USN :

CMR Institute of Technology, Bangalore
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
I - INTERNAL ASSESSMENT

Semester: 4-CBCS 2018
Subject: ELECTRIC MOTORS (18EE44)
Faculty: Dr V Agalya

Date: 20 May 2021
Time: 01:00 PM - 02:30 PM
Max Marks: 50

Answer any 5 question(s)

Q.No		Marks	CO	PO	BT/CL
1	A DC shunt motor runs at 1000 rpm on 200V supply its armature resistance is 0.8 Ω and the armature current drawn is 40 amps. What resistance must be connected in series with the armature to reduce the speed to 600 rpm, the armature current remaining same? Neglect armature reaction.	10	CO4	PO1,PO2,PO3,PO4	L4
2	Describe the characteristics of DC shunt motor.	10	CO2	PO1,PO2,PO3,PO4	L4
3	Derive the torque equation of DC motor.	10	CO5	PO1,PO2,PO3,PO4	L4
4	A 220 V shunt motor with an armature resistance of 0.5 ohm is excited to give constant main field. At full load the motor runs at 500rpm and takes an armature current of 30A. If a resistance of 1.0 ohm is placed in the armature circuit, find the speed at (a) full-load torque (b) double full-load torque.	10	CO4	PO1,PO2,PO3,PO4	L4
5	What is the necessity of a starter for a D.C. Motor? Explain, with a neat sketch, the working of a 3- point D.C. Shunt motor starter, bringing out the protective features incorporated in it.	10	CO1	PO1,PO2,PO3,PO4	L4
6	What are the limitation of speed control of a dc shunt motor by armature control method?Name and explain the method of overcoming these limitations.	10	CO4	PO1,PO2,PO3,PO4	L4
7	Briefly explain the various losses that occur in DC machine.Derive the condition for maximum efficiency of DC motor	10	CO3	PO1,PO2,PO3,PO4	L4

1. Characteristics of D.C Shunt motor —

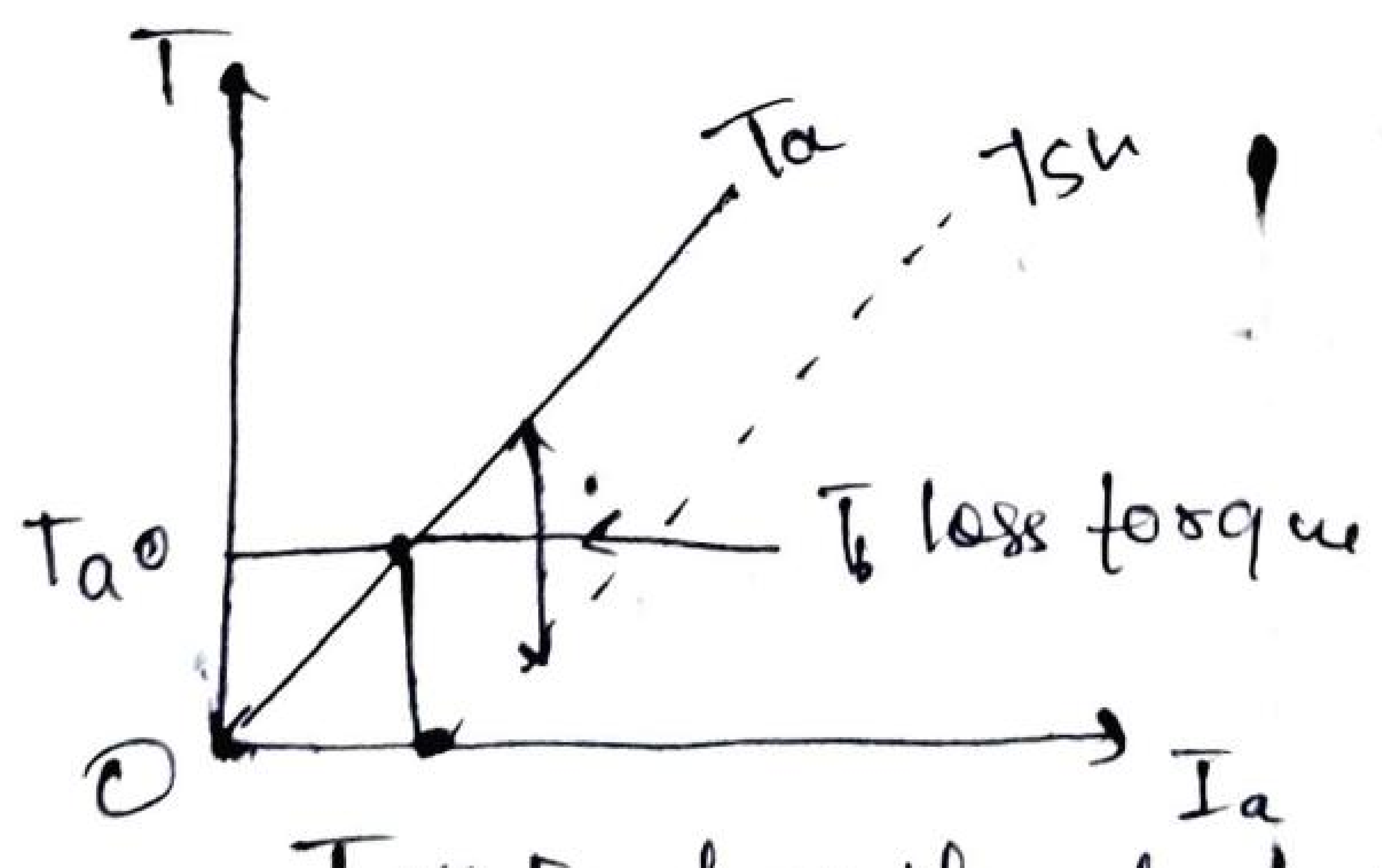
i) Torque - Armature Current Characteristics

for a d.c motor $T \alpha \phi I_a$

For a constant values of R_{sh} and supply voltage V, I_{sh} is also constant and hence flux is also constant.

$\therefore T_a \propto \phi I_a$

the equation represents a straight line, passing through the origin, as shown in the fig - Torque increases linearly with armature current. So as load increases armature current increases, increasing the torque developed linearly.



T vs Ia for shunt motor

Now if shaft torque is plotted against armature current, it is known that the 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_{a0}. The current is I_{a0} on no load to produce T_{a0} and hence T_{sh} graph has an intercept of I_{a0} on the current axis.

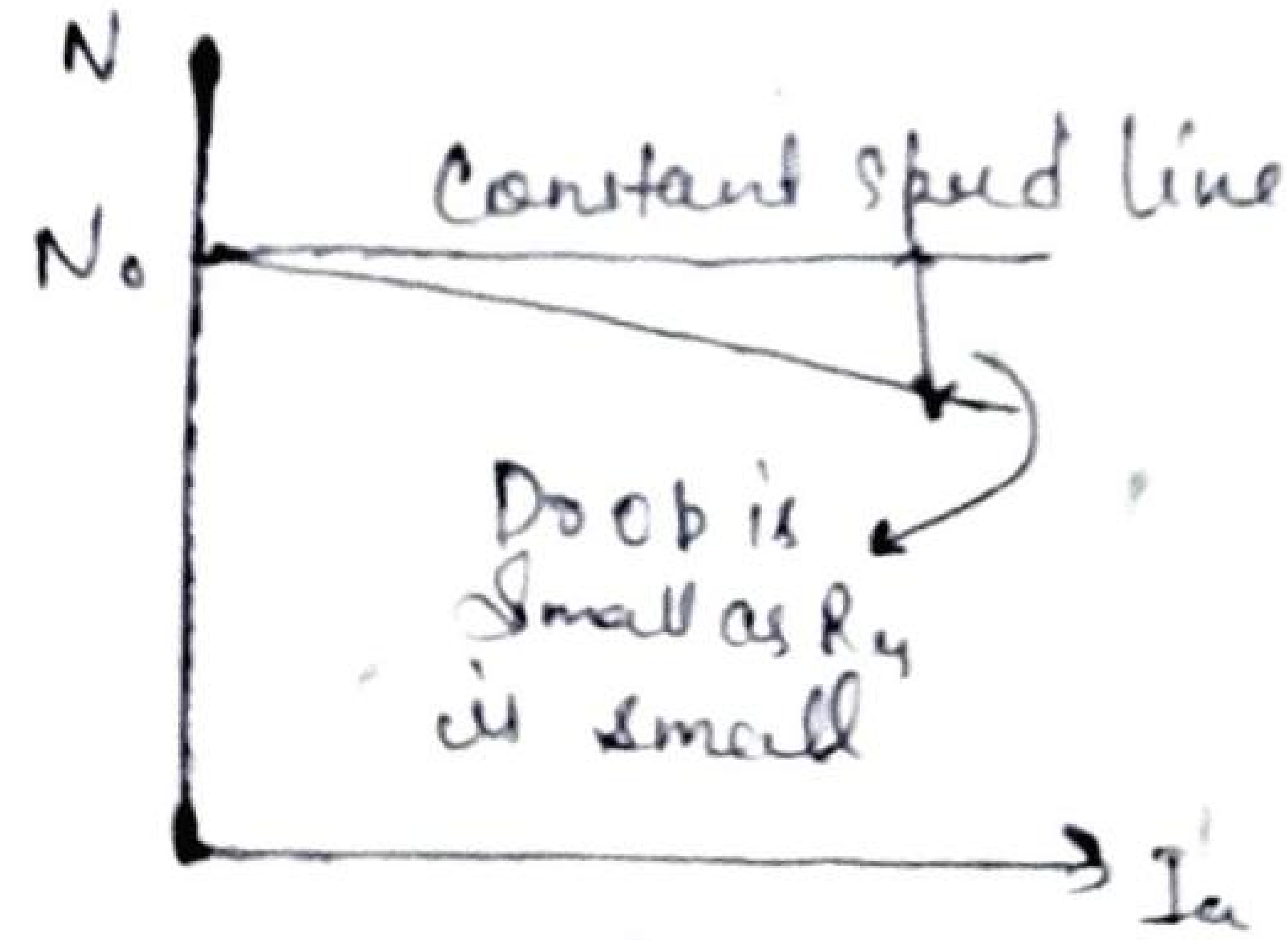
ii) Speed - Armature Current characteristics -

from the speed equation we get,

$N \propto (V - I_a R_a) / \phi$

$\propto V - I_a R_a$ as ϕ is constant.

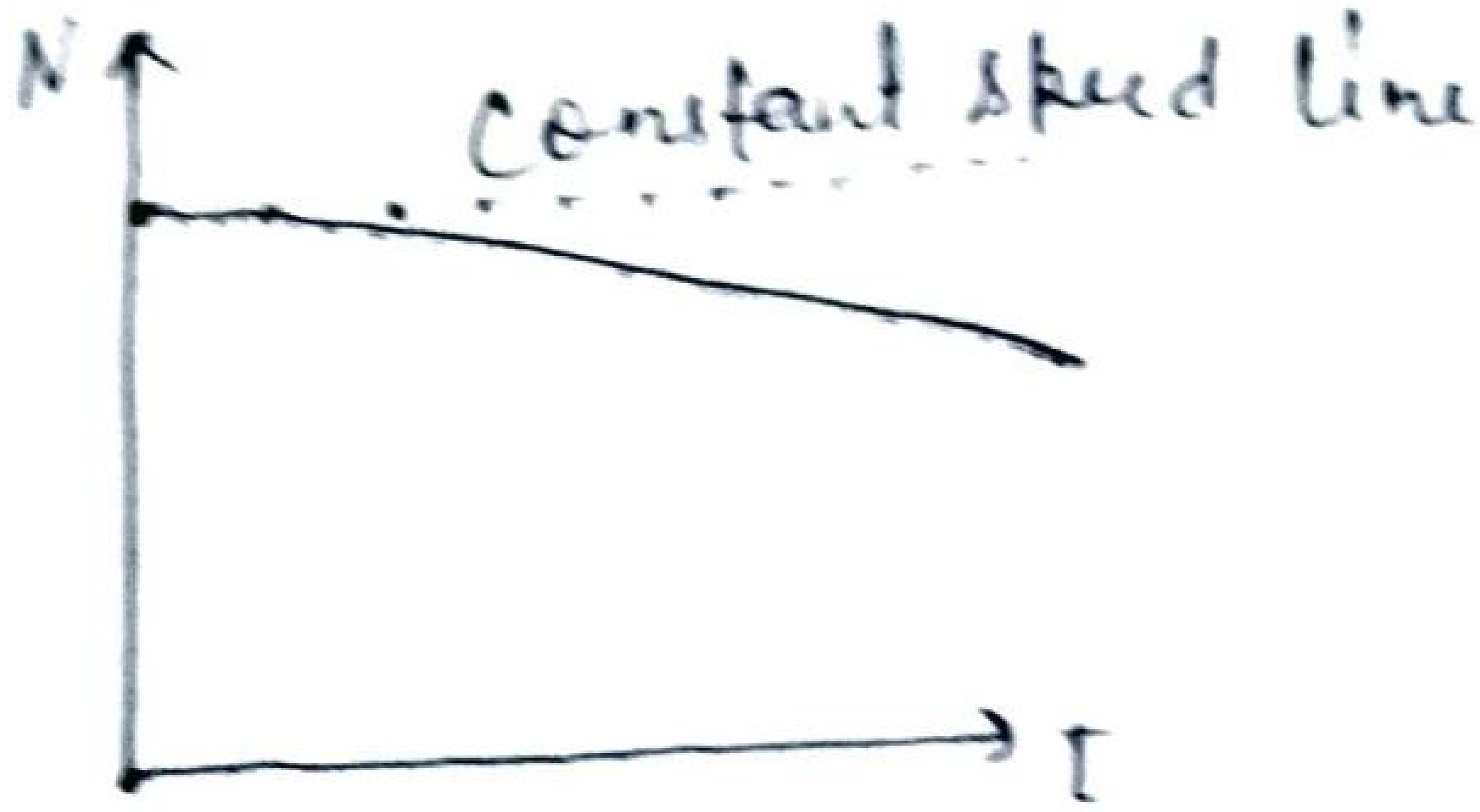
So as load increases, the armature current increases and hence drop $I_a R_a$ also increases. Hence for constant supply voltage, $V - I_a R_a$ decreases and hence speed reduces. But as R_a is very small, for change in I_a from no load to full load, drop $I_a R_a$ is very small and hence drop in speed also not significant from no load to full load.



N Vs I_a for shunt motor

iii) Speed - Torque characteristics —

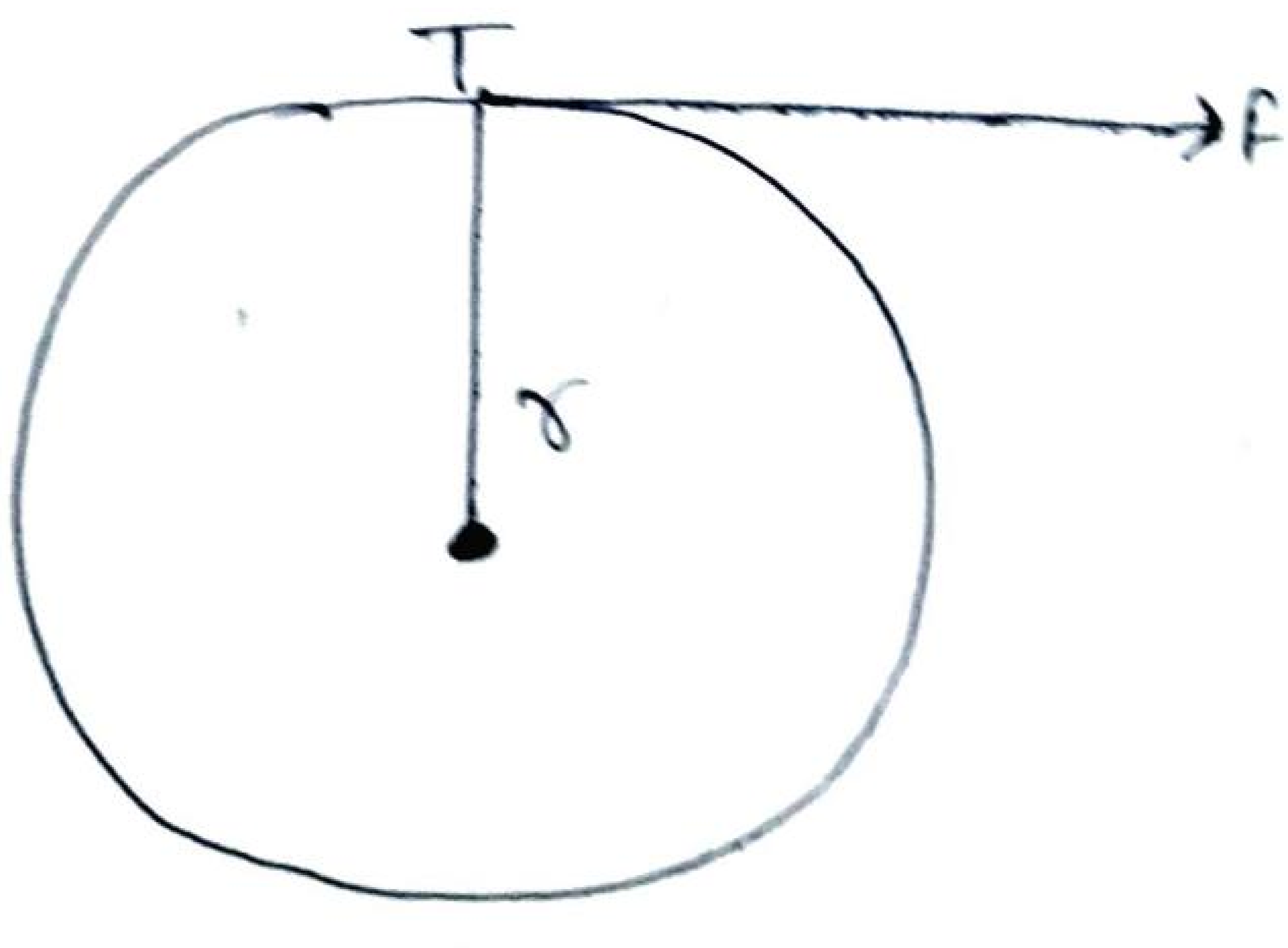
These characteristics can be derived from the above characteristics This graph is similar to speed-armature current characteristics as torque is proportional to the armature current. This curve shows that the speed almost remains constant through torque changes from no load to full load condition.



N vs T for shunt motor

3. Torque equation of DC motor —

Torque is the turning moment about its axis. It is also ~~called~~ equal to force x distance.



Consider the armature of the DC motor of radius r and let F be the force acting tangential to its surface as shown in figure.

Therefore, Torque = T_a = $F \times r$ in Newton meter — (1)

The work done by this force F is one revolution

W = F × distance covered in revolution.

∴ $W = F \times 2\pi r$ watt second

The power developed by the armature = Work done in one second.

$= F \times r \times 2\pi N / 60$ where N = no. of revolutions/min

$= (2\pi N / 60) \times T_a$ watts

But power developed in the armature = $E_b I_a$

Therefore $E_b I_a = \left(\frac{2\pi N}{60}\right) \times T_a$

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

Therefore, $T_a = \left(\frac{1}{2\pi}\right) \phi Z I_a \frac{P}{A}$ Newton meter $= 0.159 \phi Z I_a$

$= \frac{P}{A}$ Newton meter.

The actual torque or shaft torque (torque available at the shaft) or useful torque = $T_{sh} = T_a - T_L$.

where T_{sh} = Shaft Torque

T_a = armature torque

T_L = lost torque due to iron losses and mechanical losses

output = $2\pi N T_{sh} / 60$

T_{sh} = output × 60 / $2\pi N$

If output is in Horse Power,

T_{sh} = output in H.P × 735.5 / $(2\pi N / 60)$ N-M

1. Given data

$N_1 = 1000$ rpm , $R_a = 0.8\Omega$, $V = 200V$

$I_a = 40$ Amps $N_2 = 600$ rpm .

R(inserted) = ?

Soln

$E_{b1} = V - I_{a1} R_a$

$= 200 - (40 \times 0.8)$

$$\boxed{E_{b1} = 168 \text{ volts}}$$

$E_{b2} = V - I_{a2} (R_a + R)$

$E_{b2} = 200 - 40 (0.8 + R)$

$= 200 - 32 - 40R$

$$\boxed{E_{b2} = 168 - 40R}$$

$$\frac{E_{b2}}{E_{b1}} = \frac{N_2}{N_1} = \frac{168 - 40R}{168} = \frac{600}{1000}$$

$\Rightarrow 168 - 40R = 101$

$-40R = 101 - 168$

$-40R = -67$

$R = \frac{67}{40}$

$$\boxed{R = 1.675\Omega}$$

1.675Ω R is inserted to reduce the speed 600 rpm from 1000 rpm.

5. Necessity of Starter -

All the d.c motors

7. Losses that occur in DC machine →

i) Iron or Core losses

These losses are also called magnetic losses. These losses include hysteresis loss and eddy current loss.

The hysteresis loss is proportional of the frequency and the maximum flux density B_m in the air gap and is given by,

$$\text{Hysteresis loss} = \eta B_m^{1.6} f V \text{ Watts}$$

where η = Steinmetz hysteresis Cofficient

V = Volume of Core in m^3

f = frequency of magnetic reversals.

This loss is basically due to reversal of magnetisation of the armature core.

The eddy current losses exists due to eddy current. When armature core rotates, its cuts the magnetic flux and e.m.f gets induced in the core. This loss is given by —

$$\text{Eddy Current loss} = K B_m^2 f^2 t^2 V \text{ watts}$$

K = constant, t = thickness of each lamination

V = volume of core, f = frequency of magnetic reversal

ii) Copper losses —

The copper losses are the losses taking place due to the current flowing in a winding. There are basically two windings in a d.c. machine namely armature winding and field winding. The copper losses can be given by—

$$\text{Armature copper loss} = I_a^2 R_a$$

where, R_a = Armature winding resistance & I_a = Armature current

$$\text{Shunt field copper loss} = I_{sh}^2 R_{sh}$$

where R_{sh} = Shunt field winding resistance & I_{sh} = shunt field current

$$\text{Series field copper loss} = I_{se}^2 R_{se}$$

where R_{se} = Series field winding resistance & I_{se} = Series field current.

~~$I^2 R_a - P_i = 0$~~

~~$I^2 R_a = P_i = P_{cu}$~~

~~thus for the maximum~~

iii> Mechanical losses —

These losses consist of friction and windage losses. Some power is required to overcome mechanical friction and wind resistance at the shaft. The mechanical losses are also constant for a d.c machine.

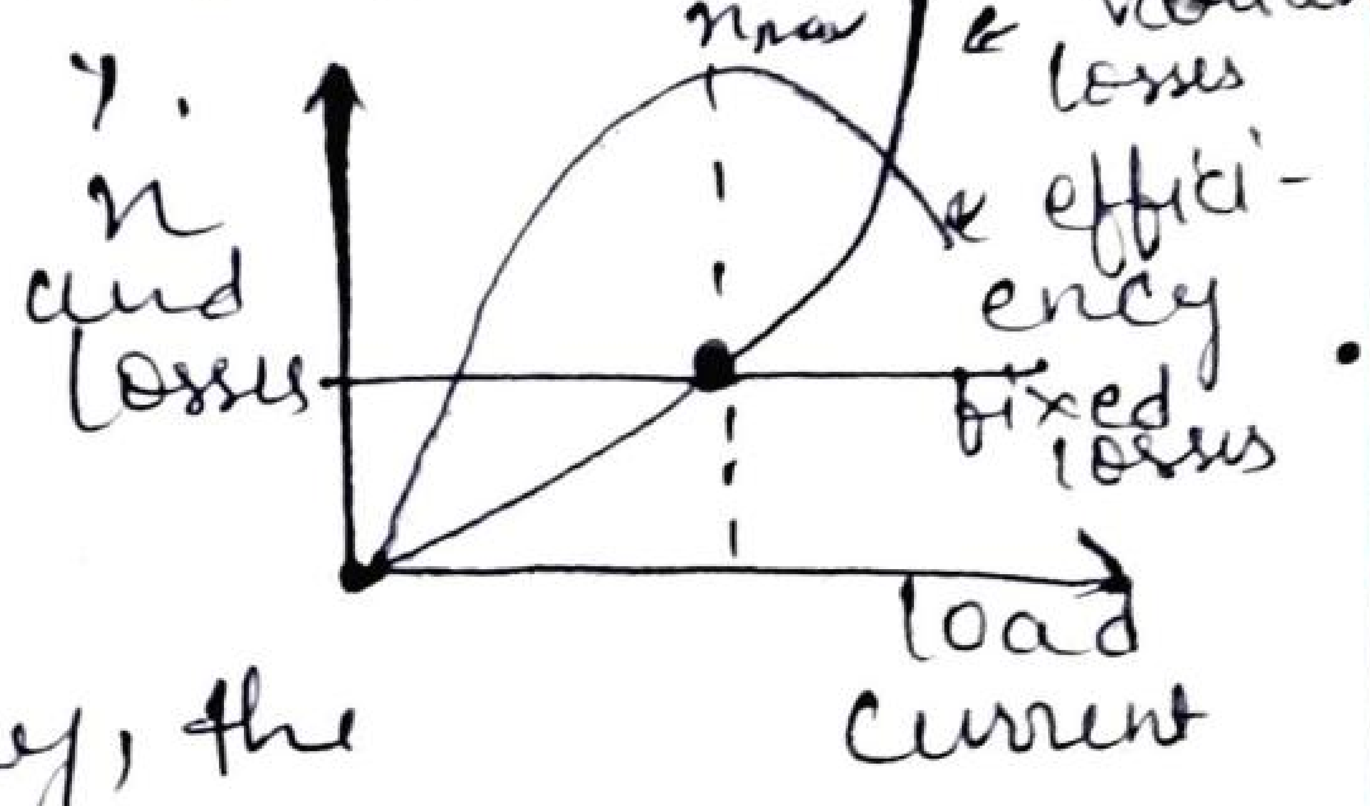
The magnetic & mechanical losses together are called stray losses. for the shunt & compound d.c machines where field current is constant, field copper losses are also constant. Thus stray losses along with constant field copper losses are called constant losses. while the armature current is dependent on the load and thus armature copper losses are called variable losses.

Thus for a d.c machine,

Total losses = Constant losses + Variable losses.

$$I^2 R_a - P_i = 0$$

$$I^2 R_a = P_i = P_{cu}$$



Thus for the maximum efficiency, the condition is,

Variable losses = Constant losses

The graph of losses and efficiency against load current.

Condition for Maximum efficiency —

In case of d.c generator the output is given by,

$P_{out} = VI$

P_{cu} = Variable losses = $I_a^2 R_a = I^2 R_a$

$I_a = I$

$$\%\eta = \frac{VI}{VI + I^2 R_a + P_i} \times 100 = \frac{1}{1+\left(\frac{IR_a}{V} + \frac{P_i}{VI}\right)} \times 100$$

The efficiency is maximum, when the denominator is minimum. According to maxima-minima theorem,

$$\frac{d}{dI}\left[1+\left(\frac{IR_a}{V} + \frac{P_i}{VI}\right)\right] = 0$$

$$\therefore \frac{R_a}{V} - \frac{P_i}{VI^2} = 0$$

4. Given data —

$V = 220V$

$R_a = 0.5\Omega$

$N_{FL} = 500rpm$

$I_a(FL) = 30A$

$R_x = 1\Omega$

(i) On full load with $R_x = 1\Omega$ in series with armature.

$E_b(FL) = V - I_a R_a$

$= 220 - 30 \times 0.5$

$= 205$ — (1)

$E_b'(FL) = V - I_a(R_a + R_x)$

$= 220 - 30(0.5+1)$

$= 220 - 45$

$= 175V$

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

$$\frac{N_{FL}}{N'_{FL}} = \frac{E_b(FL)}{E_b'(FL)}$$

$$\frac{500}{N'_{FL}} = \frac{205}{175}$$

$N(FL) = 426.8292$ rpm

(11) $T_2 = 2 \times T_{FL}$

$$\frac{T_{FL}}{2T_{FL}} = \frac{(I_a)_{FL}}{(I'_a)_{FL}}$$

$(I'_a)_{FL} = 2 \times 30 = 60A$

$(E_b')_{FL} = 220 - 60(0.5+1)$

$= 130V$

$$N'(FL) = \frac{500 \times 130}{205}$$

$= 317.073$ rpm