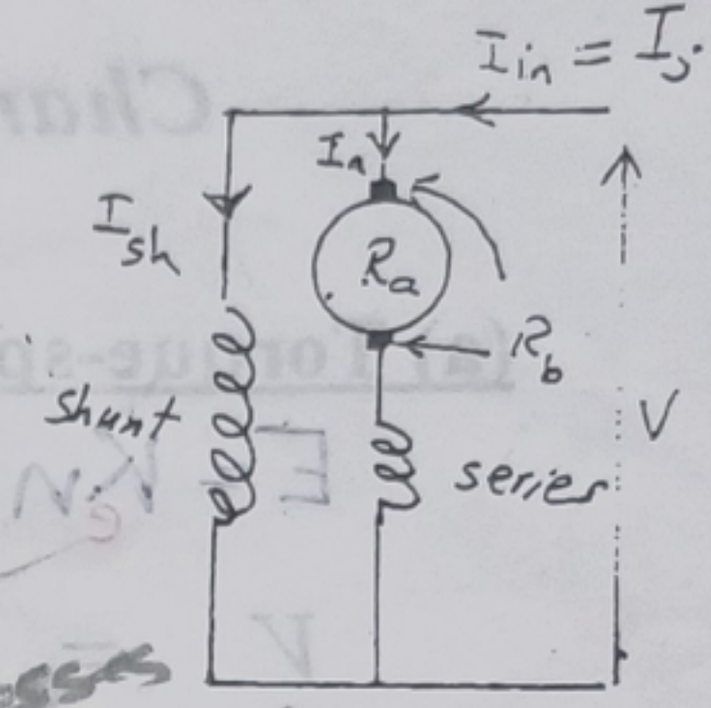
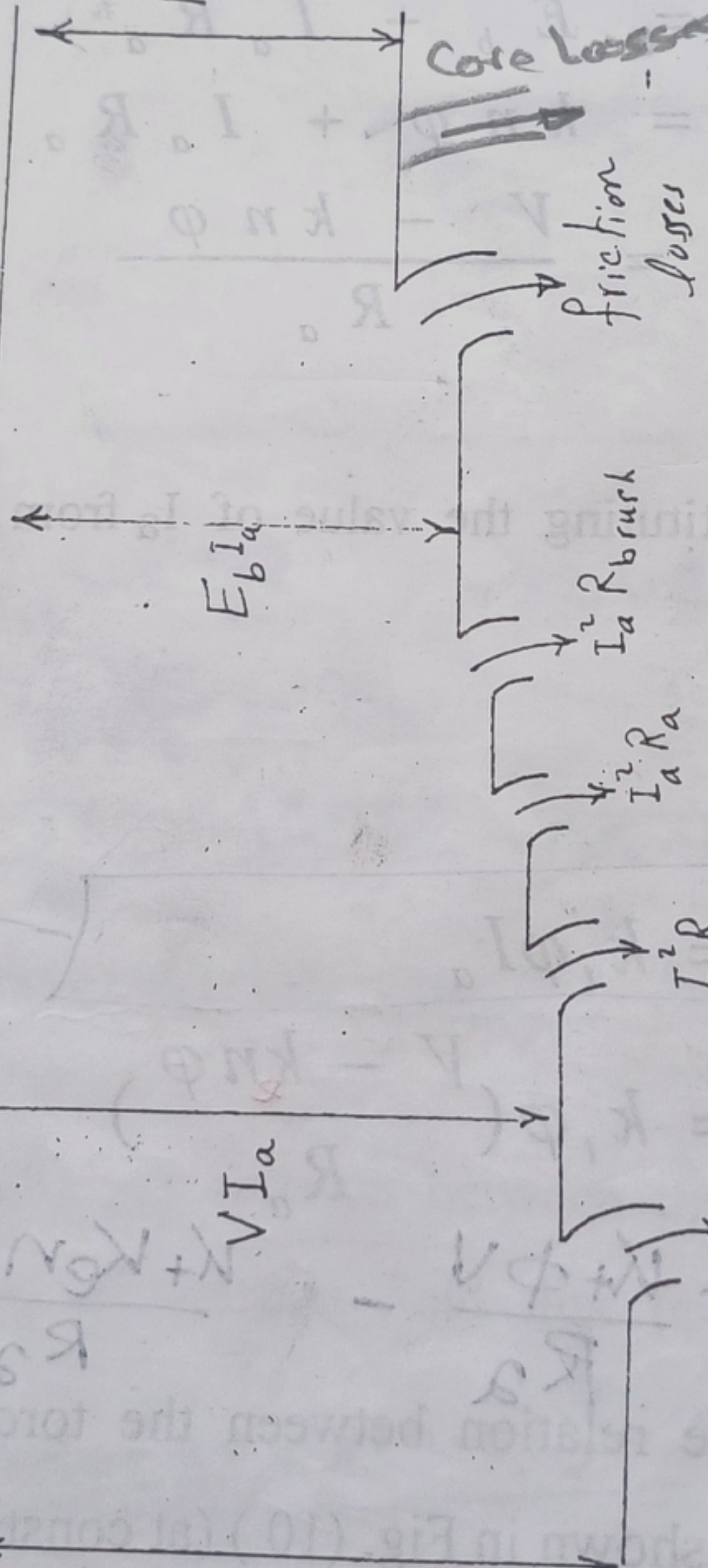
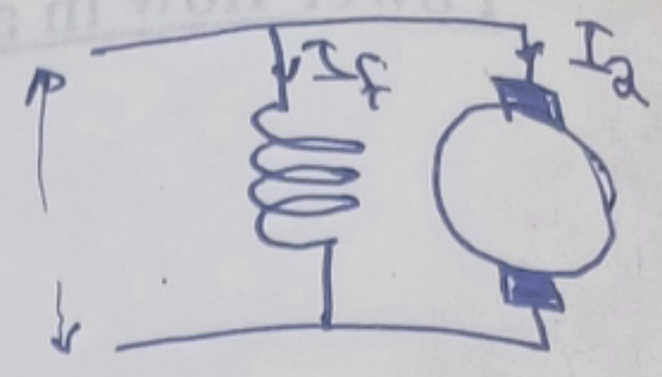
Power flow in a dc motor





Characteristic of dc shunt motor



(a) Torque-speed characteristic

$E = K_e n \Phi$

$$V = E_b + I_a R_a$$

$$V = k n \varphi + I_a R_a$$

$$I_a = \frac{V - k n \varphi}{R_a} \qquad (12)$$

Substituting the value of I_a from Eq. (12) into Eq. (9), yield

$$T = k_t \varphi I_a \qquad (9)$$

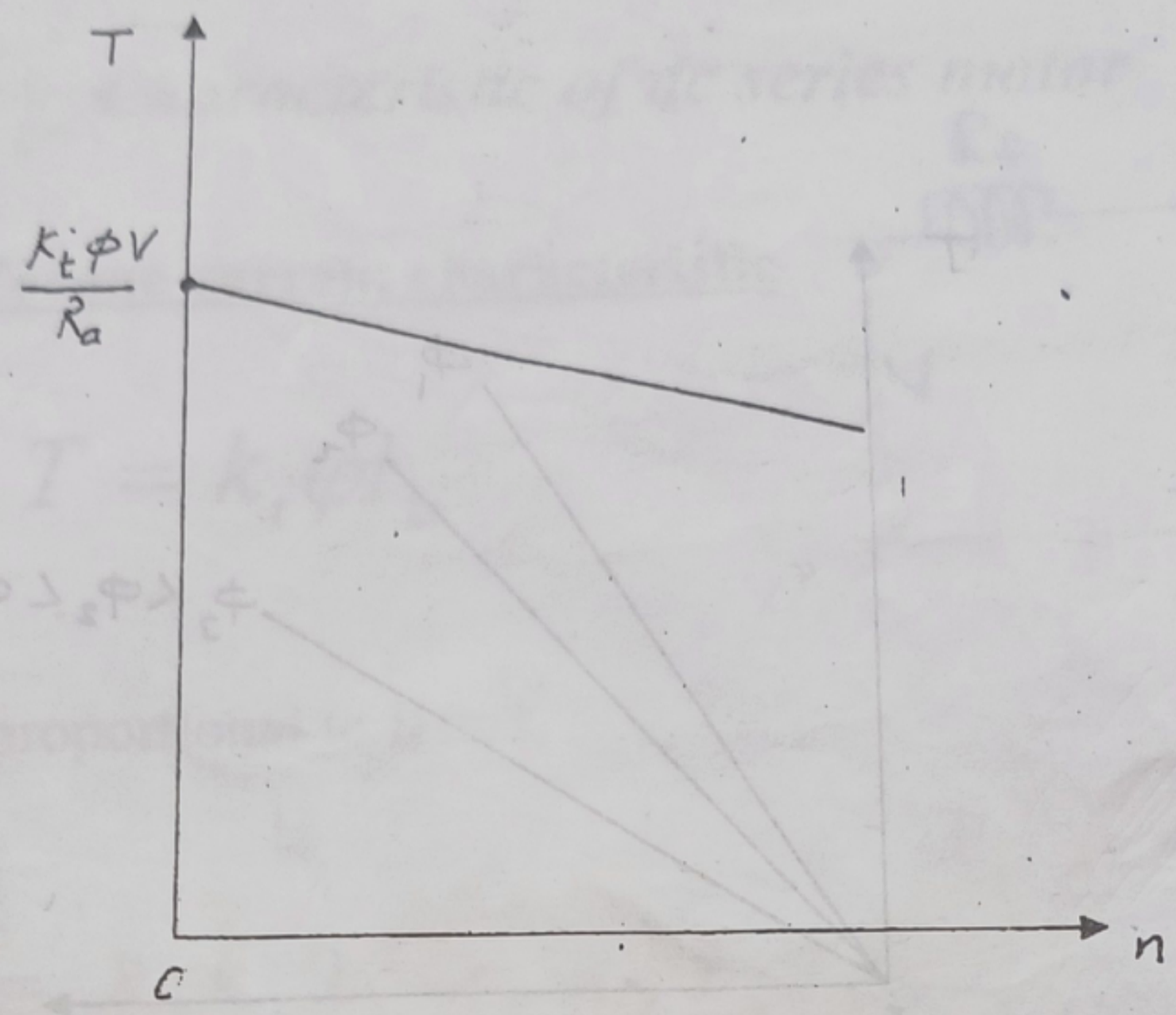
$$T = k_t \varphi \left(\frac{V - k n \varphi}{R_a}\right) \qquad (13)$$

$$= \frac{K_t \Phi V}{R_a} - \frac{K_t K_e n \Phi^2}{R_a}$$

The relation between the torque and the motor speed is shown in Fig. (10) (at constant applied voltage and field current)

Ex:- A four pole wave wound armature operating in a Field of flux of 0.01 Weber, has 720 armature conductors. Determine the for torque as a function of speed, if $V_t = 250V$ and $R_a = 0.1\Omega$

Solution



$$K_t = \frac{PZ}{2\pi a} = \frac{1}{2\pi} \times 4 \times \frac{720}{2} = 229.2$$

$$K_e = \frac{PZ}{60a} = \frac{4 \times 720}{60 \times 2} = 24$$

$$\frac{K_t \phi V_t}{R_a} = \frac{229.2 \times 0.01 \times 250}{0.1} = 5730 \text{ N.m.}$$

(b) Torque-current characteristic

From Eq.(9), the relation between the torque and armature current at constant field flux (φ) is shown in Fig.11.

$$\frac{K_e K_t \phi^2}{R_a} = \frac{229.2 \times 24 \times (0.01)^2}{0.1} = 5.501$$

$$T = (5730 - 5.501n) \text{ N.m.}$$

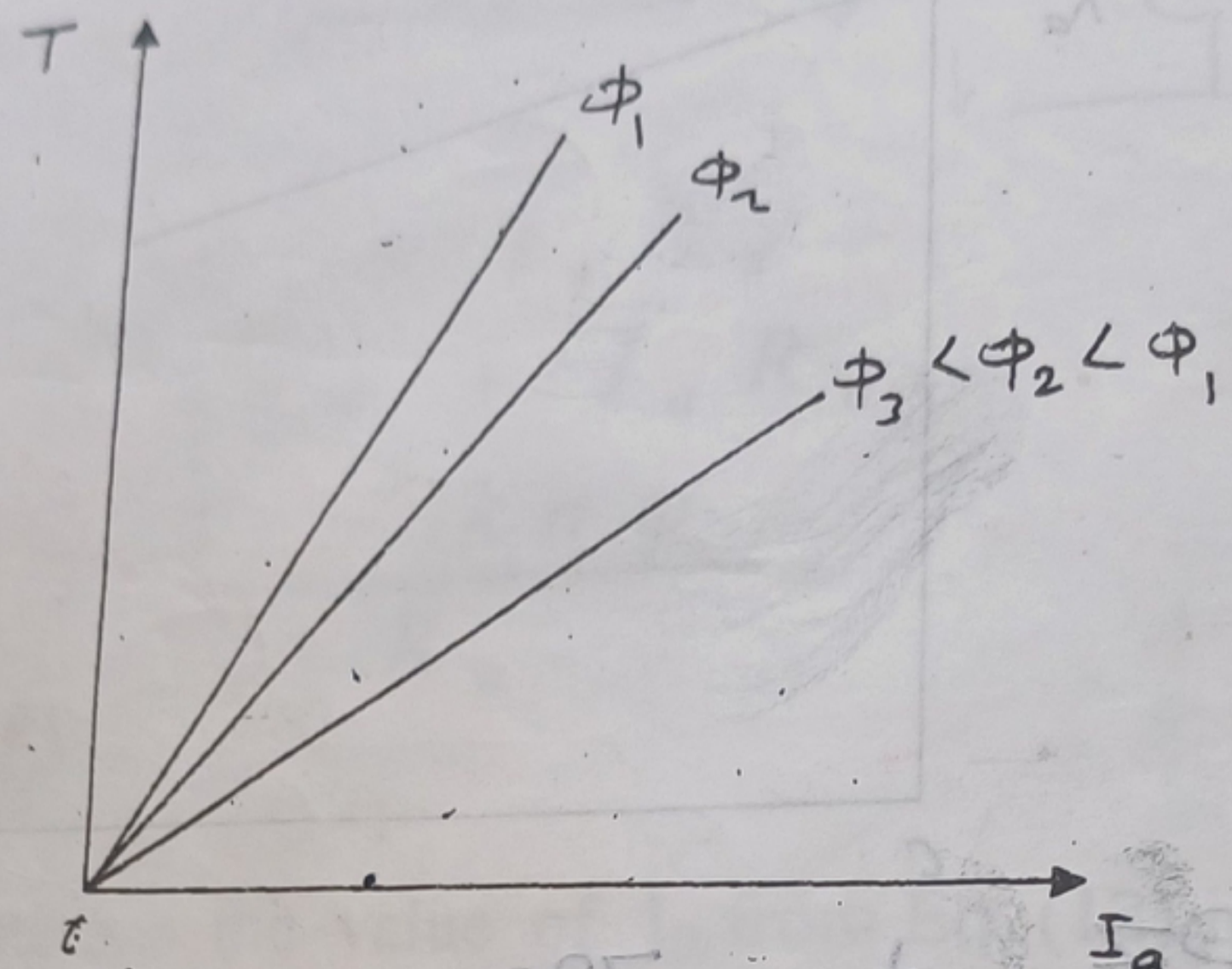


Fig.11

$$T = K_t \Phi I_a$$

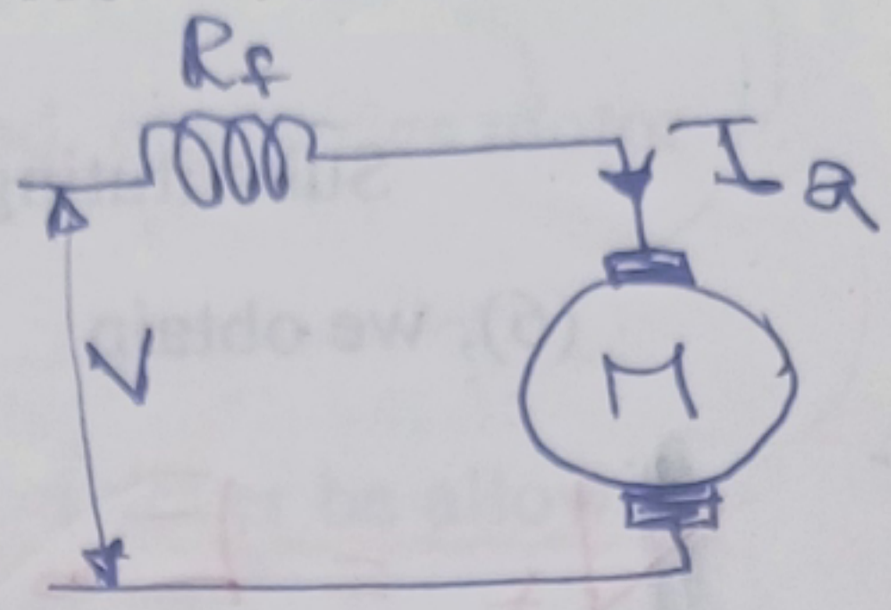
علاقة خطية

Linear ~~teanir~~

خصائص مختلفة لـ ـــــ

Field

Characteristic of dc series motor



(a) Torque-current characteristic

$$T = k_t \varphi I_a$$

φ is proportional to I_f or I_a

$$T = k_t k_1 I^2 = k_2 I_a^2 \qquad (14)$$

$$\therefore I_a = k_3 \sqrt{T}$$

The relation between torque and armature current is parabolic and as shown in Fig. 12.

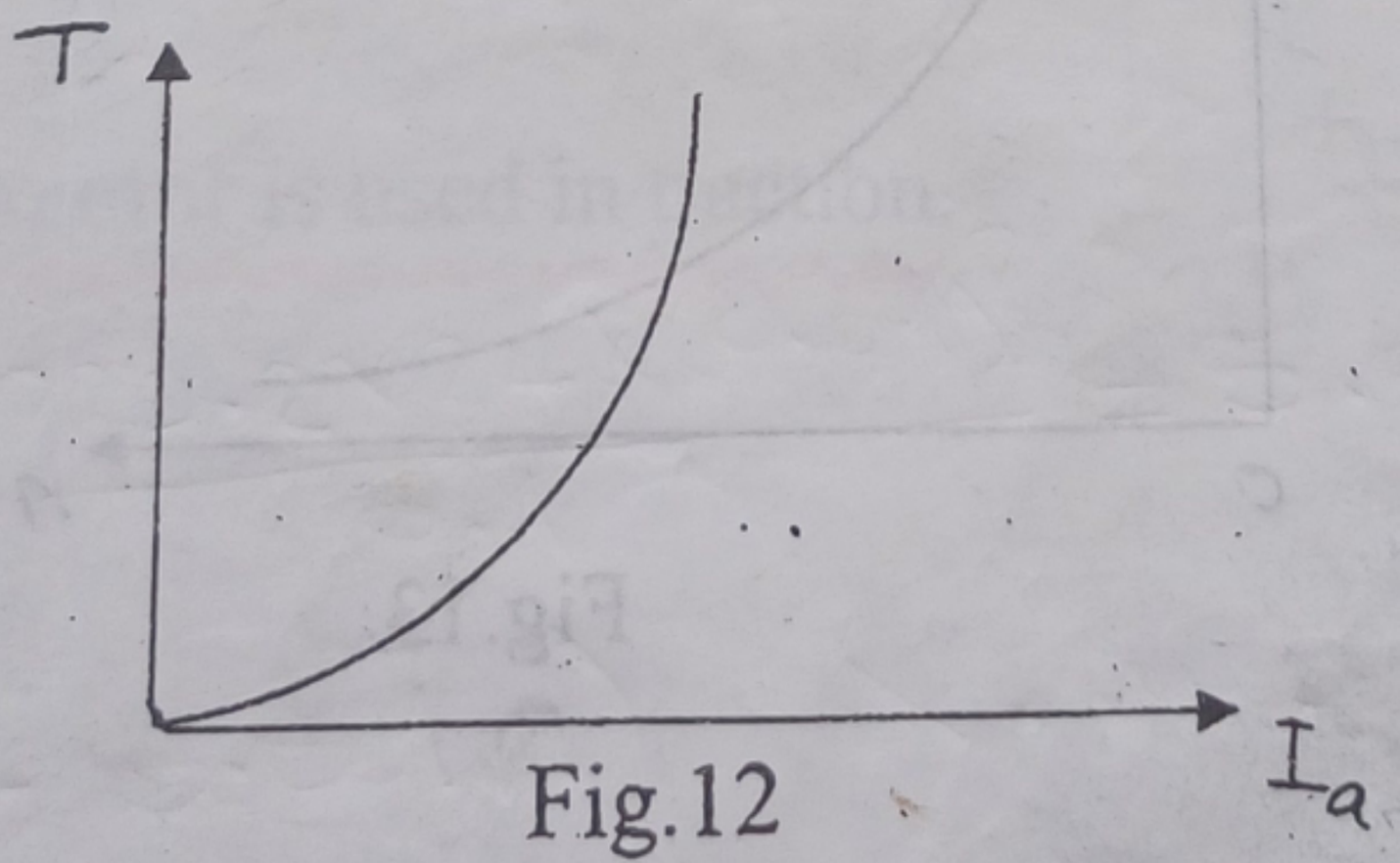


Fig.12

(b) Torque-speed characteristic

Substituting the value of I_a from Eq. (14) into Eq. (6), we obtain

$$E_b = V - I_a R_a$$

$$k_e n \varphi = V - R_a k_3 \sqrt{T}$$

$$\therefore n = \frac{V - R_a k_3 \sqrt{T}}{k_4 \sqrt{T}} \quad \ldots (15)$$

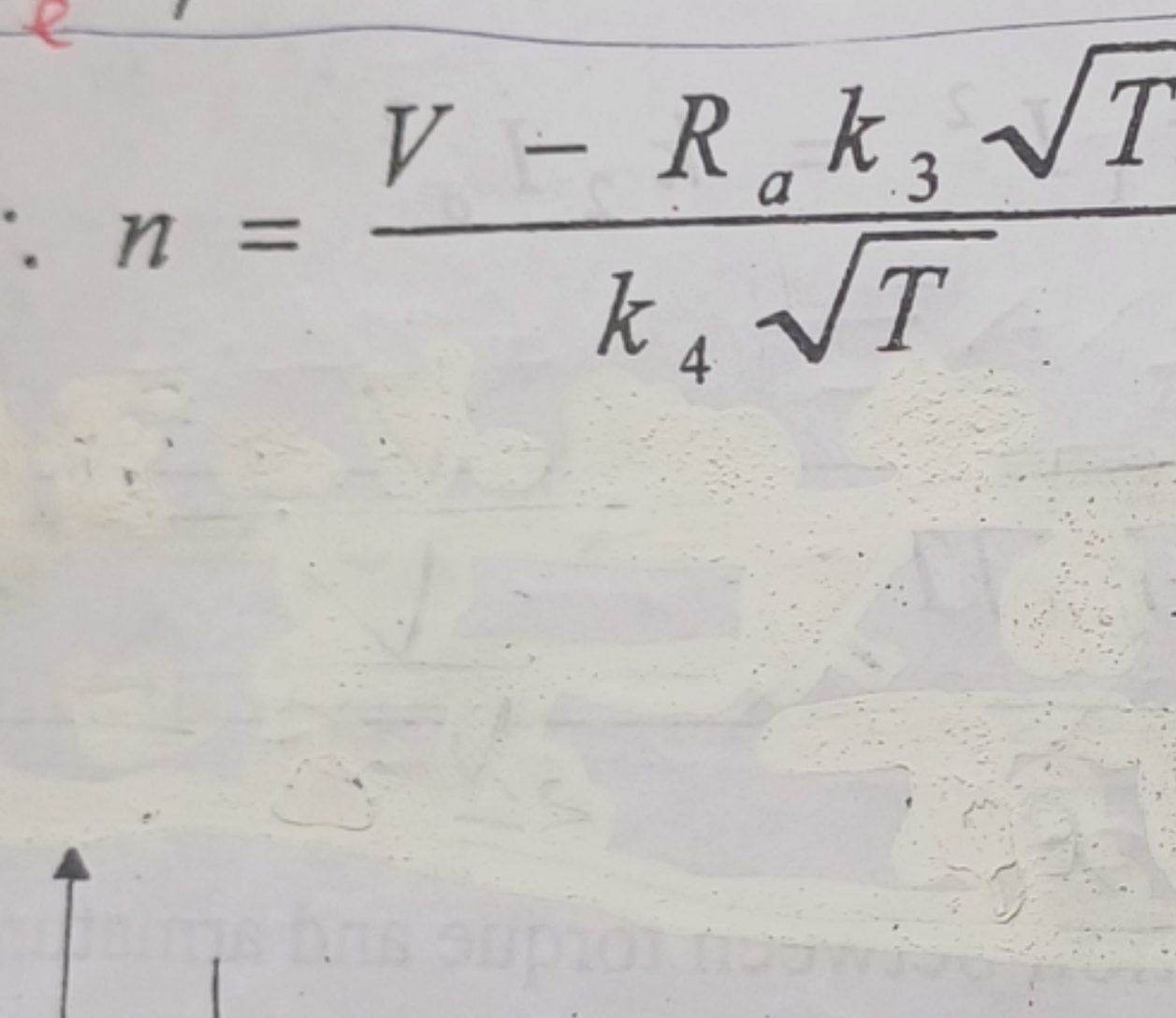


Fig. 13

- As a consequence of the inverse relationship between speed and torque, the speed of a series motor rises rapidly as the load decreases.

- In practice a series motor should never be allowed to run at light load as the excessive speeds may result in damage to the machine due to the mechanical forces present at these speeds.

- As shown from Fig.13, the series motor has **a high starting torque,** while the starting torque in the shunt motor is limited by the value $k\phi V/R_a$ as shown from Fig.10.

- Series motor is used in traction.

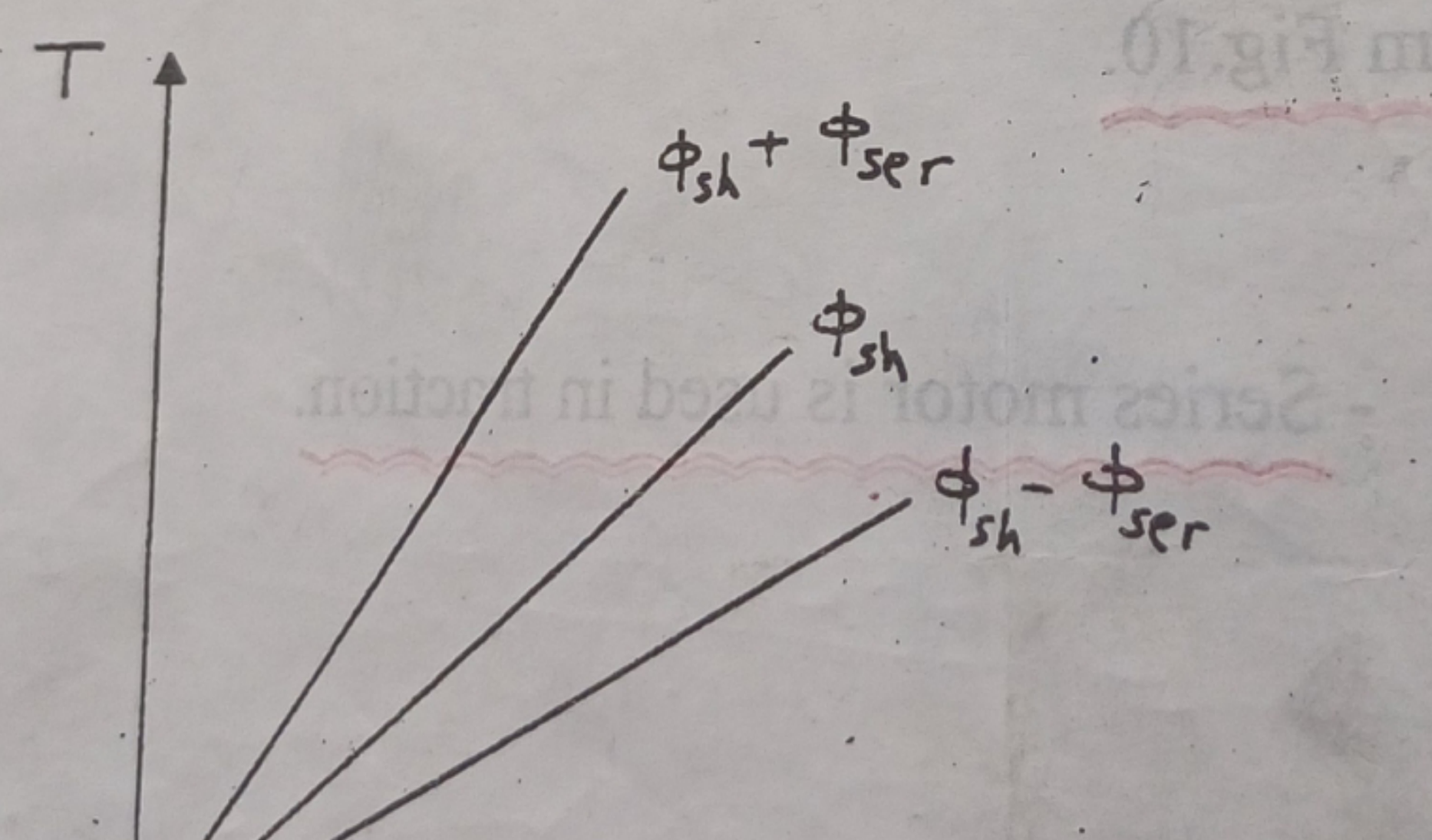
Characteristic of dc compound motor

The characteristics of dc compound motor depend on the degree of compounding.

The degree of compounding depends on the ratio of series ampere turns and the shunt ampere turns at full load.

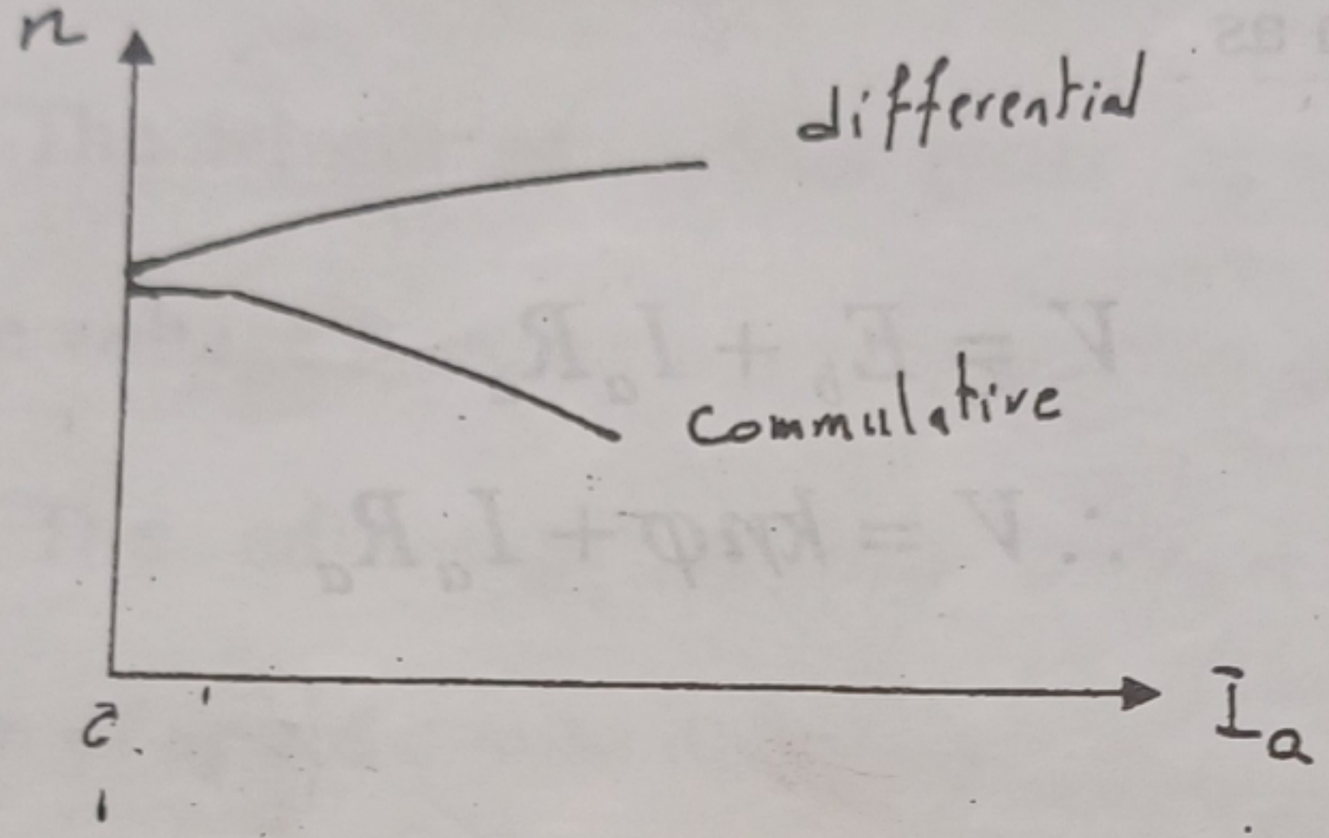
(a) Torque-current characteristic

$$T = k_t I_a (\varphi_{sh} \pm \varphi_{ser})$$



(b)Speed-current characteristic

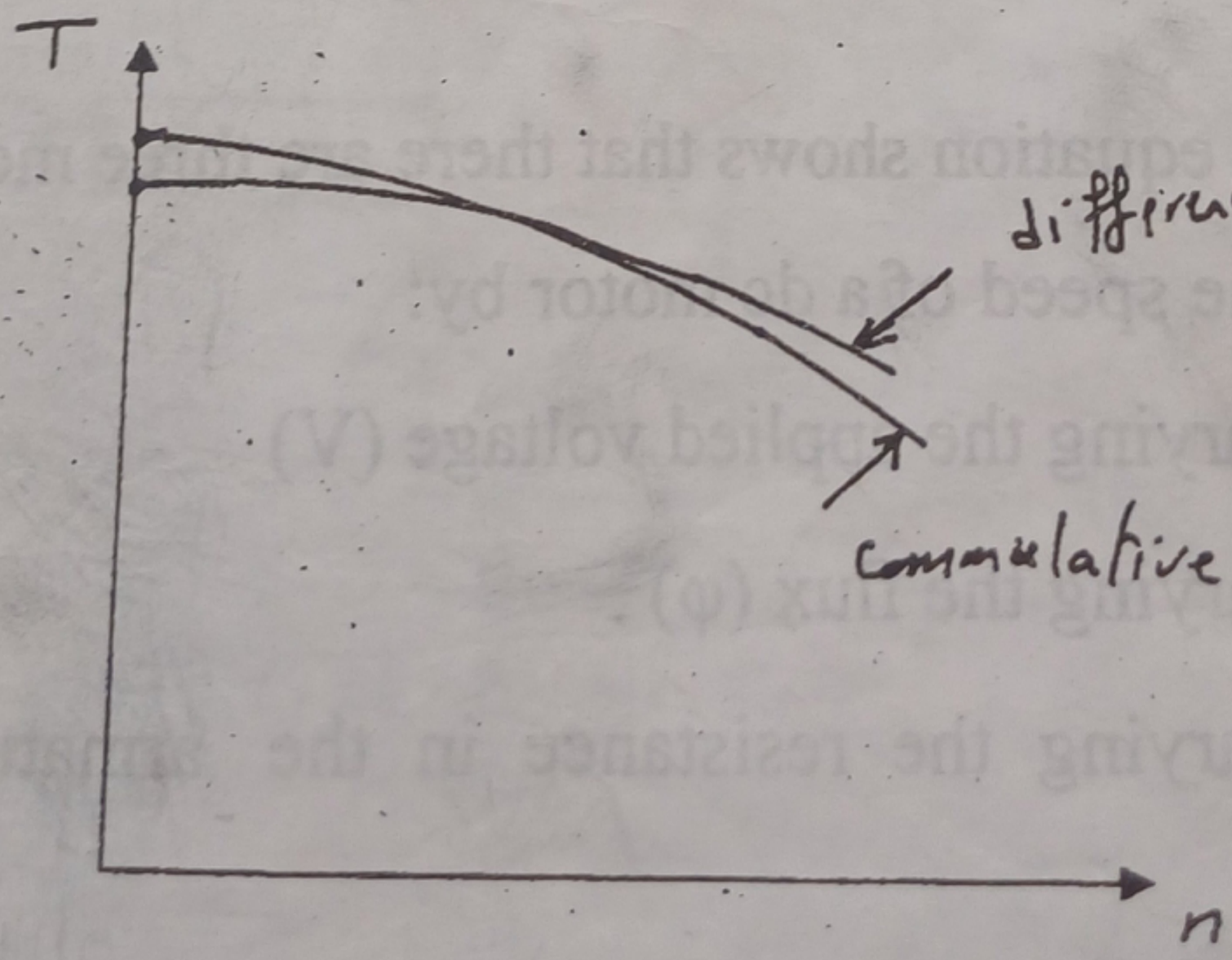
$$\therefore \quad n = \frac{V - I_a R_a}{k_2 (\varphi_{sh} \pm \varphi_{ser})}$$



(c) Torque-speed characteristic

$$T = k_t I_a (\varphi_{sh} \pm \varphi_{ser})$$

$$T = k_t (\varphi_{sh} \pm \varphi_{ser})\left(\frac{V - kn(\varphi_{sh} \pm \varphi_{ser})}{R_a}\right)$$



Speed control of dc motors

It has been shown earlier that relationship between the speed of a dc motor and the motor parameters could be written as

$$V = E_b + I_a R_a$$

$$\therefore V = kn\varphi + I_a R_a$$

$$\therefore n = \frac{V - I_a R_a}{k\varphi}$$

This equation shows that there are three methods for varying the speed of a dc motor by:

a- Varying the applied voltage (V)

b- Varying the flux (φ)

c- Varying the resistance in the armature circuit, (R_a)

a- Varying the applied voltage (V)

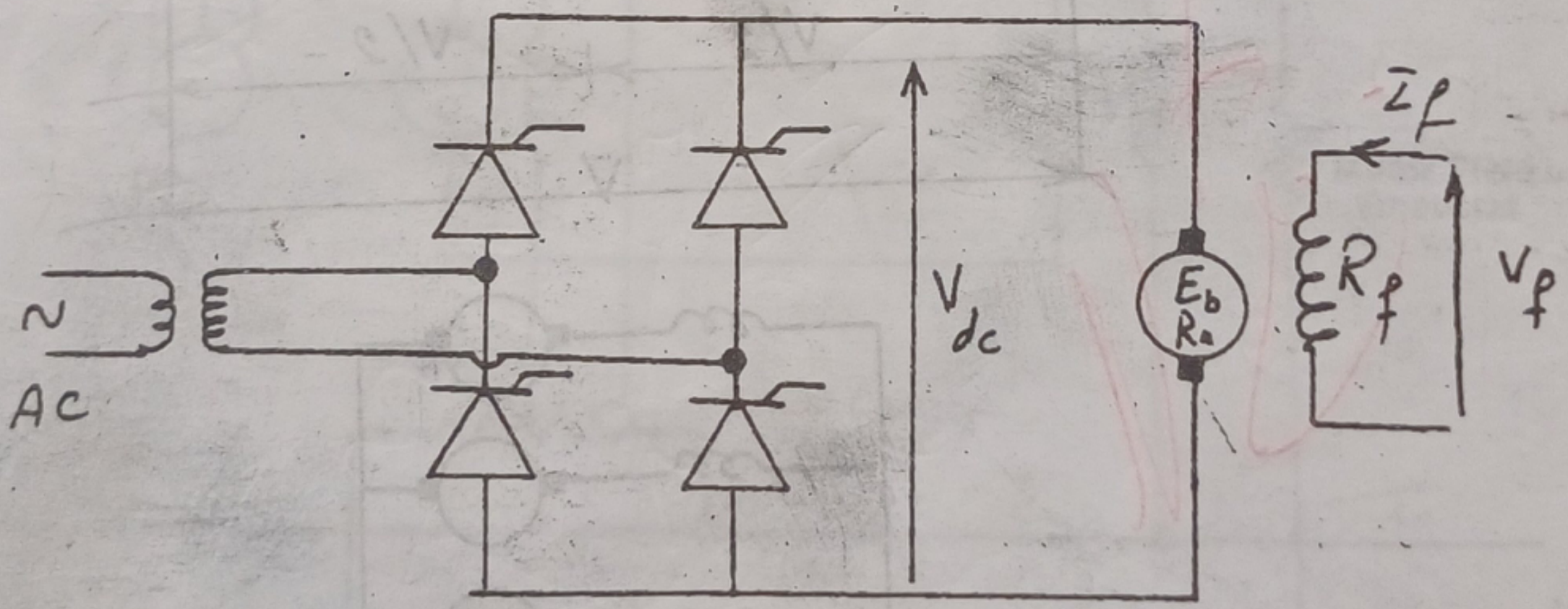
Varying the voltage applied to the armature circuit can control the speed of an armature.

i- Operation on a rectifier supply

The advent of various types of rectifiers, static variable voltage systems is used wherever possible.

The advantage of this method is a smooth variation of speed can be obtained.

The disadvantage is the cost is high.



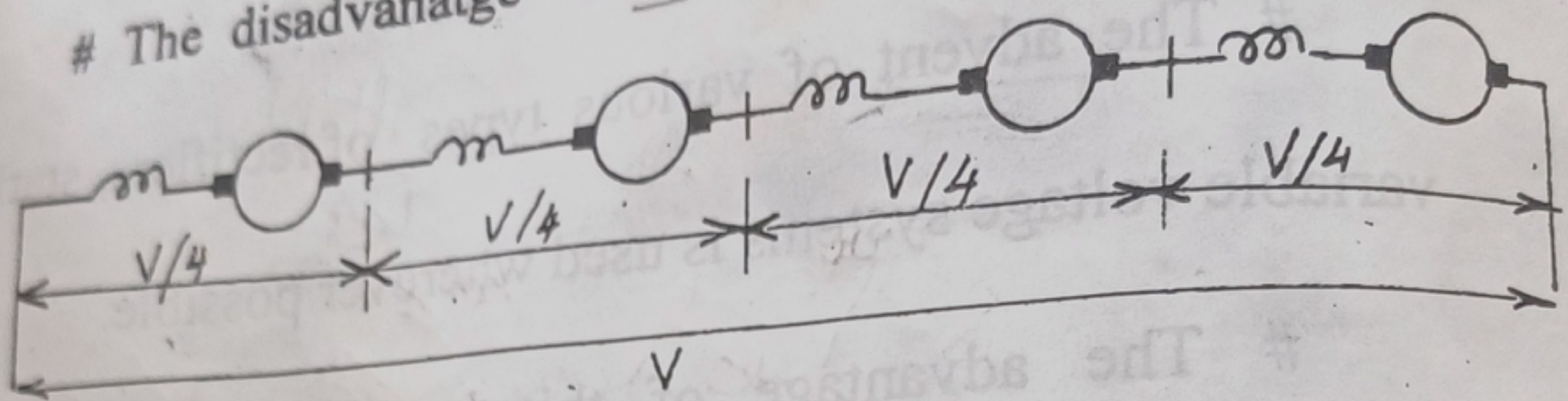
1-ph. Bridge circuit

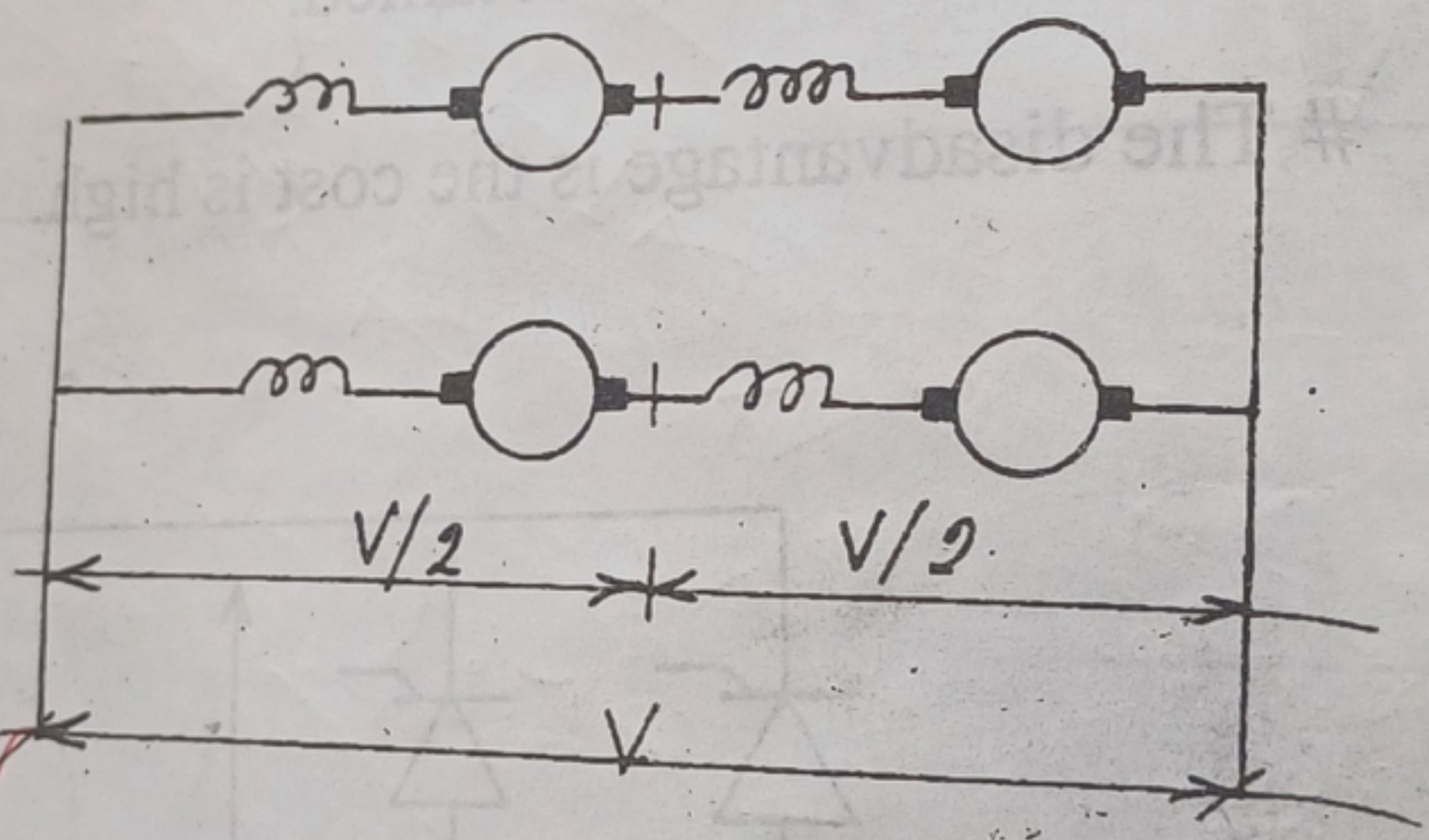
ii- Series- paralleled control

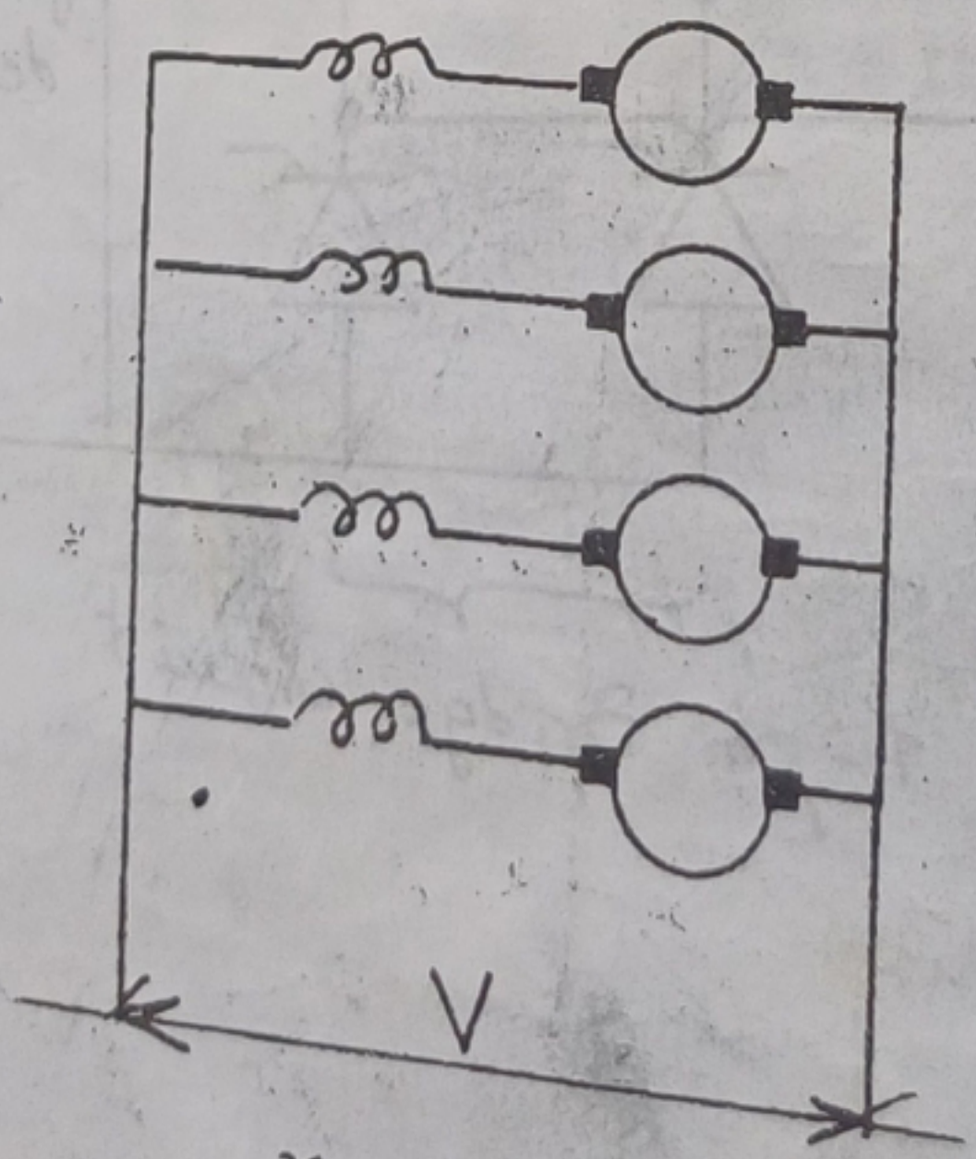
This method requires even number of dc motors

The advantage of this method is low cost

The disadvanatge is discrete values of speed are







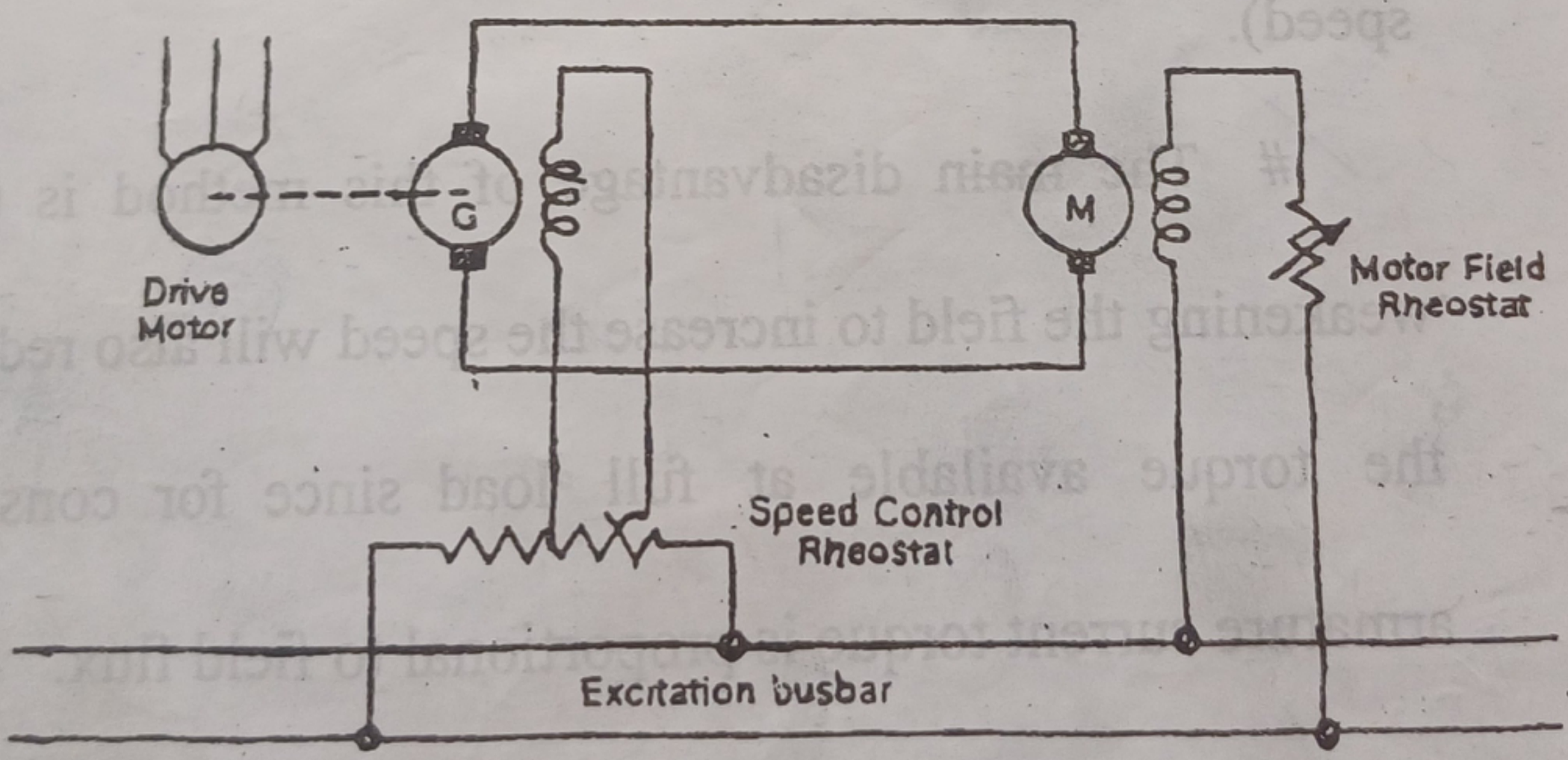
iii- variable voltage control by Ward-Leonard method

This method of control not only gives a wide range of operating speed, but also reduces to the very minimum of waste of energy that may take place at starting.

The disadvatage is high cost

In this method, the motor armature is connected directly to the variable voltage generator.

The main control is performed by varying the generator field current.



$$T = K\Phi I_a \qquad n = \frac{V - I_a R_a}{K\Phi}$$

b- Varying the flux Φ

The most common method of speed control.

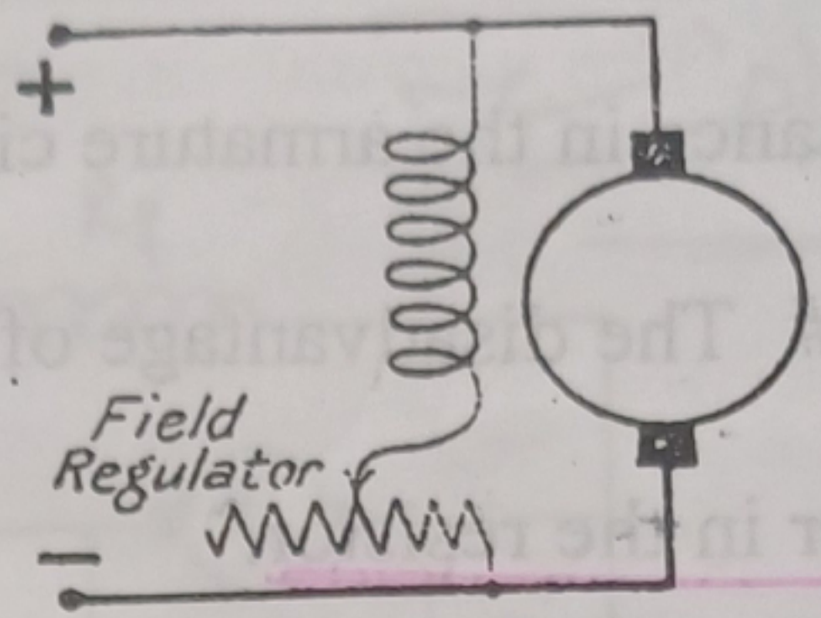
The control is occurred by means of a field rheostat placed in series with the shunt field.

As the field voltage is generally constant, varying this resistance will cause the field current to change, producing change in flux.

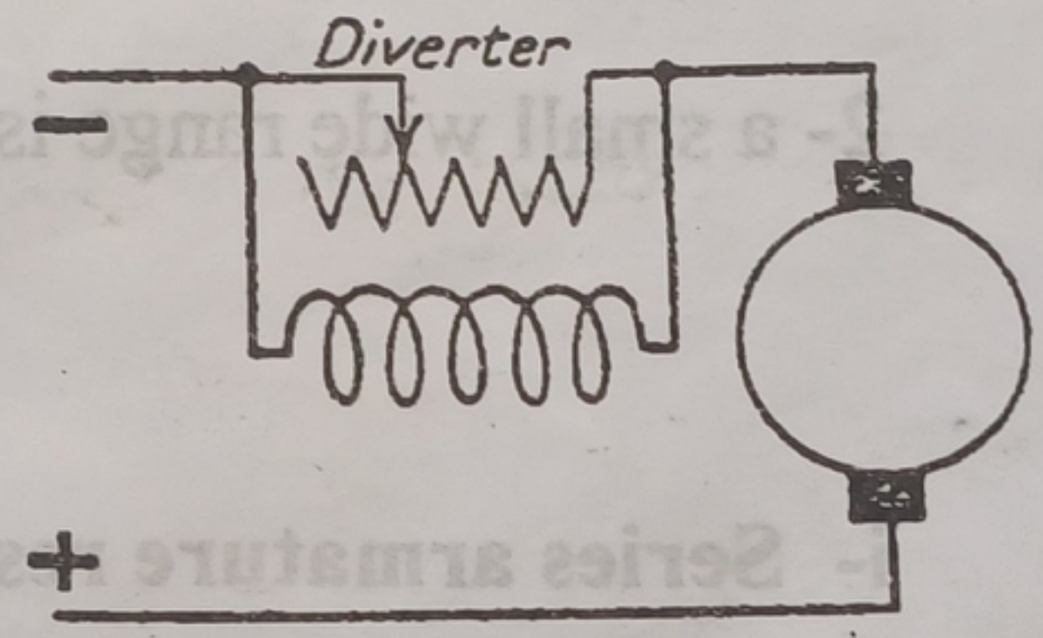
The advantage is wide speed ranges can be obtained (we can obtain a speed greater than the rated speed).

The ~~main~~ disadvantage of this method is that weakening the field to increase the speed will also reduce the torque available at full load since for constant armature current torque is proportional to field flux.

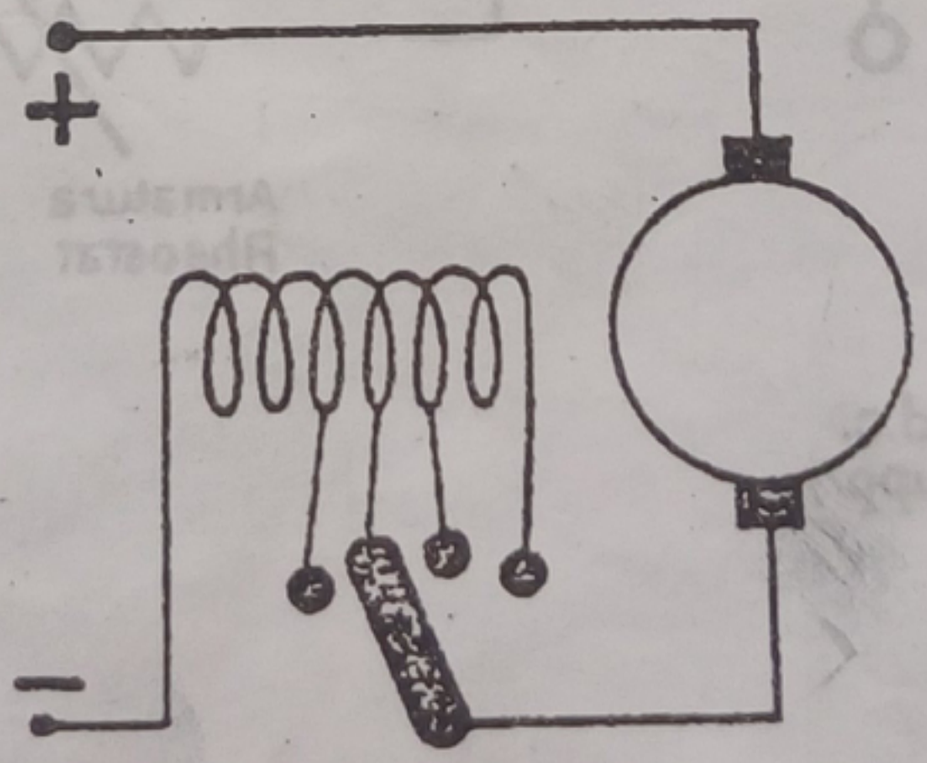
for a dc shunt motor



for a dc series motor



DIVERTER METHOD
OF FIELD CONTROL



TAPPED-FIELD
METHOD OF CONTROL

$T = K \Phi I_a$ | $n = \frac{V - I_a R_a}{K \Phi}$

c- Varying the resistance in the armature circuit, R_a

The speed of a dc motor is varied to place a resistance in the armature circuit.

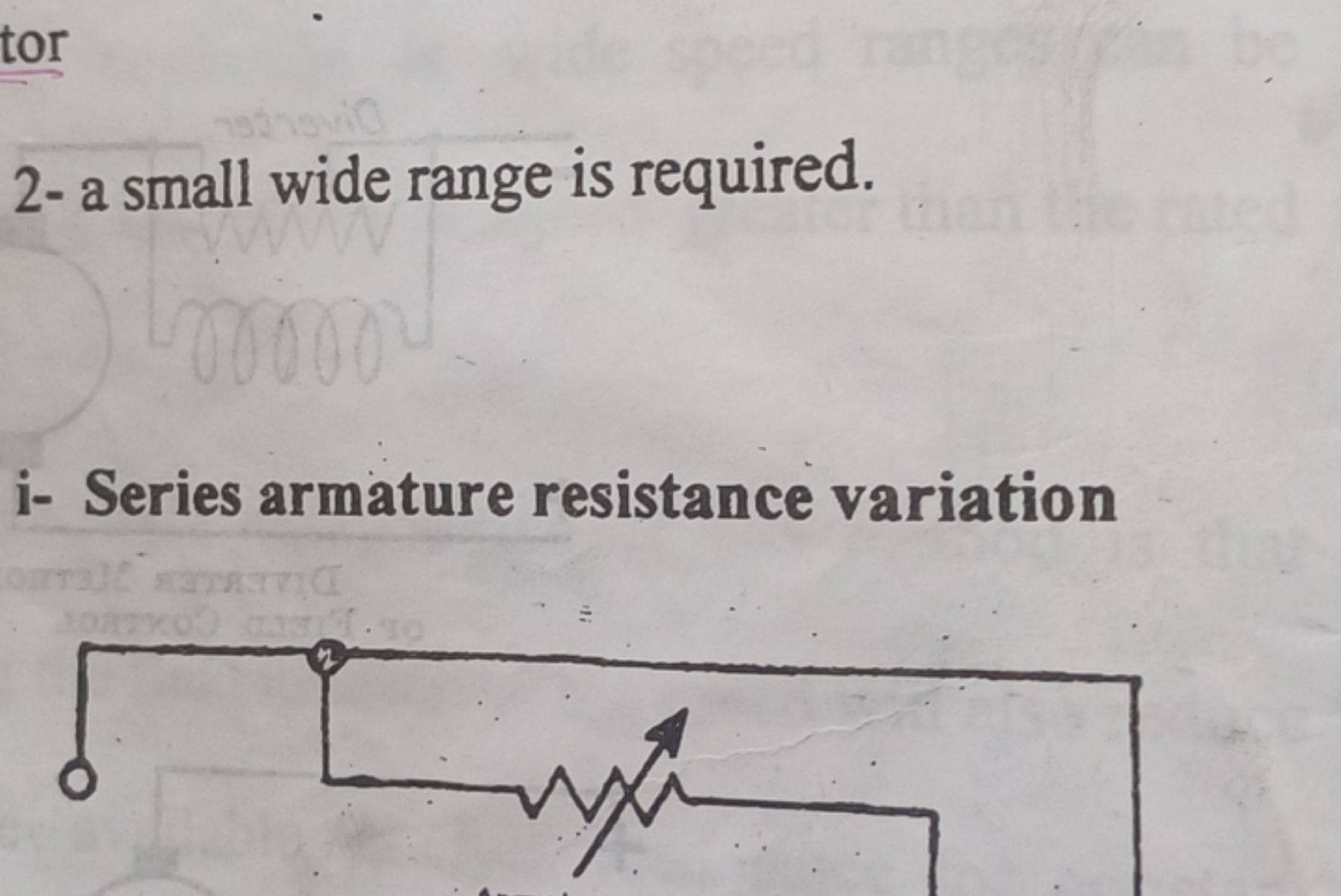
The disadvantage of this method is that the loss of power in the resistor.

This method is used:

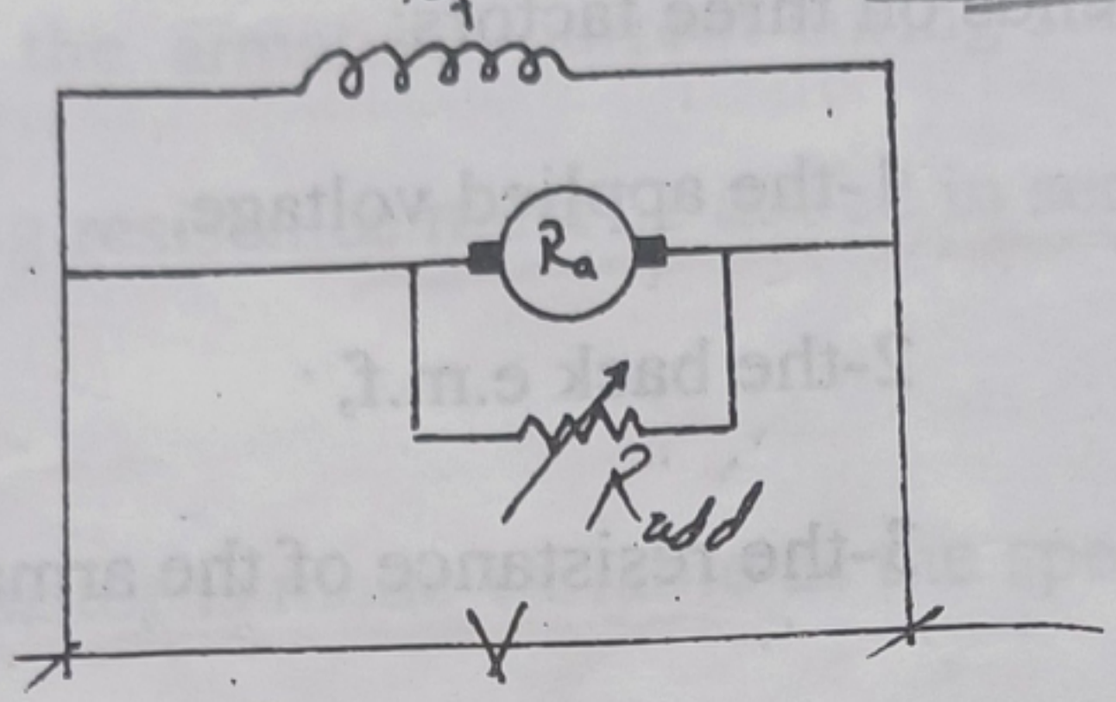
1- only where operating efficiency is not a major factor

2- a small wide range is required.

i- Series armature resistance variation



ii- Shunted armature connection



Starting of dc motors

The current in the armature circuit of a dc motor depends on three factors:

1-the applied voltage,

2-the back e.m.f,

3-the resistance of the armature circuit.

These factors are related by the expression

$$I_a R_a = V - E_b$$

$$I_a = \frac{V - E_b}{R_a}$$

$$I_a = \frac{V - kn\varphi}{R_a}$$

At standstill, when the speed is zero, there is no back emf and the expression reduced to

$$I_a = \frac{V - 0}{R_a}$$

at starting

at speed = 0

To limit the armature current during starting an additional starting resistance must be added in series with the armature.

If the resistor is made variable as the speed of the armature increases the resistance can be gradually reduced in order to ensure that is sufficient to produced the required torque.

The starting current has two limits:

- upper limit is determined by the maximum current can pass in the armature winding
- lower limit is determined by the minimum current required to produce torque in order to accelerate the load.

Starting of dc shunt motors

In practice the starting resistance is cut out in a series of steps, thus obtaining a smooth start.

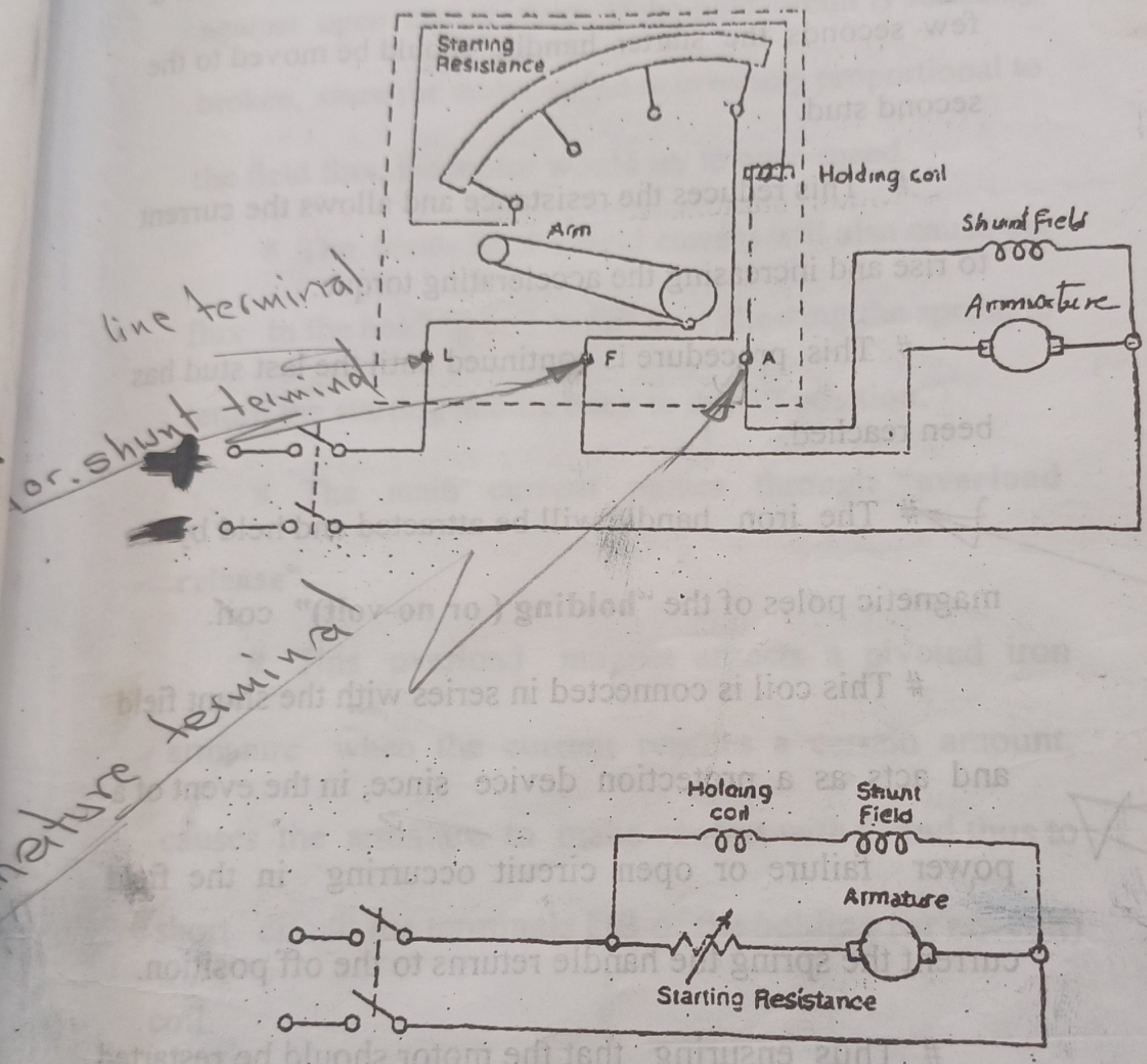
Motor starters, for industrial work, are provided with overload and no-volt releases.

The following figure shows the schematic diagram and the wiring diagram for a three-point manual starter for shunt wound dc motor.

The starter enclosed by broken lines has three terminals, L (line terminal), F (field or shunt terminal) and A (armature terminal).

The starter arm is held in the off position by a strong spiral spring.

The motor is started on by moving the starter arm to stud one with the main switch closed.


Starting Resistance
Holding coil
Arm
Shunt Field
Armature
L
F
A
line terminal
shunt terminal
armature terminal

Holding coil
Shunt Field
Armature
Starting Resistance

The armature now begin to accelerate and after a few seconds the starter handle should be moved to the second stud.

This reduces the resistance and allows the current to rise and increasing the accelerating torque.

This procedure is continued until the last stud has been reached.

The iron handle will be attracted and held by the magnetic poles of the **"holding (or no-volt)"** coil.

This coil is connected in series with the shunt field and acts as a protection device since, in the event of a power failure or open circuit occurring in the field current the spring the handle returns to the off position.

Thus ensuring that the motor should be restarted when the supply is switched off.

This arrangement provides further protection against open circuit field if the field circuit is suddenly broken, since the motor speed is inversely proportional to the field flux, the motor would try to over-speed.

The break in the field current will also cause the flux in the holding coil to fall thus allowing the spring to return the starting handle back to the off position.

The main current passes through **"overload release".**

This overload magnet attracts a pivoted iron armature when the current reaches a certain amount, causes the armature to make contact with C and thus to short circuit the terminals DB of the holding (or no-volt) coil.

A starter of this type has the **advantages:**

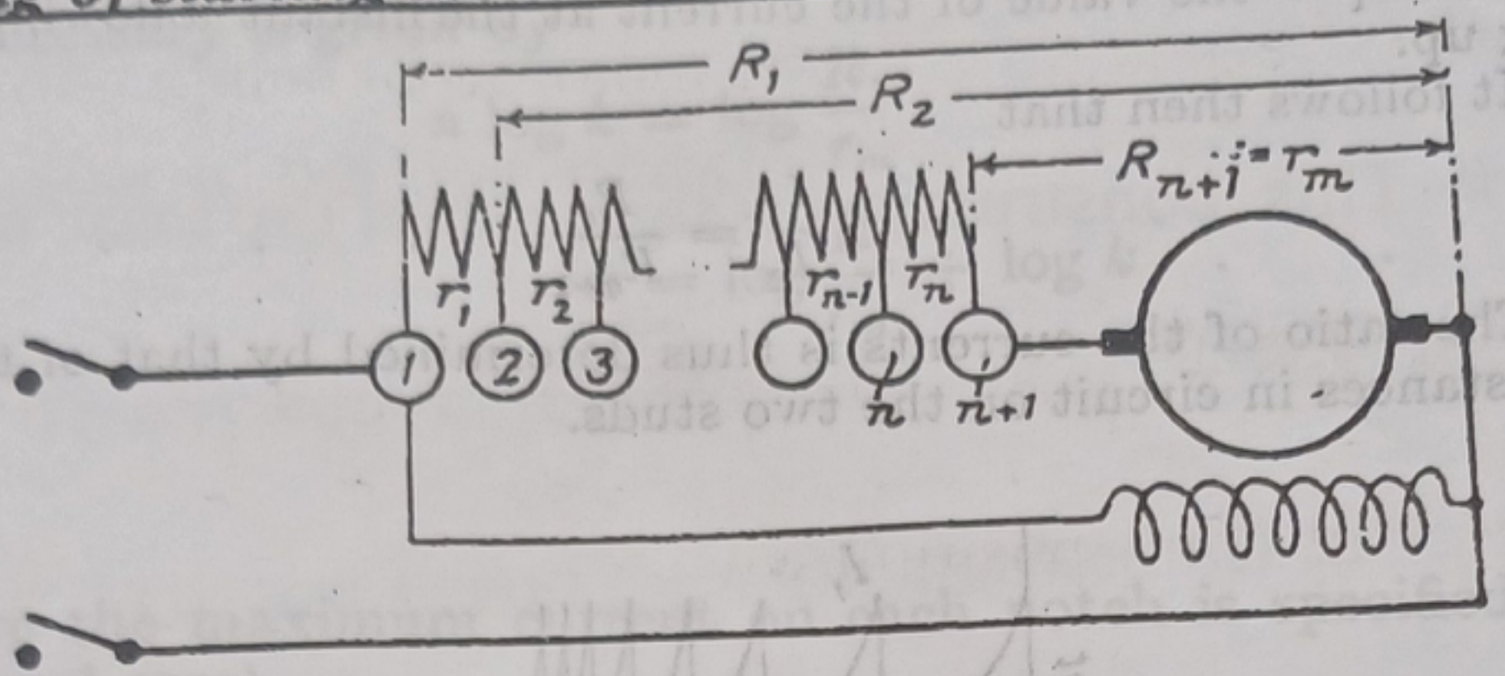
1) Prevent Prevents the motor from being burnt out due to over load.

2) Prevent the starter handle from being left in the " full on" position when the motor is shut down or the supply voltage fails.

3) Prevent the possibility of the motor starter handle being left on any intermediate studs.

4) Switches off the if the field current is weakened (avoids the possibility of a too high speed).

Grading of starting resistance for dc shunt motor



The starting resistance is reduced in steps

For n resistance elements (r_1, r_2 , r_3,...) ,and n+1

steps (n+1 studs)

$$R_1 = (r_1 + r_2 + \ldots + r_n) + r_m,$$

If then on the q^{th} stud the current has dropped to I_2

,the resistance in the circuit is reduced from R_q to R_{q+1}.

The moor speed being unaltered for a small

instant, the back emf is unchanged.

$$I_2 = \frac{V - E}{R_q}$$

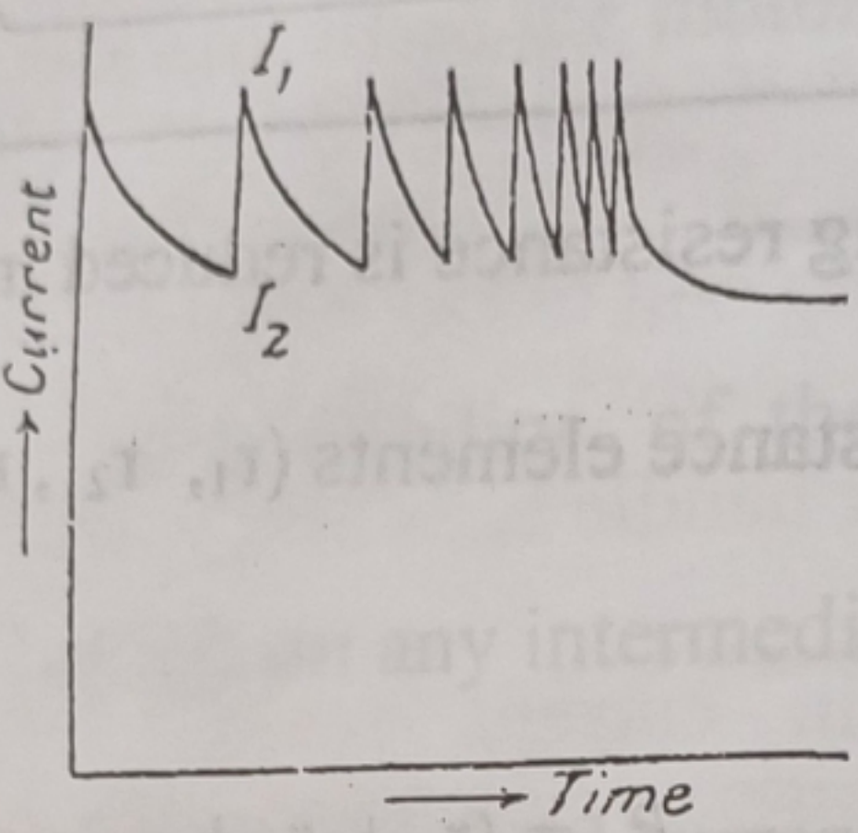
$$I_1 = \frac{V - E}{R_{q+1}}$$

where I_1 = the value of the current at the instant following notching up.

It follows then that

$$\frac{I_1}{I_2} = \frac{R_q}{R_{q+1}} \quad . \quad . \quad .$$

The ratio of the currents is thus determined by that of the total resistances in circuit on the two studs.



Variation of Starting Current with Time

$$\frac{I_1}{I_2} = \frac{R_1}{R_2} = \frac{R_2}{R_3} = \ldots = \frac{R_{n-1}}{R_n} = \frac{R_n}{R_{n+1}} \quad . \quad .$$

The resistance values thus form a geometrical progression, the common ratio of which is simply the ratio of the currents. Hence if

$$k = I_1/I_2,$$

$$k^n = \frac{R_1}{R_2} \times \frac{R_2}{R_3} \times \ldots \times \frac{R_{n-1}}{R_n} \times \frac{R_n}{R_{n+1}} = \frac{R_1}{R_{n+1}} = \frac{R_1}{r_m}$$

n being the number of resistance elements,

$R_{n+1} = r_m$ = the resistance of the main circuit of the motor, i.e. armature + interpole windings, and

Hence

$$k = \sqrt[n]{\frac{R_1}{r_m}} \quad . \quad . \quad .$$

This gives at once the common ratio k if the number of elements and the resistances R_1 and r_m are known.

If it is desired to keep the ratio k to a fixed value, the number of steps necessary is given by

$$n \log k = \log \frac{R_1}{r_m}$$

i.e.

$$n = \log \frac{R_1}{r_m} \div \log k \quad . \quad .$$

Where the maximum current on each notch is specified (this is the normal case),

$$k = \sqrt[n]{\frac{I_1 R_1}{I_1 r_m}} = \sqrt[n]{\frac{V}{I_1 r_m}} \quad . \quad . \quad .$$

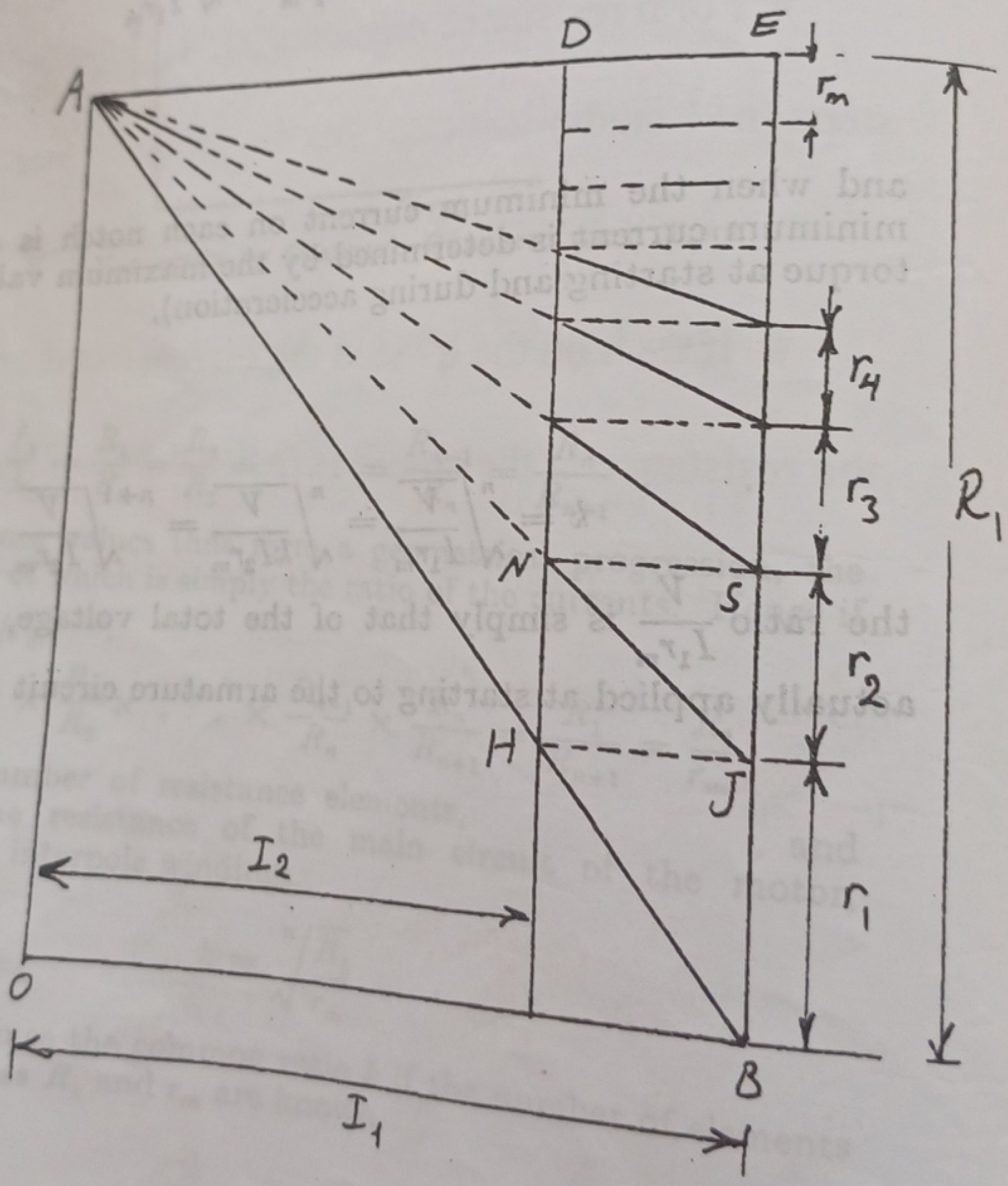
and when the minimum current on each notch is specified (this minimum current is determined by the maximum value of the load torque at starting and during acceleration),

$$k = \sqrt[n]{\frac{V}{I_1 r_m}} = \sqrt[n]{\frac{V}{k I_2 r_m}} = \sqrt[n+1]{\frac{V}{I_2 r_m}} \quad . \quad .$$

the ratio $\frac{V}{I_1 r_m}$ is simply that of the total voltage, to the voltage actually applied at starting to the armature circuit of the motor.

Graphical constructions for determining grading of starting resistance of dc shunt motor

This construction is used when the max. and min. current are given.



Procedure

* BE represents, to scale, the total resistance in the main circuit on the first stud (R_1).

* To any convenient scale BO is drawn to represent the max. current I_1 and then OC marked off to represent I_2.

* The rectangular BOAE is completed and the construction indicated in fig.

* Then HD = CD x (I_2/I_1), and represent R_2.

* The value of the first element is then r_1 =BJ.

* In a similar manner the values of the other elements are obtained.

* FE is made equal to the armature resistance of the motor.

Starting of dc series motors

The following figure shows the schematic diagram of manual starter used for dc series motor.

