddy current by laminating it.

---

5) List out the different types of DC generators and write its applications

A)

2.6 Types of DC Generators:

DC generators can be classified in two main categories, viz; (i) Separately excited and (ii) Self-excited.

(i) Separately excited: In this type, field coils are energized from an independent externalDC source.

(ii) **Selfexcited:** In this type, field coils are energized from the current produced by thegenerator itself. Initial emf generation is due to residual magnetism in field poles. The generated emf causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing emf generation. Self excited dc generators can further be divided into three types

(a) Series wound - field Winding in series with armature winding

(b) Shunt wound - field Winding in parallel with armature winding

(c) Compound wound - combination of series and shunt winding

---

6) Write the EMF equation of a DC generator.

A)
$$E_g = \frac{P\Phi NZ}{60\,A}$$

P = number of field poles, ∅ = flux produced per pole in Wb (weber)

Z = total no. of armature conductors, A = no. of parallel paths in armature

N = rotational speed of armature in revolutions per min. (rpm)

Case – 1

Simple lap winding A=P

$$E_g = \frac{P\Phi NZ}{60\,P}$$

Case – 2

Simple wave winding P=2

$$E_g = \frac{P\Phi NZ}{120}$$

---

7) Classify the different types of DC generators

2.6 Types of DC Generators:

DC generators can be classified in two main categories, viz; (i) Separately excited and (ii) Self-excited.

(i) Separately excited: In this type, field coils are energized from an independent externalDC source.

(ii) **Selfexcited:** In this type, field coils are energized from the current produced by thegenerator itself. Initial emf generation is due to residual magnetism in field poles. The generated emf causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing emf generation. Self excited dc generators can further be divided into three types

(a) Series wound - field Winding in series with armature winding

(b) Shunt wound - field Winding in parallel with armature winding

(c) Compound wound - combination of series and shunt winding

---

8) Differentiate DC motor from a DC generator.

A)DC motor converts electrical energy into mechanical energy

DC generator converts mechanical energy into an electrical energy.

---

9) Define the principle of operation of DC motor.

A) A motor is an electrical machine which converts electrical energy into mechanical energy. The principle of working of a DC motor is that "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". It also uses Flemings Left Hand rule.

$$F = BIL$$

B = magnetic flux density

I = current and L = length

---

10) Explain why the EMF generated in the armature of a DC motor is called the back EMF?

A) When the armature of a DC motor rotates under the influence of the driving torque, emf is induced in them as in a generator. The induced emf acts in opposite direction to the applied voltage V (Lenz's law) and is known as Back EMF or Counter EMF (Eb).

---

11) Write the expression for torque produced in DC motor

A) Torque is given by the product of the force and the radius at which this force acts

$$T = F \times r$$

Units N/m

where, F = force

r = radius of the armature

---

12) List out the different types of DC motors.

A) DC motors are usually classified of the basis of their excitation configuration, as follows

a)Separately excited (field winding is fed by external source)

b) Self excited

- Series wound (field winding is connected in series with the armature)
- Shunt wound (field winding is connected in parallel with the armature)
- Compound wound
- Long shunt
- Short shunt

---

13) State the condition for maximum power developed in DC motor

A) The condition for maximum power in case of D.C. motor is

Supply voltage =1/2 × back e.m.f.

---

14) Describe why a series motor should not be run without load.

A) A series motor should never be started at no load. With no mechanical load on the series motor, the current is low, the back-EMF produced by the field winding is weak, and so the armature must turn faster to produce sufficient back-EMF to balance the supply voltage. The motor can be damaged by overspeed.

---

15) List out the different types of losses occurred in DC motors.

A)

a.Copper losses

b.Loss due to brush contact resistance

c.Iron Losses

d.Hysteresis loss

e.Eddy current loss

f.Friction loss

----

16) Define hysteresis and eddy current losses.

A)

HYSTERESIS LOSS:

The loss which occurs because of the reversal of the magnetising force is known as the hysteresis loss.

EDDY CURRENT LOSS:

The eddy current loss occurs because of the interaction of magnetic field and conductor. Eddy current losses are the result of Farady's law.

----

17) Describe how the eddy current and hysteresis losses be minimized

A) The eddy current loss is minimised by using the thin core of lamination. The silicon steel material is used for minimising the hysteresis loss.

----

18) Describe about core losses and copper losses in DC machines.

A) CORE LOSSES:

As iron core of the armature is rotating in magnetic field, some losses occurs in the core which is called core losses.

Core losses are of 2 types:

- Hysteresis losses
- Eddy current loss

COPPER LOSSES:

These losses occur in armature and field copper windings

Copper losses are of 3 types:

- Armature copper loss
- Field copper loss
- loss due to brush contact resistance.

---

19) Define the speed regulation for a DC motor.

A)Speed Regulation of a DC Motor:

The speed regulation is defined as the change in speed from no load to full load, A motor which has nearly constant speed has good speed regulation.

$$\text{Per Unit Speed Regulation} = \frac{N_{nl} - N_{fl}}{N_{fl}}$$

$$\text{Per Unit Speed Regulation} = \frac{N_{nl} - N_{fl}}{N_{fl}} \times 100$$

Where,

- N_{nl} is the no-load speed
- N_{fl} is the full load speed

---

20) Explain the back EMF of DC motor.

A) As the armature rotates, a voltage is generated in its coils. In the case of a motor, the emf of rotation is known as Back emf or Counter emf

FORMULA:

$$E_b = \frac{P\Phi NZ}{60\,A}$$

- **P** – number of poles of the machine
- **ϕ** – Flux per pole in Weber.
- **Z** – Total number of armature conductors.
- **N** – Speed of armature in revolution per minute (r.p.m).
- **A** – number of parallel paths in the armature winding.

8.3.2021

Module - III

Part-A

11. write the expression for torque produced in DC motor.

Ans:

$$T_a = \left(\frac{PZ}{2\pi A}\right) \times \phi I_A \ (N\text{-}M)$$

$$T_a = 0.159\, \phi I_a \left(\frac{PZ}{A}\right)$$

P = no. of poles
Z = no. of Conductors
A = no. of parallel paths
I_a = armature current
ϕ = flux per pole.

12. List out the different types of DC motors.

Ans: (i) Series DC Motors ; In a series DC motor, the field is wound with a few turns of a large wire carrying the full armature current.

(ii) Shunt DC Motors; In shunt DC motors the field is connected in parallel (shunt) with the armature windings.

(iii) Compound DC Motors: Compound DC motors, like shunt DC motors, have a separately excited shunt field.

13. State the condition for maximum power developed in DC motor.

Ans: The condition for maximum power in DC motor is

Back. emf = ½ × supply voltage

The motor will deliver max power when the back EMF is equal to half of the applied armature voltage.

$$\boxed{E_b = \frac{V_b}{2}}$$

14. Describe why a series motor should not be run without load.

Ans: A series motor should never be started at no load. With no mechanical load on the series motor, the current is low, the Counter-EMF produced by the field winding is weak, and so the armature must turn faster to produce sufficient Counter-EMF to balance the supply voltage. The motor can be damaged by overspeed.

15. List out the different types of losses occurred in Dc motors.

Ans:

Losses in a Dc machine
- Copper losses
  - Armature Copper loss
  - Shunt field Copper loss
  - Series field Copper loss
- Iron losses
  - Hysteresis loss
  - Eddy Current loss
- Mechanical losses
  - Friction loss
  - windage loss

16. Define hysteresis and eddy current losses.

Ans: The losses which occur because of the reversal of the magnetism is known as the hysteresis loss.

The loss occur because of the relative motion between the core and the magnetic flux is known as eddy current loss.

17. Describe how the eddy current and hysteresis losses be minimized.

Ans: Minimising methods :-

(i) Eddy current loss : By making the core of thin lamination.

(ii) Hysteresis loss ; By using silicon steel material.

18. Describe about core losses and copper losses in DC machines

Ans: Core losses or Iron losses in dc machine :-

The core losses are the hysteresis and eddy current losses. These losses are considered almost constant as the machines are usually operated at constant flux density and

Constant Speed. These losses are about 20 percent of the full load losses.

Copper losses in dc machine:

These losses are also known as winding losses as the Copper loss occur because of the resistance of the windings.

$\boxed{\text{Armature Copper losses} = I_a^2 R_a}$ where I_a is armature Current, and R_a is the armature resistance. These losses are about 30 percent of the total full load losses.

9. Define the speed regulation for a DC motor.

Ans: The speed regulation of a DC motor is defined as the change in speed from no load to full load. It is expressed as a fraction or a percentage of the full load speed.

$$\text{Speed regulation} = \frac{N_{nl} - N_{fl}}{N_{fl}}$$

N_{nl} = noload speed $\quad N_{fl}$ = full load speed.

20. Explain the back EMF of DC motor.

Ans: The coil of a DC motor is represented as a resistor in this Schematic. The back emf is represented as a variable emf that opposes the one driving the motor. Back emf is zero when the motor is not turning, and it increases Proportionally to the motor's angular velocity.

Part-B

(1.)

Principle (working principle): the working principle of ~~dc-mac~~ ~~dc-m~~ ~~are~~ ~~of~~ ~~two~~ dc-motors are whenever an electric current passes through the coils of the magnet. the magnetic power produces and which develops the torque ~~to~~ which makes the Armature to rotate. ~~And for~~ ~~dc generators.~~ 'And the principle of dc-generators are when the Armature is placed in dynamically induced electromagnetic force. when a conductor is placed in carrying magnetic field. the Armature rotates and which produces required EMF.

Construction:

~~the construction of dc machine needs tell as are follows~~

~~so~~ In the dc machine for construction the parts are majorly divided into two types:

(a) stator (b) rotor.

(a) stator: the parts which will be in ~~are~~ stationary. while the dc-machine is working

(i) YOKE

(ii) poles

(iii) pole shoes

(iv) pole winding

(v) Brushes

(vi)

(b) Rotor: the parts which rotate when the dc-machine is working

(i) Armature
(ii) Armature winding
(iii) commutator

a(i) yoke: It is a hard metal substance which is the outer most part and it's main aim is to protect the machine from external condn's and to produce low reluctance path.

a(ii) Pole and pole shoes: They are attached to the yoke with the help of bolts and then to them pole shoes are fastened. and poles are the one which carry feild windings. And pole shoes are attached to the poles to increase the magnetic field area.

a(iii) Field winding: these are made of copper and they are coiled to the poles. ~~these main aim as~~ when electric current passes through them these gets converted into North and south poles.

a(iv) Brushes: these are usually made of carbon/or graphite these will be in contact with commutator to collect the electricity (or) to supply the electricity.

b(i) Armature core:

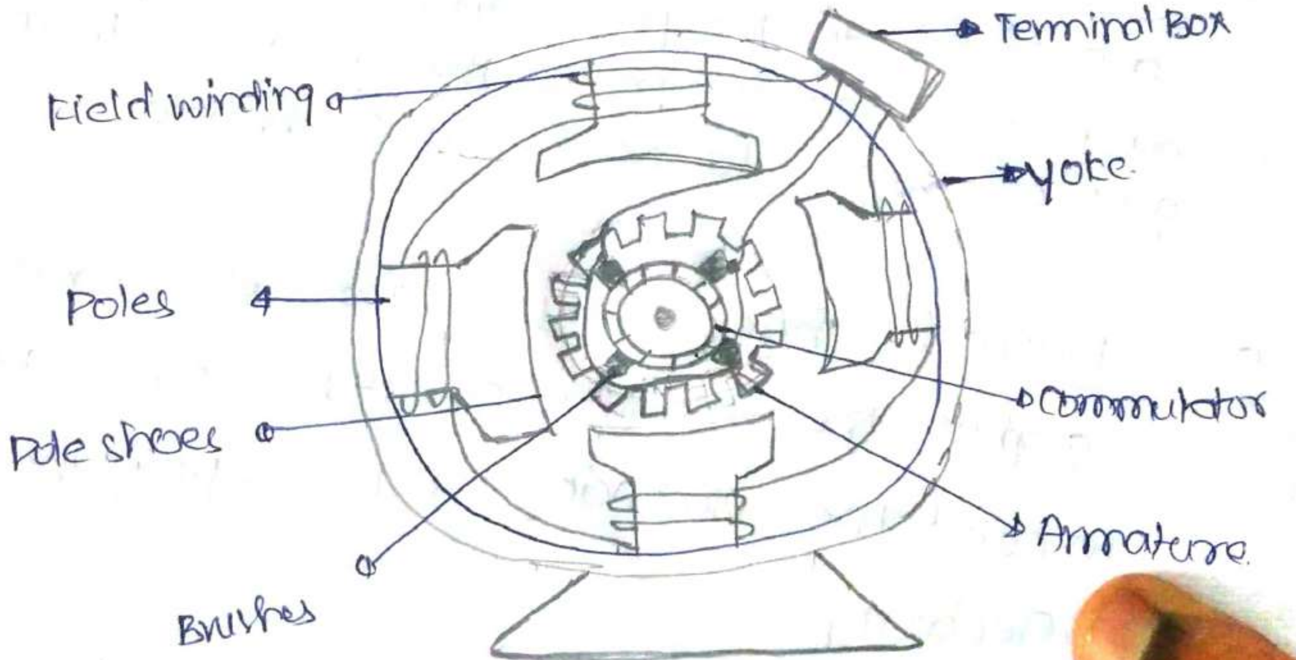
It is the rotor of the machine and this is usually in cylindrical shape and provided with slots for Armature winding.. These are usually made up of laminated circular steel sheet to prevent Eddy current losses

b(ii) Armature winding

These are usually made of copper these provide the connection b/w commutator and Armature.

b(iii) Commutator:

Actually, the arrangement in the dc machine will be as commutator and brush-arrangement its main aim is to collect all the electric current and pass to brushes in case of generator. And in case of motor is to collect all the electric current from brushes and to provide them to Armature core via Armature winding



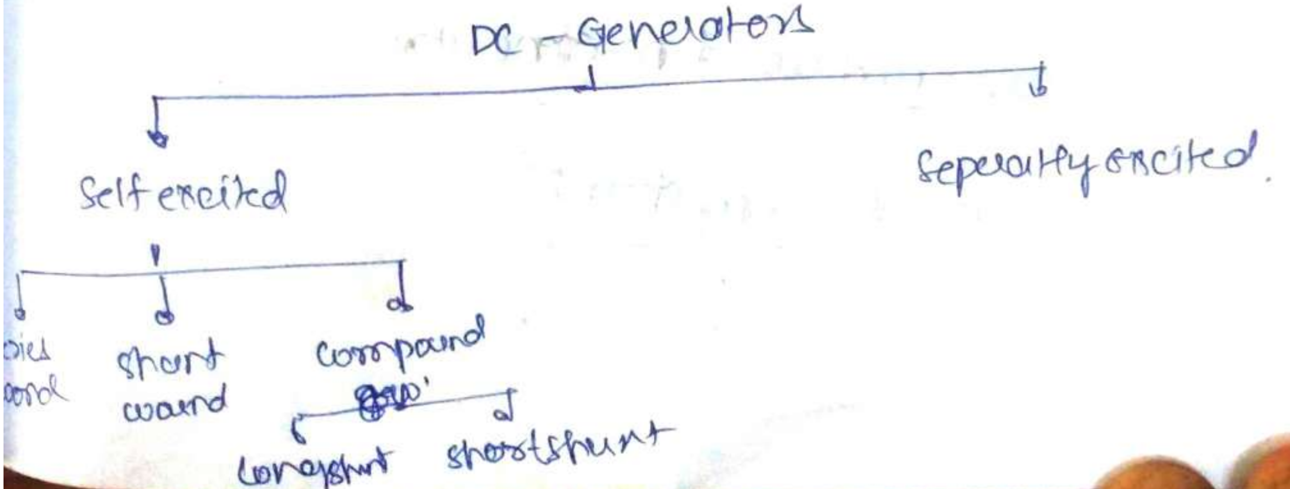
(2B)
Working principle:
DC generators work on the principle of dynamically induced electromagnetic force. According to this when a conductor is placed in a varrying magnetic field it rotates and ~~produces~~ ~~some~~ generate emf.

Derivation of emf eqn of DC-generator:

* Flux produced by one conductor $(d\phi) = \phi \times P$
* Time take by a conductor to complete one revolution $= 60/N$
* so emf induced in one conductor $= \frac{d\phi}{dt} = \frac{\phi \times P}{\left(\frac{60}{N}\right)}$
* so for the total conductor $= \frac{N \times \phi \times P}{60} \times \frac{Z}{A}$

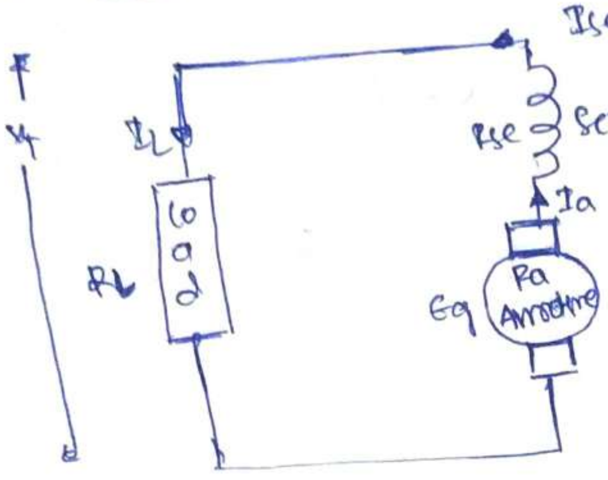
(3) classify and explain the different types of DC Generators with neat circuit diagrams

(A) Types of DC-Generator



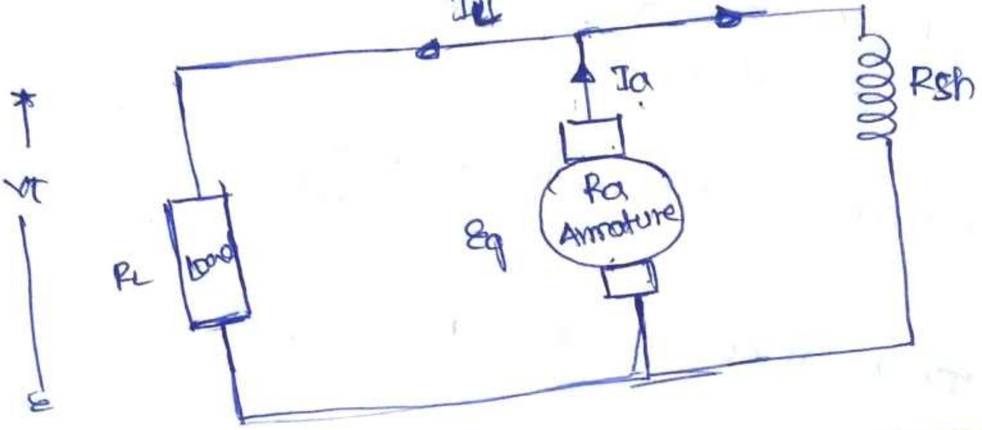
(a) self excited DC generators

a(1) series wound DC-generator:



$$\boxed{E_g - I_a R_a - I_{se} R_{se} = V_T}$$

a(2) shunt wound DC-generator:



$$\boxed{E_g - I_a R_a = V_T}$$

$$\boxed{P_{produced} = E_g \cdot I}$$

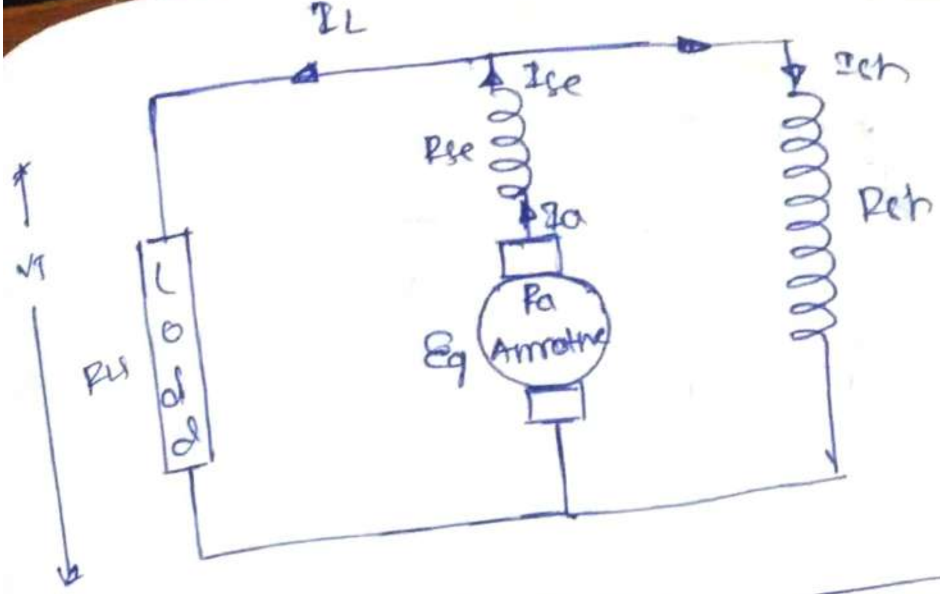
$I_a = I_L + I_{sh}$

$$\boxed{P_{delivered} = V_T I}$$

$$\boxed{I_{sh} = \frac{V_T}{R_{sh}}}$$

a(3) compound wound DC-Generator:

a.3.1 long shunt:



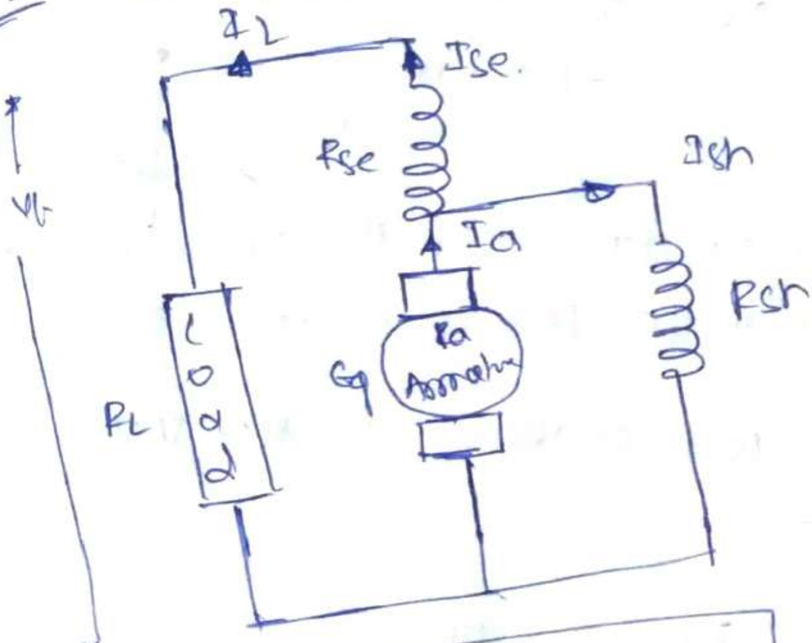
$$\boxed{V_T = E_g - I_a R_a - I_{se} R_{se}}$$

$$\boxed{I_a = I_{se}}$$

$$\boxed{I_a = I_L + I_{sh}}$$

$$\boxed{I_{sh} = \frac{V_T}{R_{sh}}}$$

a.3.2 Short-shunt



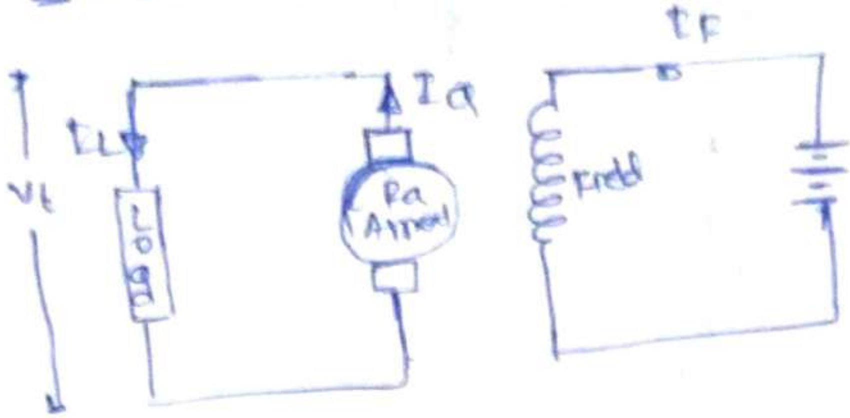
$$\boxed{V_T = E_g - I_a R_a - I_{se} R_{se}}$$

$$\boxed{I_{se} = I_L}$$

$$\boxed{I_a = I_{sh} + I_{se}}$$

$$\boxed{I_{sh} = \frac{V_T}{R_{sh}}}$$

(b) Separately excited



$$\boxed{V_t = E_g - I_a R_a}$$

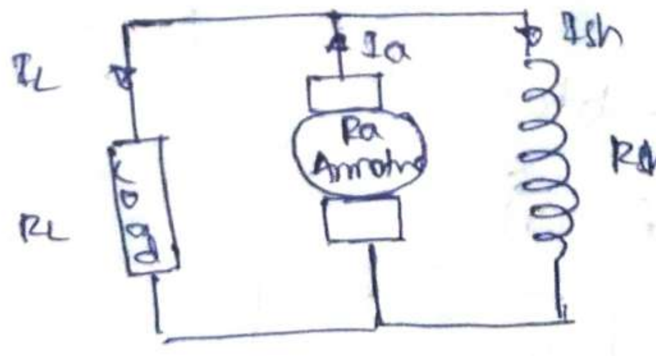
$$\boxed{I = I_L = I_a}$$

(4A)
the process of voltage build up in self-excited Dc generators are as follows :-

(i) we know that according Magnetic Hysteresis loop there will be some residual magnetic flux will present in Dc-machine system.

(ii) voltage build up depends on the presence of a residual flux in the pole of the generator.

(iii) For example let's consider a shunt wound Dc-generator



and initially due to the presence of residual flux the emf gets induced

$$\boxed{E_{a\,res} = K\phi_{res}\omega}$$

v) So, As 'E_a' gets induced then $I_{sh} = \frac{E_a}{R_{sh}}$ (I_{sh} gets increased)

vi) then due to the flux get's increased.

vii) And then due to increase in flux the 'E_a' get increased as we know that ($E_a = K\phi\omega$)

(viii) And due to this 'V_T' get increased

(ix) And due to increase in 'V_T' $\left(I_{sh} = \frac{V_T}{R_{sh}}\right)$ 'I_{sh}' gets increased

(x) As we know that '$I_{sh} \propto \phi$' due to this the flux again get increased.

(xi) this process continues till the flux reaches the saturation point

Conditions for self excitation:

(i) there should be some residual magnetic should present in the system

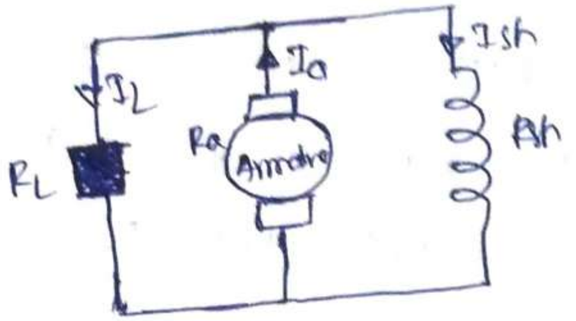
(ii) And the residual magnetic flux should be in right direction.

~~(5) Voltage build up~~

~~same as last answer~~

~~separately excited~~

(6)
characteristics of DC-shunt generator:



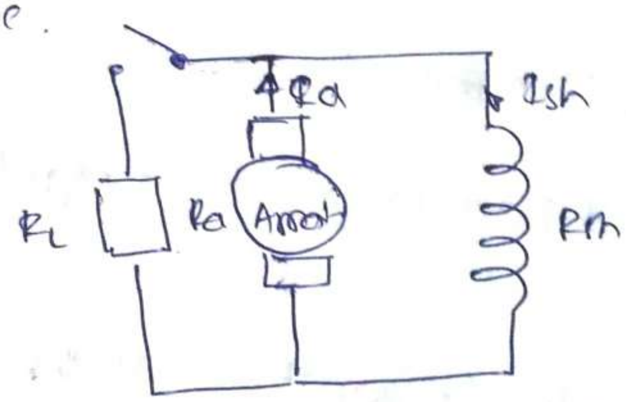
(i) Magnetic characteristics. (E_0 vs I_{sh})

(ii) Internal characteristic (E_g vs I_L)

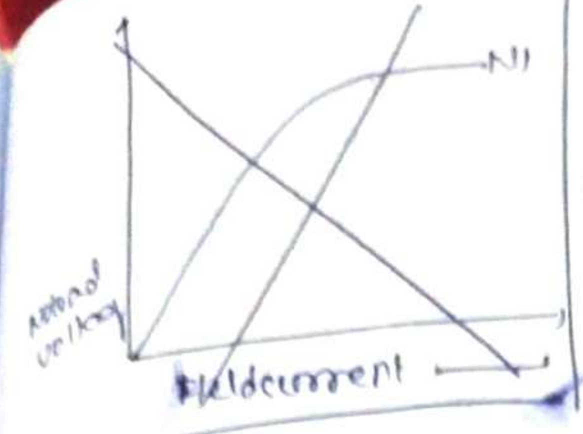
(iii) External characteristics (V_t vs I_L)

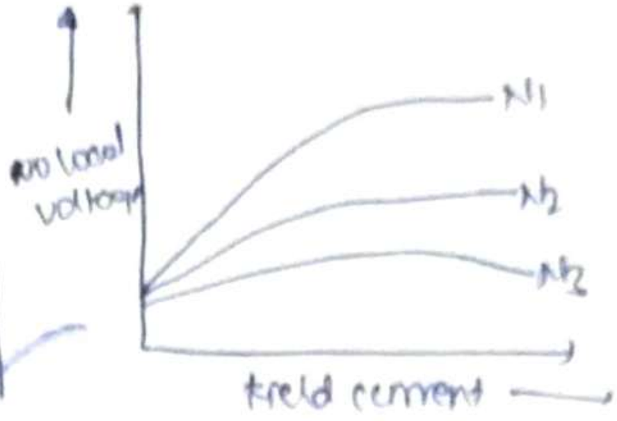
(i) Magnetic characteristics

For this we consider an open circuit without load resistance.



So, the voltage is directly dependent on speed of the Armature as it is no load circuit





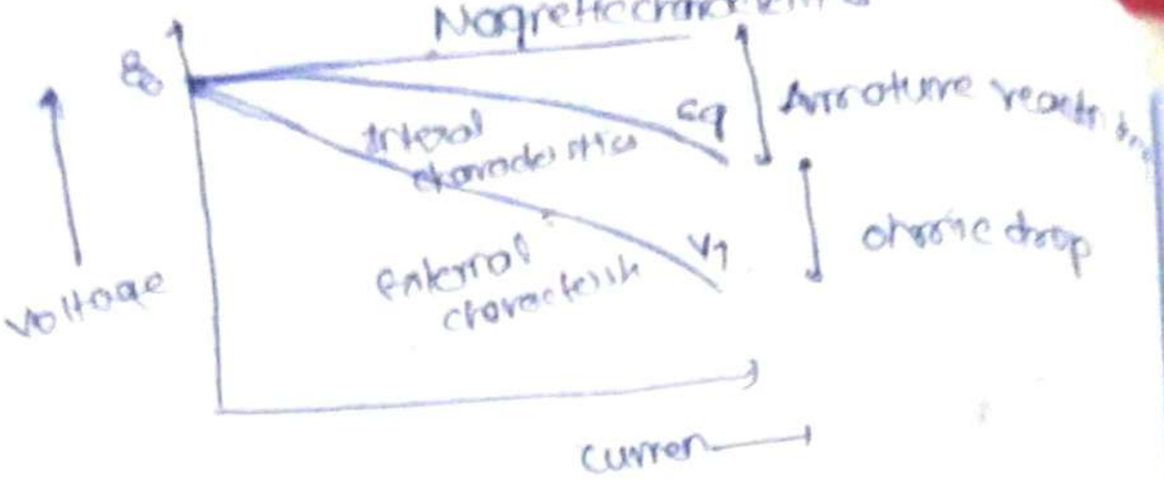
Internal characteristics.

this is drawn b/w E_g and I_L and we know that $\boxed{V_t = E_g - I_a R_a}$ and as this cond'n comes from noload circuit to full load circuit so, 'I_L' gets increased.

and we know that $\boxed{I_a = I_L + I_{sh}}$ as $I_L(\uparrow)$ then $I_a(\uparrow)$ so, 'E_g' value will get's decreased as $I_L(\uparrow)$ and $E_0 < E_g$.. this drop due to Armature reaction.

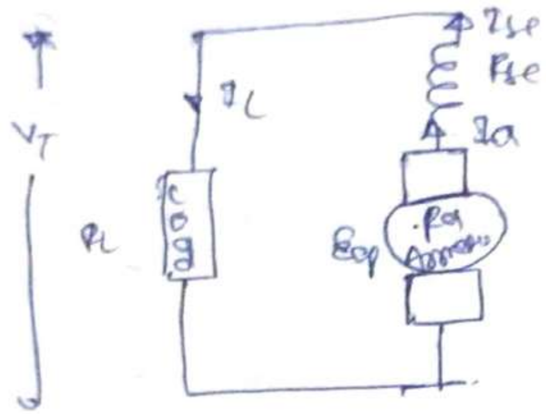
External characteristics

the is drawn b/w V_t and I_L and we know that $\boxed{V_t = E_g - I_a R_a}$ and as 'I_L' gets increased 'I_a' gets increased so, the -ve value get increased so, 'V_t' will decrease due to ohmic drop.



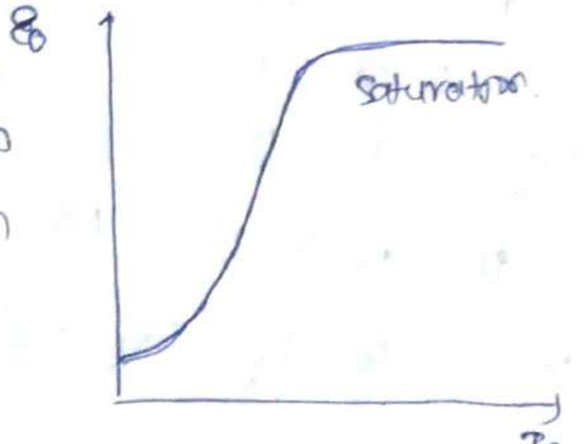
(7A)

characteristics of DC-series generator.



$$\boxed{V_T = E_g - I_aR_a - I_{se}R_{se}}$$

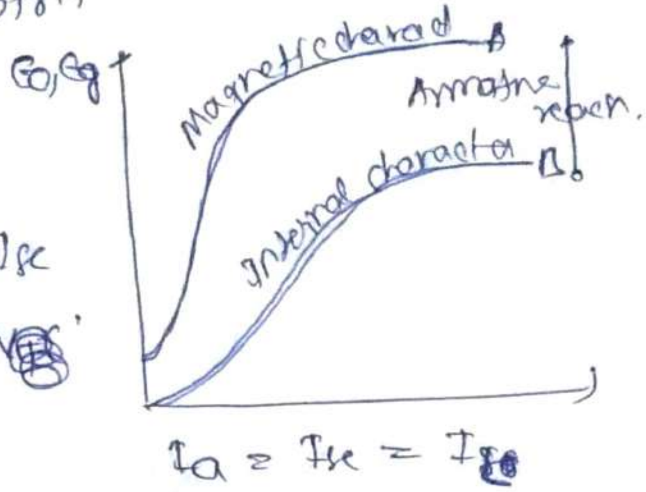
(i) Magnetic characteristics.



As there is no load resistance the E_0 value will be so high and after a certain point the E_0 value will gets saturated.

(ii) Internal characteristics!

As the condn is changed from no load to full load circuit the 'E_g' value gets increased as the 'I_{se}' increases and after it becomes constant at a saturation point

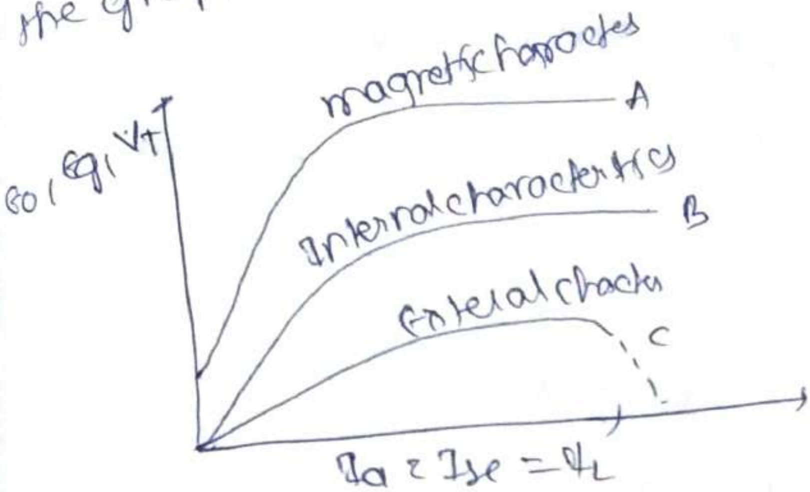


(iii) External characteristic:

As the's codn is b/w V_T and I_{se}

as the value of I_{se} (↑) V_T

the graph will be



(8) causes of failure of voltage buildup in self-excited DC generator:

(i) No residual magnetism:

this Means that the voltage build up wont start without the presence of residual magnetic flux. As we all know it. This residual magnetic flux can be lost during transportation and in other circumstances so it can't build up the voltage.

(ii) the field resistance and critical resistance:

In practical life due to some carelessness of humans ~~the~~ if field resistance is greater than its critical resistance. the emf will not get's induced.

(iii) Due to low speed of Armature:

In practical life, if the speed of the Armature is less than critical speed the emf will not get induced.

Remedies to overcome the problem:

(i) ~~the~~ For transportation and for other purposes the DC-generator must be handled with care. to prevent the loss of residual magnetic flux

(ii) Before getting rust to the commutators and field windings they must be taken care to prevent it

(iii) the threading of the Armature should be cleaned regularly to prevent rusting.

of
on the
duced
is
i

9A) The basic working principle of DC motor is whenever a current carrying conductor is placed in a magnetic field it experience a mechanical force.

$$\boxed{F = BIL}$$

(10A)

Torque: turning or twisting force acting on a body about its axis is known as torque.

we know that in a DC motor input power (P_{in}) is in electrical and output power (P_{out}) is mechanical

W.K.T

$$\boxed{\tau = r \times F} \quad -(1)$$

we also know that

W = F x (distance covered)

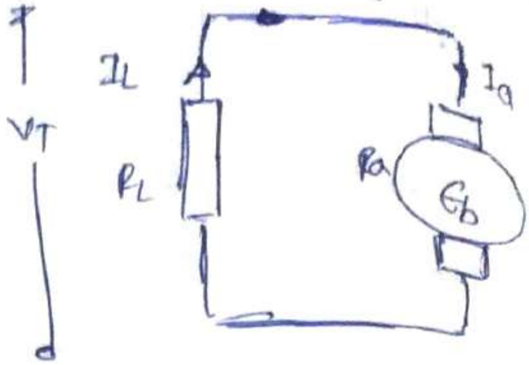
$$\boxed{W = F \times (2\pi r)}$$

$$P_{out} = \frac{dw}{dt} = \frac{F \times 2\pi r}{\left(\frac{60}{N}\right)} = \frac{N \times 2\pi r \times F}{60}$$

By eq(1)

$$\boxed{P_{out} = \tau \times \frac{2\pi N}{60}} \quad -(2)$$

Q



$$V_T - I_a R_a - E_b = 0$$

$$\boxed{V_T = E_b + I_a R_a}$$

$$V_T I_a = E_b I_a + I_a^2 R_a$$

as $I_a^2 R_a$ is amount of heat released from the motor so it is negligable

$$\boxed{V_T I_a = E_b I_a}$$

$$\boxed{P_{in} = E_b I_a}$$

W.k.t theoritically,

$$P_{in} = P_{out}$$

$$E_b I_a = \tau \times \frac{2\pi N}{60}$$

$$\tau = \frac{60 \times E_b I_a}{2\pi N}$$

$$= E_b \times \frac{60 \times I_a}{2\pi N}$$

$$= \left(\frac{\phi Z N P}{60 A}\right) \times \frac{60 \times I_a}{2\pi N}$$

$$\boxed{\tau = \frac{\phi Z I_a P}{2\pi A}}$$

(4)

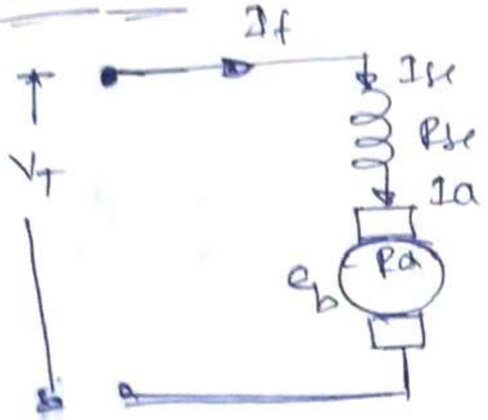
Dcmotors are

(ii) Types of D.C. motors

- DC - Motors
  - Permanent magnetic
  - Seperately excicted
  - selfexcicted
    - Series wound
    - shunt wound
    - compound wound
      - Long shunt
      - short shunt

selfexcited

(a) series wound

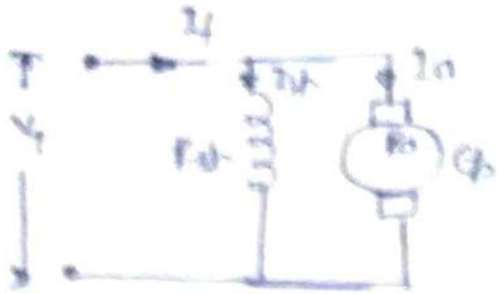


$$\boxed{I_f = I_{se} = I_a}$$

$$V_T - I_{se}R_{se} - I_aR_a - E_b = 0$$

$$\boxed{V_T = E_b + I_aR_a + I_{se}R_{se}}$$

(b) Shunt wound



$$\boxed{I_{sh} = \frac{V_t}{R_{sh}}}$$

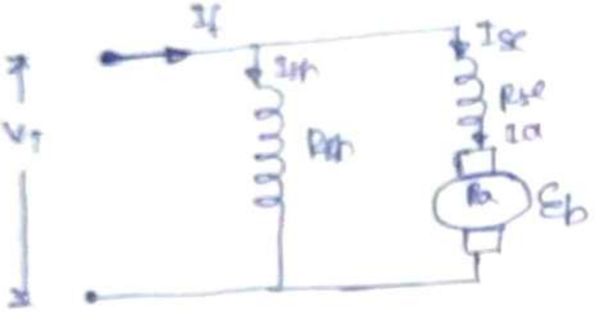
$$V_t - I_a R_a - E_b = 0$$

$$\boxed{V_t = E_b + I_a R_a}$$

$$\boxed{I_L = I_{sh} + I_a}$$

(c) Compound wound

(i) Long shunt



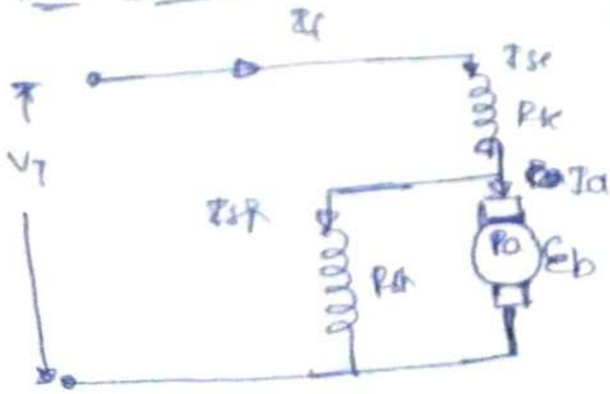
$$V_t - I_{se} R_{se} - I_a R_a - E_b = 0$$

$$\boxed{V_t = E_b + I_a R_a + I_{se} R_{se}}$$

$$\boxed{I_L = I_{sh} + I_{se}} \qquad \boxed{I_{se} = I_a}$$

$$\boxed{I_{sh} = \frac{V_T}{R_{sh}}}$$

(ii) Short shunt



$$V_T - I_{se} R_{se} - I_a R_a - E_b = 0$$

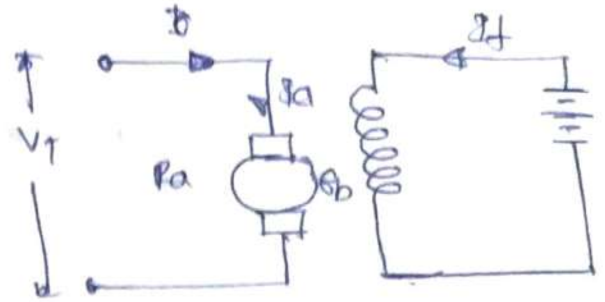
$$\boxed{V_t = E_b + I_a R_a + I_{se} R_{se}}$$

$$\boxed{I_{sh} = \frac{V_t}{R_{sh}}}$$

$$\boxed{I_{se} = I_{sh} + I_a}$$

$$\boxed{I_f = I_{se}}$$

Seperately wound



$$V_t - I_a R_a - E_b = 0$$

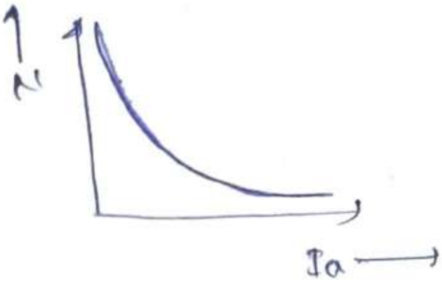
$$\boxed{V_t = E_b + I_a R_a}$$

(12)

characterstics of DC motors

(i) series wound

(a) speed vs Ia



we know that,

$$E_b = \frac{P \times \phi \times N}{60} \times \frac{Z}{A}$$

$$N \propto \frac{E_b}{\phi}$$

As in series wound the "E_b" (back emf) is low for low current.

$$N \propto \frac{1}{\phi} \quad (\text{wkt } \phi \propto I_a)$$

$$\boxed{N \propto \frac{1}{I_a}}$$

(b) torque vs Ia

we know that,

$$\boxed{T \propto \phi I_a}$$

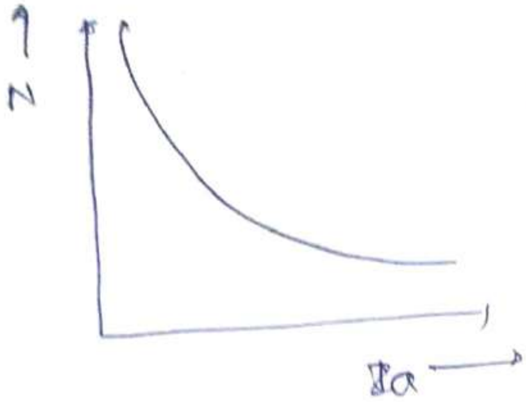
as we know that

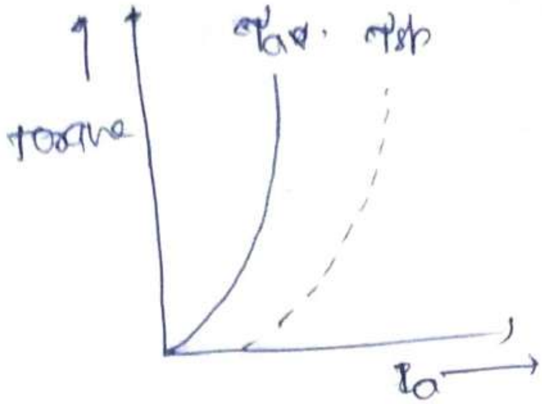
$$\boxed{\phi \propto I_a}$$

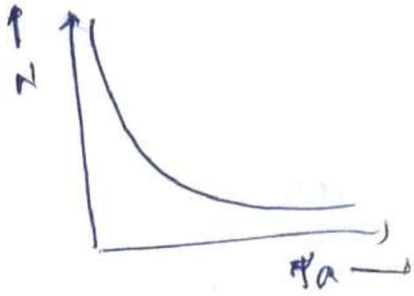
$$\boxed{T \propto I_a^2}$$

(c) torque v/s speed

$\boxed{N \propto \frac{1}{\sqrt{T}}}$







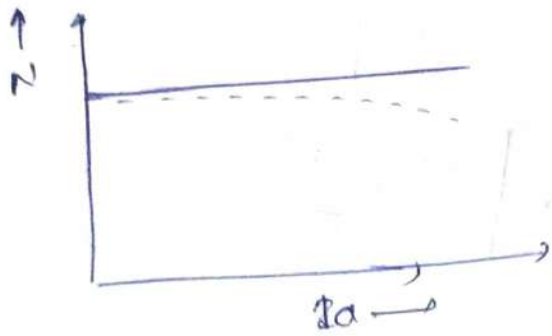
(ii) shunt wound

(a) speed v/s Ia

$\boxed{N \propto \frac{E_b}{\phi}}$

As in shunt wound 'ϕ' is constant

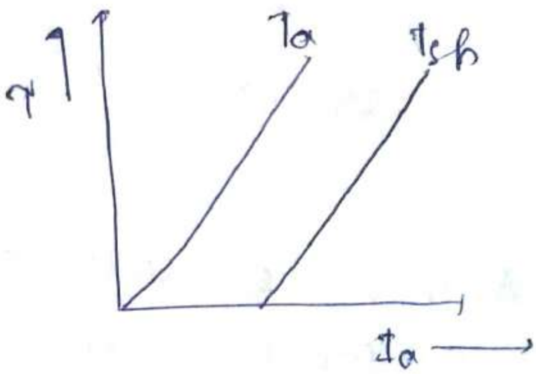
$\boxed{N \propto E_b}$



(b) torque v/s Ia

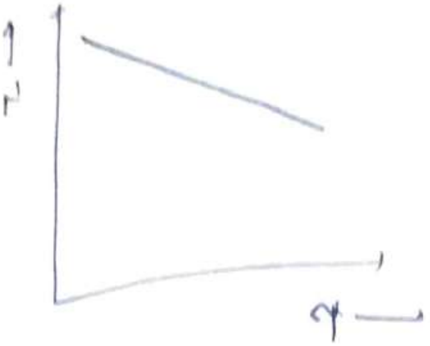
$\boxed{T \propto \phi I_a}$

$\boxed{T \propto I_a}$



(c) torque and speed

$\frac{E_b}{N} \propto \phi$



Compound Motor

cumulative compound motor

cumulative motors are used where series characteristics are req but the load is likely to be removed completely. series winding takes care of the heavy load whereas the shunt winding prevents the motor from running at high speed

(b) Differential compound motor:

since in differential compound motors, series flux opposes shunt flux, the total flux decreases with increase in load. Due to this the speed remain almost constant.

10

3A)

Series motors:

these are used where high starting torque is req.

Eg:- vaccumcleaner, sewing machine, etc

Shunt motors

Shunt motors are used where they need const speed and starting condn's are not severe.

Eg:- Fans, Blowers, spinning machine, etc

Compound motors:

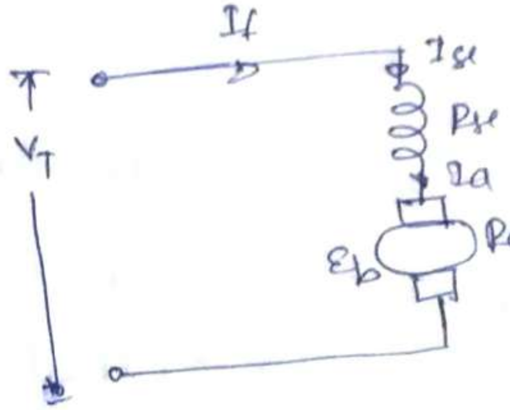
These are used where high starting torque and fairly cons speed is req

eg: Rolling machines, Rolling mills, elevators, etc

14A)

The factors that affect the speed of a DC motor

Let us consider a series wound DC motor:



$V_T - I_{se}R_{se} - I_aR_a - E_b = 0$.

$V_T = E_b + I_aR_a + I_{se}R_{se}$

$V_T = \frac{P\phi \times N \times Z}{60 \times A} + I_aR_a + I_{se}R_{se}$.

$\left(\frac{V_T - I_aR_a - I_{se}R_{se}}{\phi Z \times P}\right) 60A = N$

so, we know that $R_a, I_{se}, R_{se}, Z, P, A$ are constant so, the factors affect the speed of motor are. V_T (Field voltage), Armature current (I_a), ϕ.

(15)

Losses in DC motor :-

(i) electrical or copper loss.

These losses are also known as winding losses as the copper loss occurs because of the resistance of the windings. The ohmic loss is produced by the current flowing in the windings

Armature cu losses $= I_a^2 R_a$

(ii) Magnetic or iron core losses

the core loss are the hysteresis and eddy current losses. these are considered almost constant as the machines are usually operated at constant flux

(iii) Brush loss :-

~~Brush~~ Brush losses are losses that takes place b/w commutator and carbon brushes.

$$\boxed{P_{BD} = V_{BD} \cdot I_a}$$

If the value of brush voltage drop is not given it is assumed as '2'

Mechanical losses

The losses that take place because of mechanical effect of machines are known as mechanical losses.

Eg: Bearing friction loss, windage loss, etc

(16A)

1(a) Refer Part-B Q-① a, b, continues

(b) The electric current (or) voltage which comes from the Battery will flow Brushes as the brushes are stators. these will pass the voltage (or) current to commutator from commutator through field windings this gets delivered to the armature.

(17A) Refer Part B 11 Q

(20A) we know that

$$\boxed{\tau = F \times R}$$

linear distance $= t \times \omega \times r$

$$P = \frac{W}{t} = \frac{F \times S}{t}$$

$$P = \left(\frac{\tau}{R}\right) \times \frac{(t \times \omega \times r)}{t}$$

$$P = \frac{\tau}{R} \times \omega \times r \qquad \text{So} \quad \boxed{P = \frac{\tau}{\omega}}$$

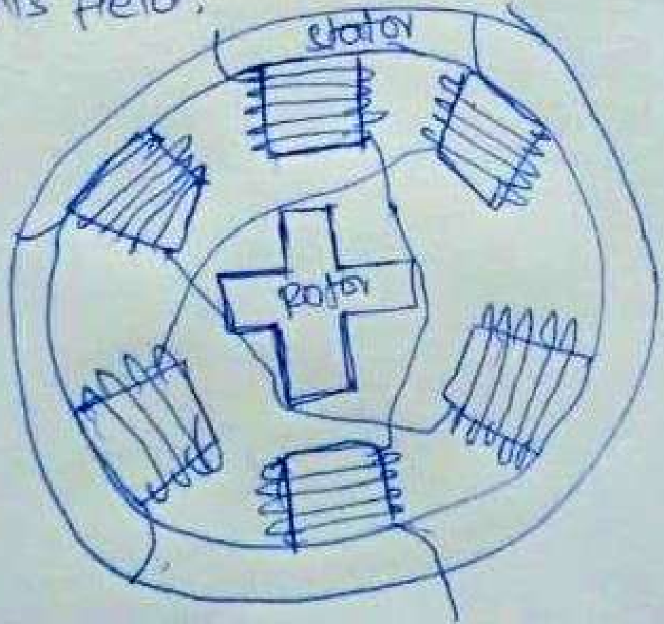
And we know that

$$\boxed{H = \frac{T \times N}{5252}}$$

(ii) A stepper motor also known as step motor (or) simply we can say that as brushless DC electric motor.

The basic working principle of the stepper motor is the following. By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor align with this field.

ex:



① A 250V lap wound generator has full load armature current of 100A. The armature resistance is 0.2 Ω and the number of armature conductors is 272. The contact drop of two brushes is 2V and the flux/pole is 0.05 wb. Determine the generated EMF and speed:

Ⓐ GIVEN: $V = 250V$ lap $A = P$

$I_a = 100A$ $R_a = 0.2\,\Omega$ $Z = 272$

$V_{brush} = 2V$ $\phi = 0.05\,wb$

$$E_g = \frac{\phi Z N P}{60A} = V + I_a R_a + V_{brush}$$

$$E_g = V + I_a R_a + V_{brush} = 250 + 100 \times 0.2 + 2$$

$$\boxed{E_g = 272\ V}$$

Also $E_G = \frac{\phi Z N P}{60A}$ $\boxed{N = \frac{E_g \times 60\,A}{\phi Z P}}$

$$\boxed{N = \frac{\cancel{272} \times 60 \times \cancel{P}}{0.05 \times \cancel{272} \times \cancel{P}} = 1200\ rpm}$$

(2) A 4 pole DC Shunt generator with wave connected armature has 41 slots and 12 conductors/slot. Ra = 0.5 Ω, Rsh = 200 Ω and flux/pole is 125 mwb. When the generator is driven at a speed of 1000 rpm, calculate the voltage across 10 Ω load resistance connected across the armature terminals.

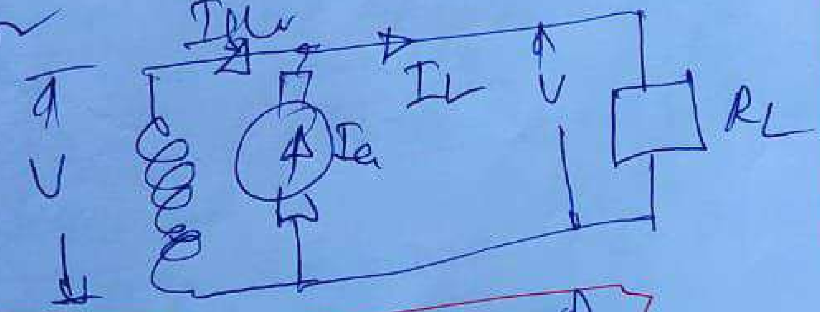
(A) Given: $R_a = 0.5$ $R_{sh} = 200\Omega$

$Z = \text{slots} \times \text{conductors/slot} = 41 \times 12 = 492$

$P = 4$, $\phi = 0.125\,wb$ $N = 1000$ rpm

$R_L = 10\Omega$

$\boxed{A = 2}$



$I_a = I_L + I_{sh}$

$I_a = \frac{V}{R_L} + \frac{V}{R_{sh}}$

$\boxed{E_g = V + I_a R_a}$ $\boxed{E_g = \frac{\phi Z N P}{60 A}}$

$E_g = \frac{0.125 \times 492 \times 1000 \times 4}{60 \times 2} = 2050\,V$

Also $E_g = V + \left(\frac{V}{R_L} + \frac{V}{R_{sh}}\right) R_a = V + \left(\frac{V}{10} + \frac{V}{200}\right) 0.5$

$2050 = 1.0525 V$, $\boxed{V = \frac{2050}{1.0525} = 1947.7\,V}$

(3) A 4 pole DC generator having wave wound armature has 50 slots and 25 conductors/slot. Find the generated EMF, if it is driven at 25 rpm and useful flux/pole in the machine is 0.03 wb.

(A) Given: $P=4$ $Z=50\times25=1250$

$N=25$ rpm $\phi=0.03$ wb $\boxed{A=2}$ wave

$$E_g=\frac{\phi ZNP}{60A}=\frac{0.03\times1250\times25\times4}{60\times2}$$

$$\boxed{E_g=31.25\,V}$$

(4) A ~~DC~~ 4 pole lap wound 750 rpm DC shunt generator has an armature resistance of $0.4\,\Omega$ and $R_{sh}=200\,\Omega$. The armature has 720 conductors and the flux/pole is 30 mwb. If the load resistance is $10\,\Omega$ determine V.

(A) Given $R_a=0.4$ $R_{sh}=200$ $R_L=$ con

$\phi=0.03$ wb, $\boxed{A=P}$

$Z=720$

$N=750$

$$\boxed{E_g=\frac{\phi ZNP}{60A}=\frac{0.03\times720\times750\times\cancel{P}}{60\cancel{A}}=270V}$$

$$I_a=I_L+I_{sh}=\left(\frac{V}{10}+\frac{V}{200}\right)=\frac{21}{200}V$$

$$270=E_g=V+I_aR_a=V+\frac{21}{200}V\times0.4=1.042V$$

$$\boxed{V=\frac{270}{1.042}=259.11}$$

(5) A 25 KW, 250 V DC shunt generator has armature and field resistances of 0.06 Ω and 100 Ω. Determine the total armature power delivered when working
(i) as generator delivering 25 kW output
(ii) as motor taking 25 kW input.

(A) Given $P = 25\times10^3$ W $V = 250$

$R_a = 0.06\,\Omega$ $R_{sh} = 100\,\Omega$

(i) $E_g = V + I_a R_a$

$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100}$

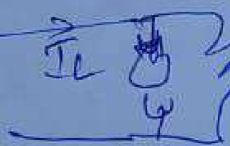
$I_L = \frac{P}{V_L} = \frac{25\times10^3}{250} = 100\,A$, $I_{sh} = 2.5\,A$

$I_a = 102.5\,A$, $\boxed{E_g = 250 + 102.5\times0.06 = 256.15}$

Power delivered $= E_g I_a = 256.15 \times 102.5$

$\boxed{P = 26.255\ kW}$

(ii) $V = E_b + I_a R_a$ $(I_a = I_L - I_{sh})$



$I_L = \frac{P}{V_L} = \frac{25\times10^3}{250} = 100\,A$

$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100} = 2.5\,A$, $\boxed{I_a = I_L - I_{sh} = 97.5\,A}$

$E_b = 250 - 97.5\times0.06 = 244.15$

$\boxed{\text{Power delivered} = E_b I_a = 23.8\ kW}$

IARE BEE UNIT-III Part C ⑥

⑥ A 230 V series motor is taking 50A. field Resistances of armature and series field windings are 0.2 and 0.1 Ω respectively. Calculate (i) brush voltage (ii) Back emf (iii) power wasted in armature and mechanical power developed. (Assume missed data)

A) Given: $V = 230V$ $I_L = I_a = 50A$

$R_a = 0.2\,\Omega$ $R_{se} = 0.1\,\Omega$

(i) Brush voltage = V − voltage drop in series field

Brush Voltage = $230 - 50 \times 0.1 = 225V$

(ii) Back emf $= V - I_a R_a - I_a R_{se}$

$= 230 - 50 \times 0.2 - 50 \times 0.1$

$\boxed{E_b = 215V}$

(iii) power wasted in armature

$= I_a^2 R_a = 50^2 \times 0.2 = 500W$

P_m = Mechanical power developed

$P_m = E_b I_a = 215 \times 50 = 10750W$

7) A 250 V shunt motor has armature and field resistance of 1 Ω and 125 Ω respectively. When running light, it takes a current of 5 A and the speed is 1500 rpm. (i) Find the motor speed at full load, the input current being 25 A. (ii) Find also the speed at (which) this load if a resistance is 2.5 Ω inserted in the armature circuit (2.5 Ω)

A) Given data: $V = 250V$ $R_a = 1\Omega$ $R_{sh} = 125\Omega$

$I_{0L} = 5A$ $N_0 = 1500 rpm$ Extra resistance $= 2.5$

(i) $V = E_{b0} + I_{a0} R_a$ $E_{b0} = V - I_{a0} R_a$ $\left(I_{sh} = \frac{V}{R_{sh}} \right)$

$I_{L0} = I_{a0} + I_{sh} \Rightarrow 5 = I_{a0} + \frac{250}{125}$

$\therefore I_{a0} = 5 - 2 = 3A$

$$\boxed{E_{b0} = 250 - 3 \times 1 = 247V}$$

When $I_L = 25A$, $I_{a_1} = 25 - 2 = 23A$

$$\boxed{E_{b_1} = V - I_{a_1} R_a = 250 - 23 \times 1 = 227V}$$

$E_{b0} \propto N_0$

$E_{b1} \propto N_1$

$N_1 = \frac{E_{b1}}{E_{b0}} N_0$

$$\boxed{N_1 = \frac{E_{b1}}{E_{b0}} N_0 = \frac{227}{247} \times 1500 = 1378.5 \text{ rpm}}$$

(ii) $I_L = 25A$, $R_{a_2} = 1 + 2.5 = 3.5\Omega$

$I_{a_2} = 25 - 2 = 23$

$E_{b_2} = V - I_{a_2} R_{a_2}$

$E_{b_2} = 250 - 23 \times 3.5 = 169.5V$

$$\boxed{N_2 = \frac{E_{b2}}{E_{b0}} N_0 = \frac{169.5}{247} \times 1500 = 1029.4 \text{ rpm}}$$

(8) A DC series motor runs at 500 rpm on 220V supply drawing a current of 50A. The total resistance of the machine is 0.15Ω. Calculate the value of extra resistance to be connected in series with the motor circuit that will reduce the speed to 300 rpm. The load torque being then half of the previous value. Assume flux ∝ current.

(A) Given data: $V = 220V$ $I_{a_1} = 50A$ $R_{T1} = 0.15\Omega$ an

$N_1 = 500\,rpm$ $N_2 = 300\,rpm$ $T_2 = \frac{T_1}{2}$

$$\frac{T_2}{T_1} = \frac{I_{a_2}^2}{I_{a_1}^2}, \quad I_{a_2} = \boxed{\sqrt{\frac{T_2}{T_1}}\, I_{a_1}}$$

$$\boxed{I_{a_2} = \frac{1}{\sqrt{2}} \times 50 = 35.36\,A}$$

$$\frac{E_{b_2}}{E_{b_1}} = \frac{N_2\, I_{a_2}}{N_1\, I_{a_1}}$$

$$\boxed{\begin{aligned} E_{b_1} &= V - I_{a_1} R_{T1} \\ &= 220 - 50 \times 0.15 \\ E_{b_1} &= 212.5\,V \end{aligned}}$$

$$\frac{E_{b_2}}{212.5} = \frac{300}{500} \times \frac{35.36}{50}$$

$$\boxed{E_{b_2} = 90.168\,V}$$

$$E_{b_2} = V - I_{a_2} R_{T2}$$

$$90.168 = 220 - 35.36 \times R_{T2}$$

$$\boxed{R_{T2} = 3.67\,\Omega}$$

$I_{L_1} = I_{a_1}$ $\quad I_{L_2} = I_{a_2}$

$T_1 \propto \phi_1 I_{a_1}$ $\quad (\phi_1 \propto I_{a_1})$

$T_1 \propto I_{a_1}^2$

$T_2 \propto I_{a_2}^2$

$$\frac{T_2}{T_1} = \frac{I_{a_2}^2}{I_{a_1}^2}, \quad T_2 = \frac{I_{a_2}^2}{I_{a_1}^2} \times T_1$$

$$\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}} \times \frac{I_{a_1}}{I_{a_2}}$$

$E_{b_2} \propto N_2 I_{a_2}$

$E_{b_1} \propto N_1 I_{a_1}$

$$\frac{E_{b_2}}{E_{b_1}} = \frac{N_2\, I_{a_2}}{N_1\, I_{a_1}}$$

$$\boxed{\text{EXTRA RESISTANCE} = R_{T2} - 0.15 = 3.52\,\Omega}$$

IARE BEE UNIT-III part C (8)

(9) A 220 V, 4 pole shunt motor has 540 lap wound conductors. It takes 32 A from the supply mains and develops output output power of 5.595 KW. The field winding takes 1 A. The armature resistance is 0.9 Ω and flux/pole is 30 mWb. Calculate (i) The speed and (ii) the torque developed ~~to in~~ direction motor.

(A) Given data : $V = 220V$ $P = 4$ $A = 4$ $\boxed{A = P \text{ lap}}$

output = 5595 KW, $I_{sh} = 1A$, $R_a = 0.9\,\Omega$

$\phi = 30 \times 10^{-3}$ wb $Z = 540$

$E_b = V - I_a R_a = 220 - 31 \times 0.9$

$$\boxed{E_b = \frac{\phi Z N P}{60 A} = V - I_a R_a}$$

$I_L = I_a + I_{sh}$

$I_a = I_L - I_{sh} = 32 - 1$

$I_a = 31\,A$

$$\frac{30 \times 540 \times N \times P}{60\, P} = 220 - 31 \times 0.9$$

$$\boxed{N = \frac{192.1V \times 60}{30 \times 540} = 711.5 \text{ rpm}}$$

$$T_a = \frac{9.55\, E_b I_a}{N} = \frac{192.1 \times 31 \times 9.55}{711.5} = 80 \text{ Nm}$$

$$T_{sh} = \frac{9.55 \times \text{output}}{N}$$

$$\boxed{T_{sh} = \frac{9.55 \times 5595 \times 10^{3}}{711.5} = 75 \text{ Nm}}$$

$$\boxed{T_a = 9.55\,\frac{E_b I_a}{N} \qquad T_{sh} = \frac{9.55 \times \text{output}}{N}}$$

IARE BEE UNIT-III part C (9)

(10) A 440 V DC shunt motor takes a no load current of 2.5A. The resistance of shunt field and the armature are 550 Ω and 1.2 Ω respectively. The full load output line current is 32 A. Find full load output and the efficiency of the motor.

(A) Data given: $I_0 = 2.5A$ $R_{sh} = 550\Omega$

$R_a = 1.2\Omega$ $I_{FL} = 32A$ $V = 440V$

$\boxed{\text{output} = \text{input} - \text{losses}}$

input = output + losses

At No load:

output = 0

input = 1100 W

$440 \times 2.5 = 1100W$

$1100 = 0 + T.\text{losses}$: $\boxed{T.\text{losses} = 1100W}$

(i) armature cu loss $= I_{a0}^2 R_a = 1.7^2 \times 1.2 = 3.5W$

$I_0 = I_{a0} + I_{sh}$ $I_{sh} = \frac{V}{R_{sh}} = \frac{440}{550} = 0.8A$

$I_{a0} = I_0 - I_{sh} = 2.5 - 0.8 = 1.7A$

(ii) field Cu loss $= I_{sh}^2 R_{sh} = (0.8)^2 550 = 352$

$\boxed{\text{Total cu loss} = 3.5 + 352 = 355.5W}$

Friction and Iron loss = T.loss − total cu loss = 1100 − 355.5 = 744.5 W

$\boxed{\rightarrow \text{constant loss} = 1100 + 352 =}$

At Full load: $I_L = 32A$ $\boxed{I_a = 32 - 0.8 = 31.2A}$

Input $= 440 \times 32 = 14080W$

Armature copper loss $= (31.2)^2 \times 1.2 = 1168W$

field copper $= 352W$

Total loss = Iron loss + field copper loss + Arm. cu loss

$= 744.5 + 1168 + 352 = 2264.5W$

$\boxed{\text{output} = 11815.5W}$ $\boxed{\eta = \frac{14080 - 2264.5}{14080} = 84\%}$