Q7. Explain dynamic braking.

Dynamic braking is the use of the electric traction motors of a railroad vehicle as generators when slowing the Locomotive. It is termed rheostatic if the generated electrical power is dissipated as heat in brake grid resistors, and regenerative if the power is returned to the supply line. Dynamic braking lowers the wear of friction-based braking components, and additionally regeneration can also lower energy consumption.

GO44 –ASSIGNMENT

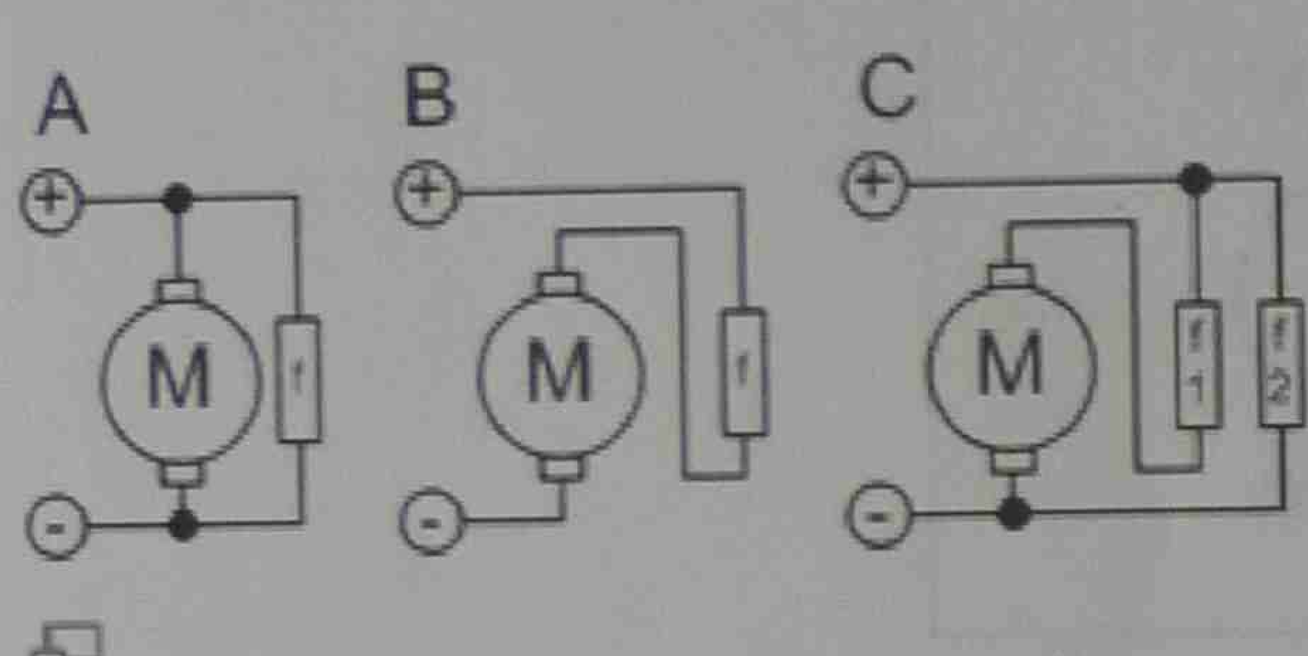
1. DC MACHINE

Q1. Explain generator action & motor action.

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

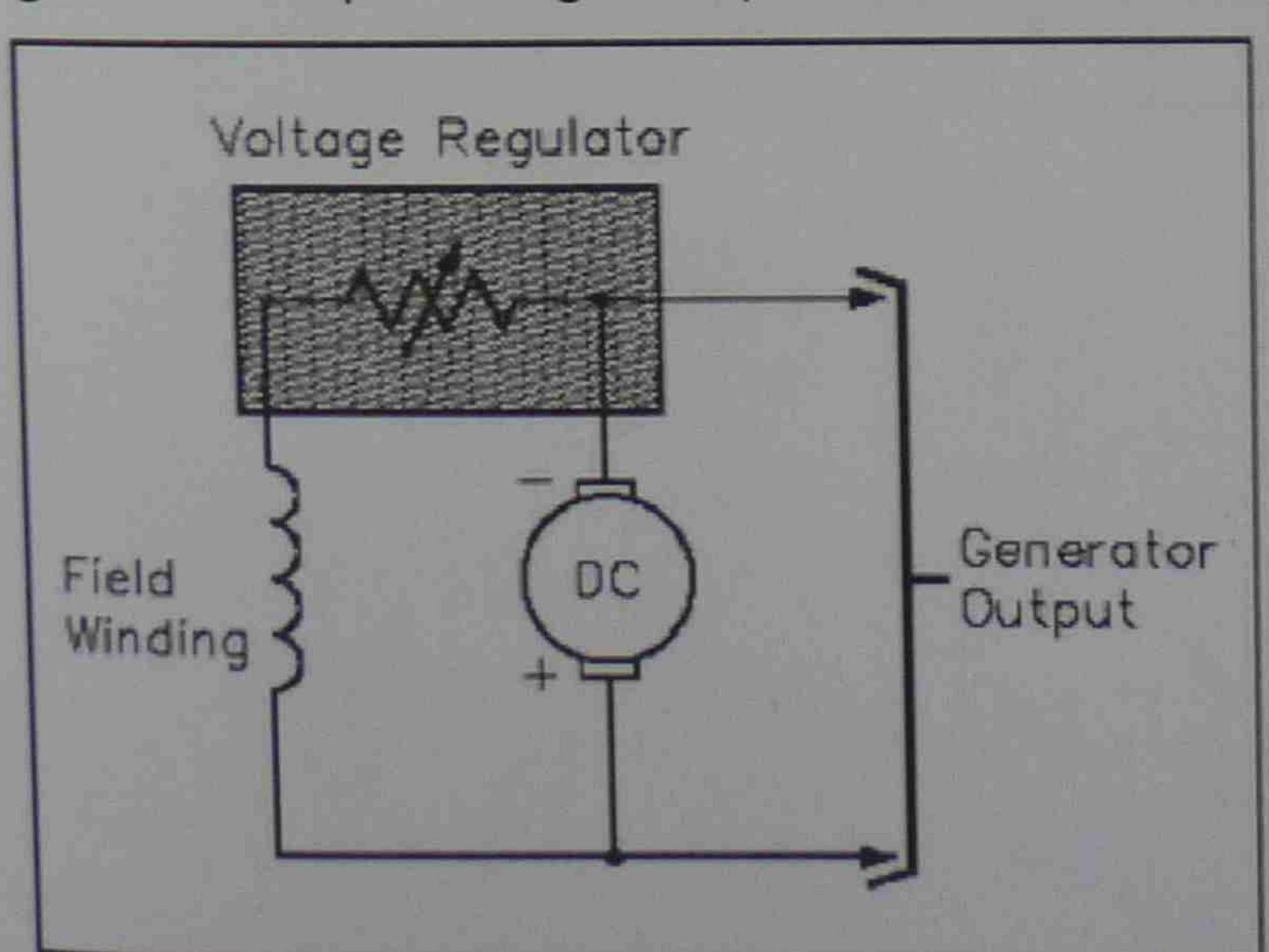
Q2.Sketch the construction of dc generator.

Wound stators



A: shunt
B: series
C: compound
f= field coil

DC generator output voltage is dependent on three factors : (1) the number



of

Varying Generator Terminal Voltage

Q3.Write the generated voltage equation.

In general generated e.m.f

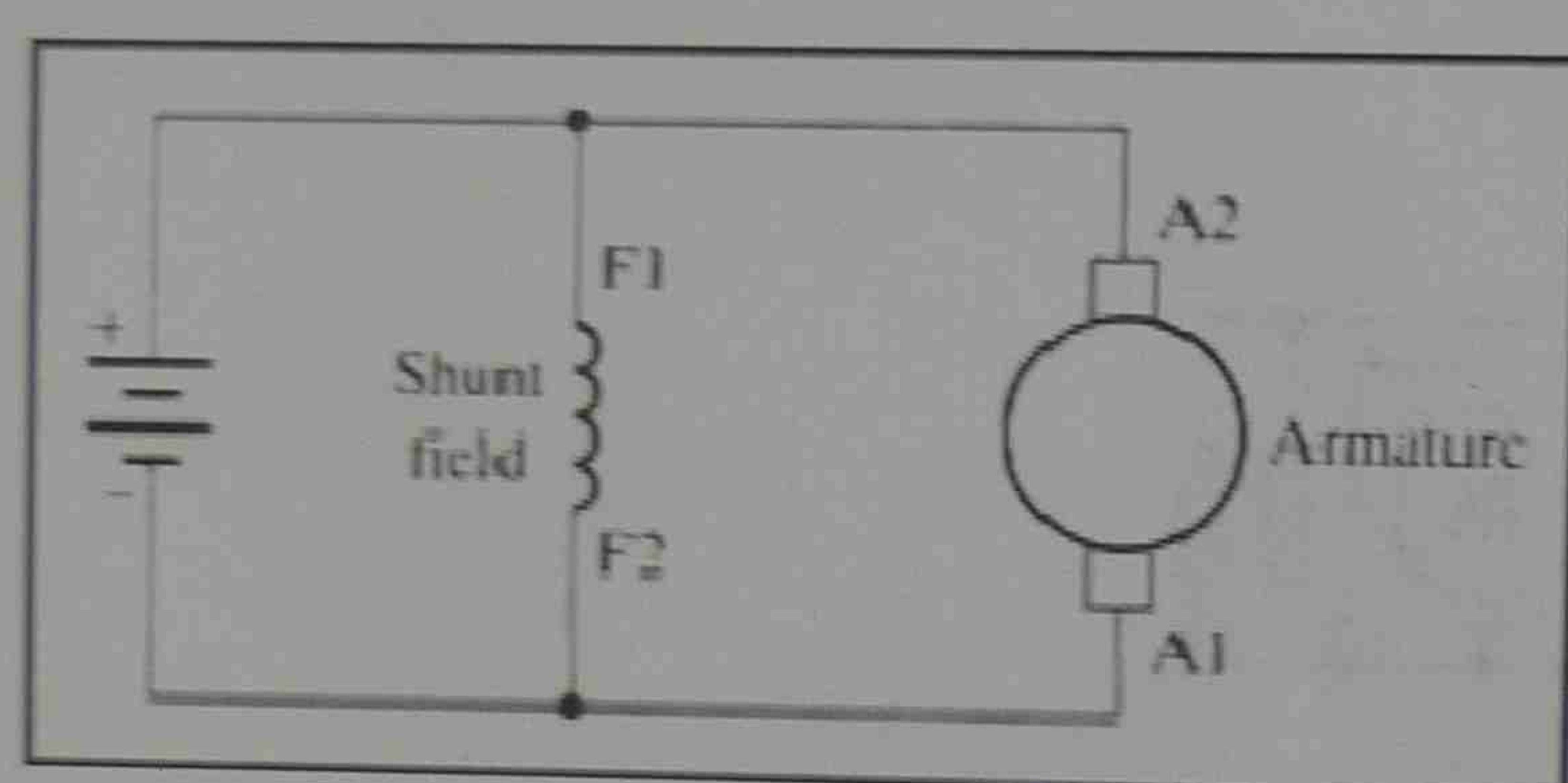
$$E_g = \frac{\varnothing ZN}{60} \times \left(\frac{P}{A}\right) \text{ volt}$$

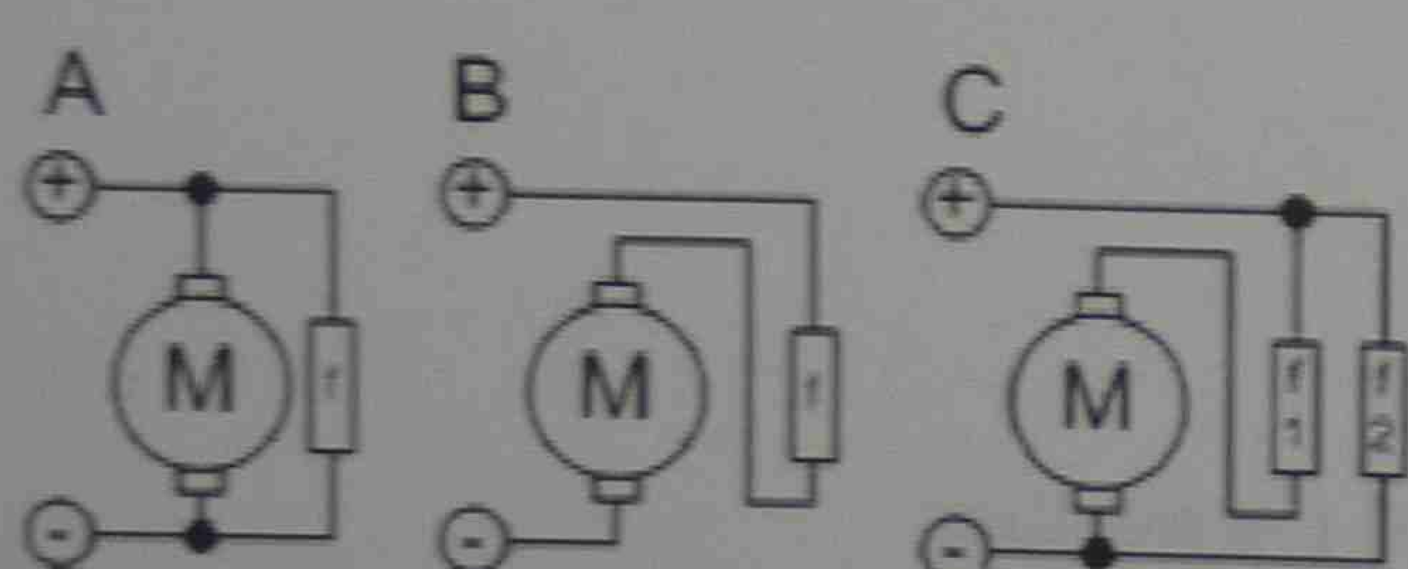
Q4.Label the parts of dc machine

Produce, Electronics, Distribution Centers,

Q5.Sketch the following connections of dc machine

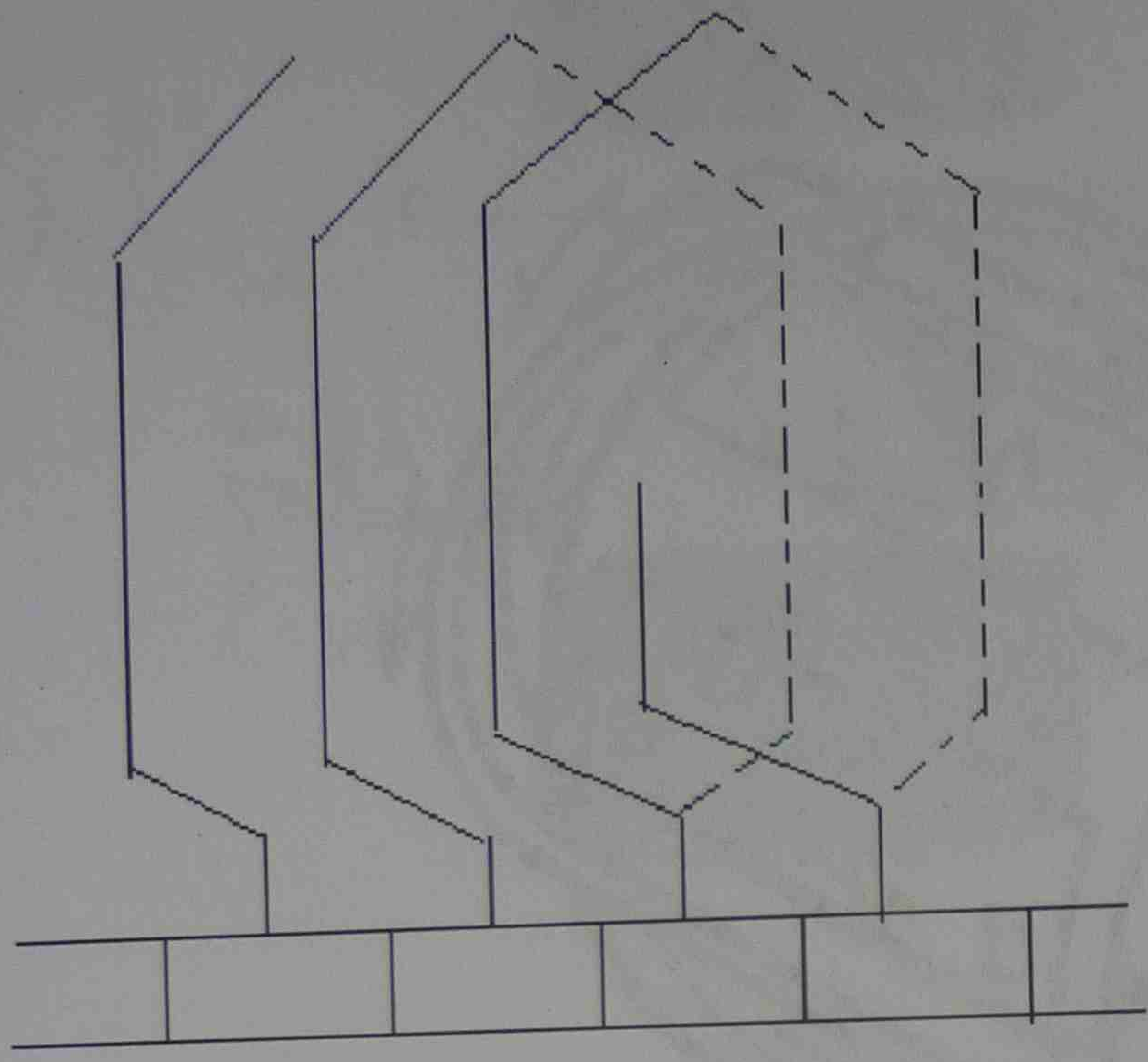
(a) Shunt (b)Series (c)Separately excited (d) Compound

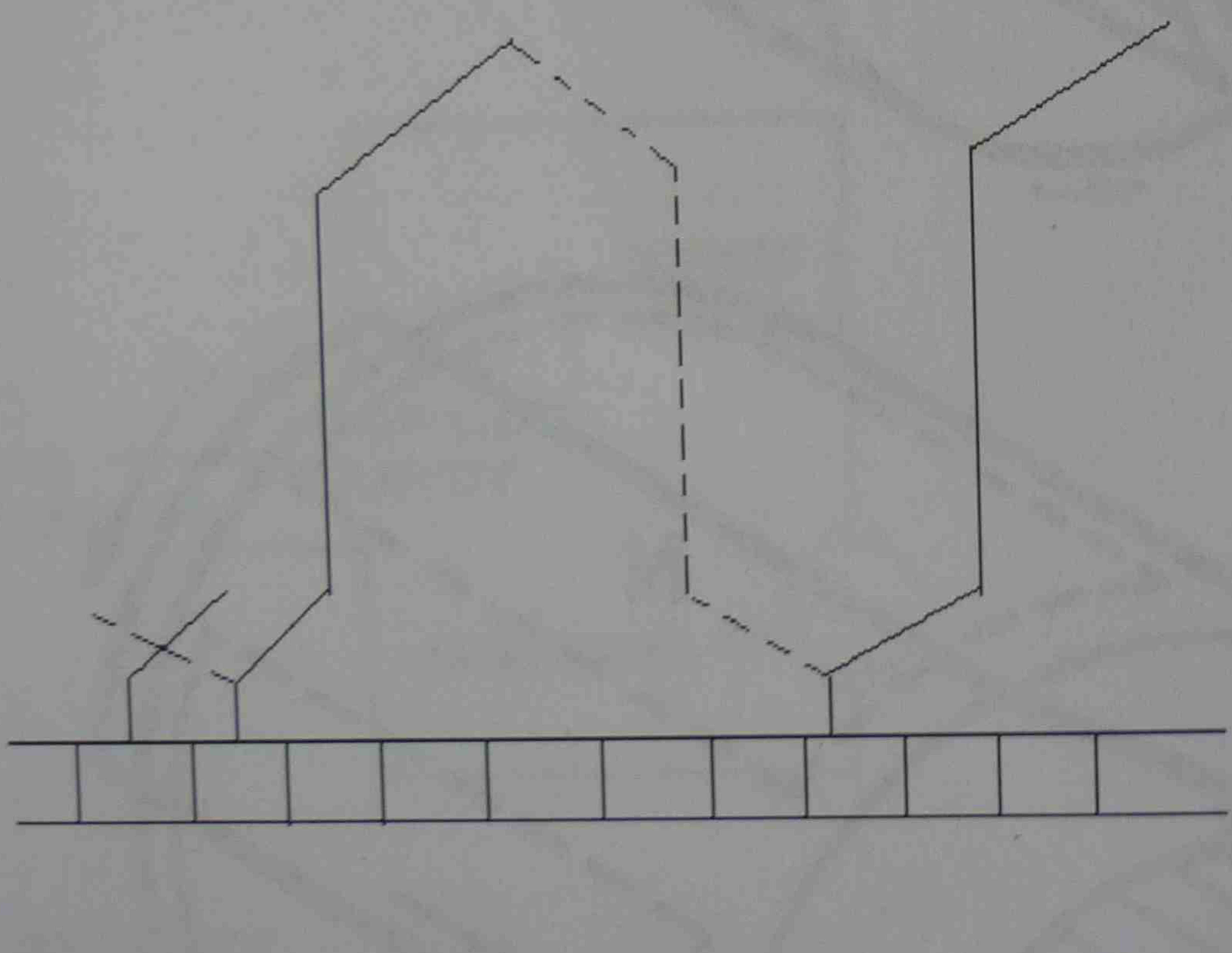




A: shunt
B: series
C: compound
f= field coil

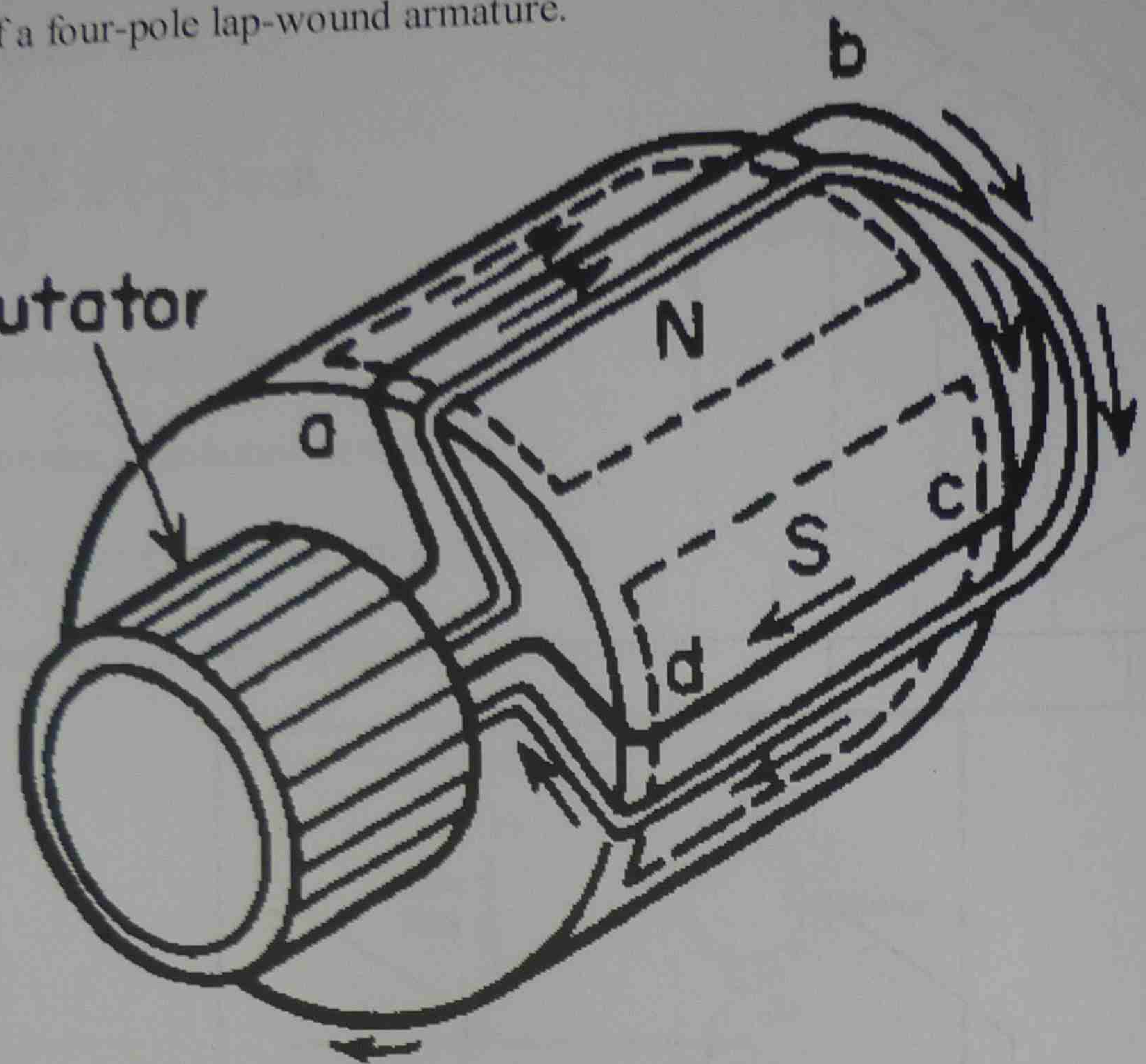
Q6.Sketch lap winding and wave winding

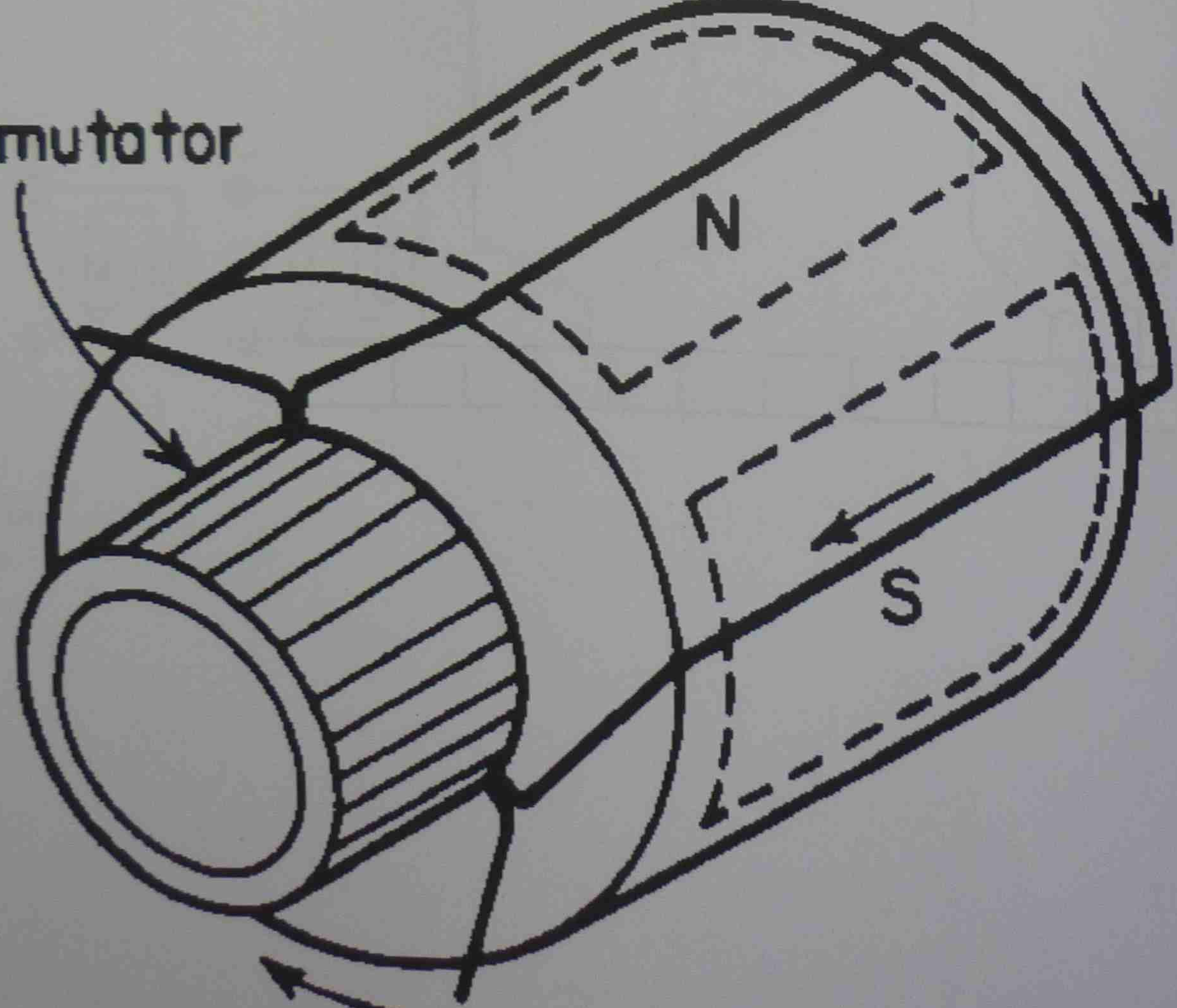




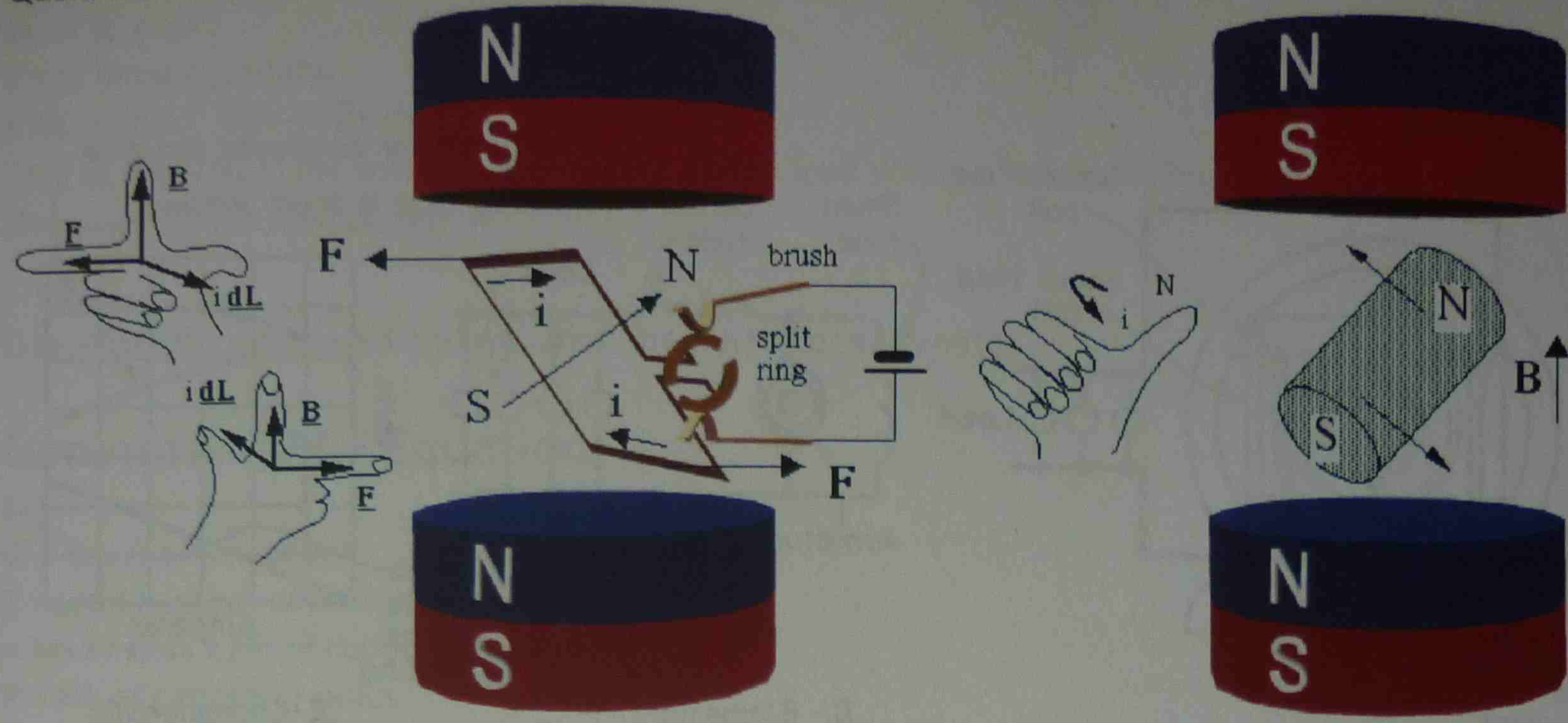
Q9.Sketch (a) Progressive lap (b) Retrogressive lap

Two coils of a four-pole lap-wound armature.

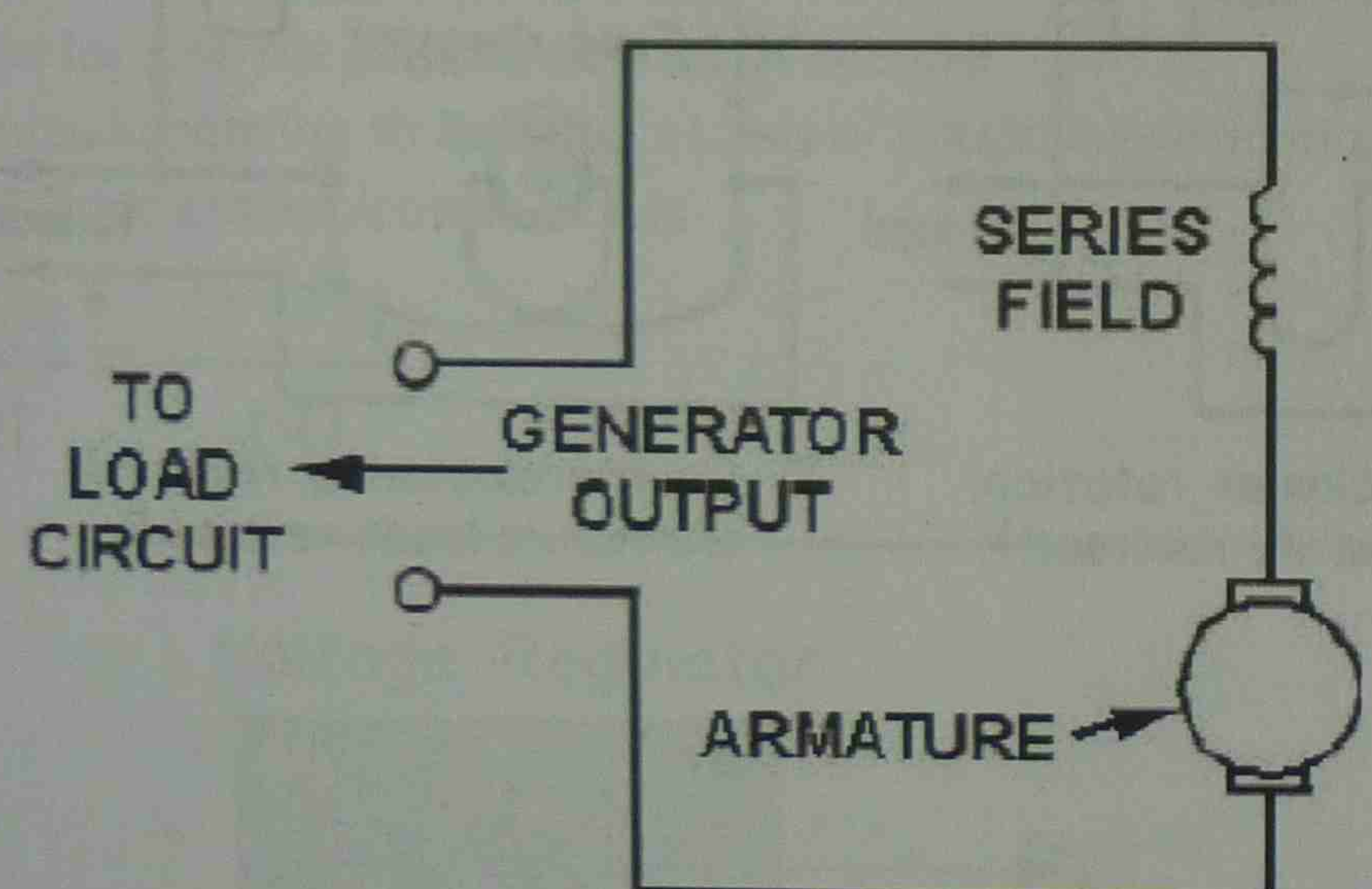




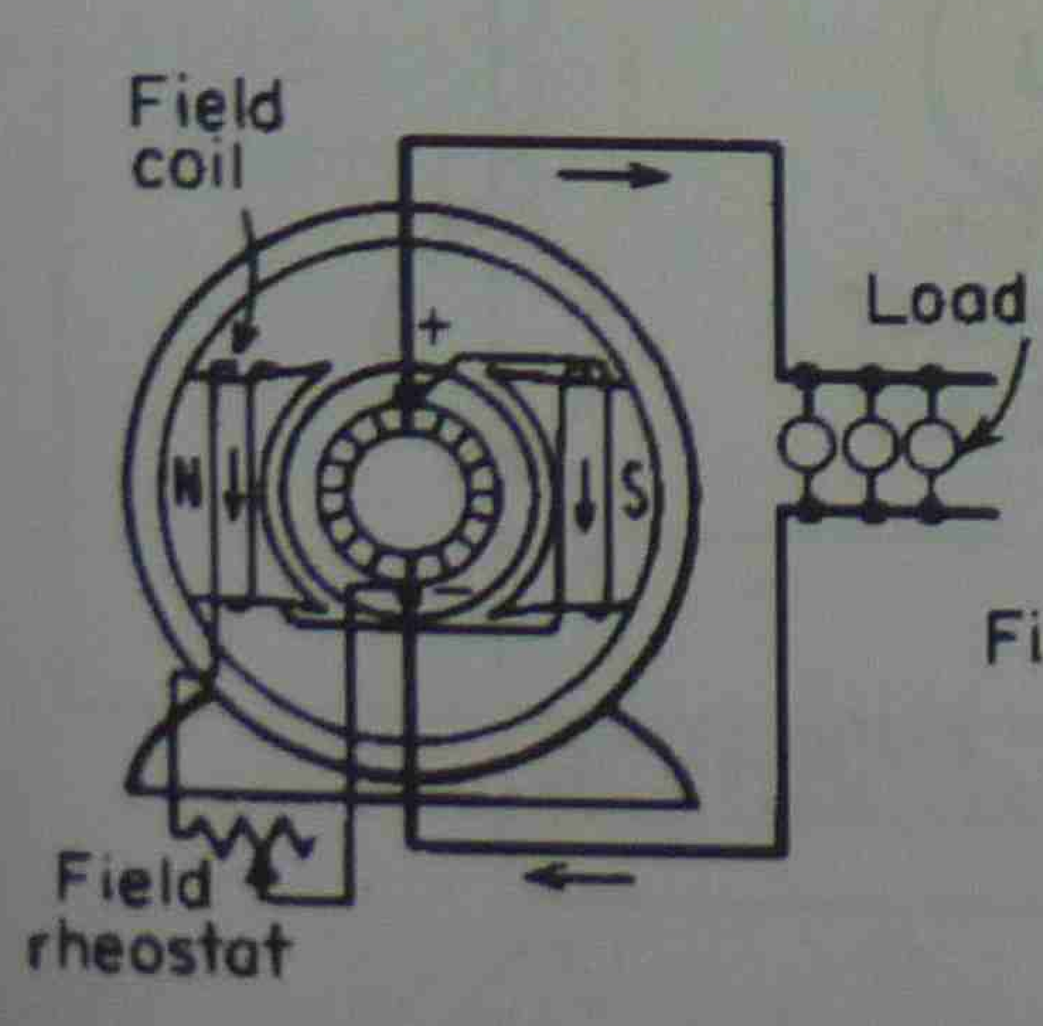
Q11.Sketch mechanical action of dc generator & motor



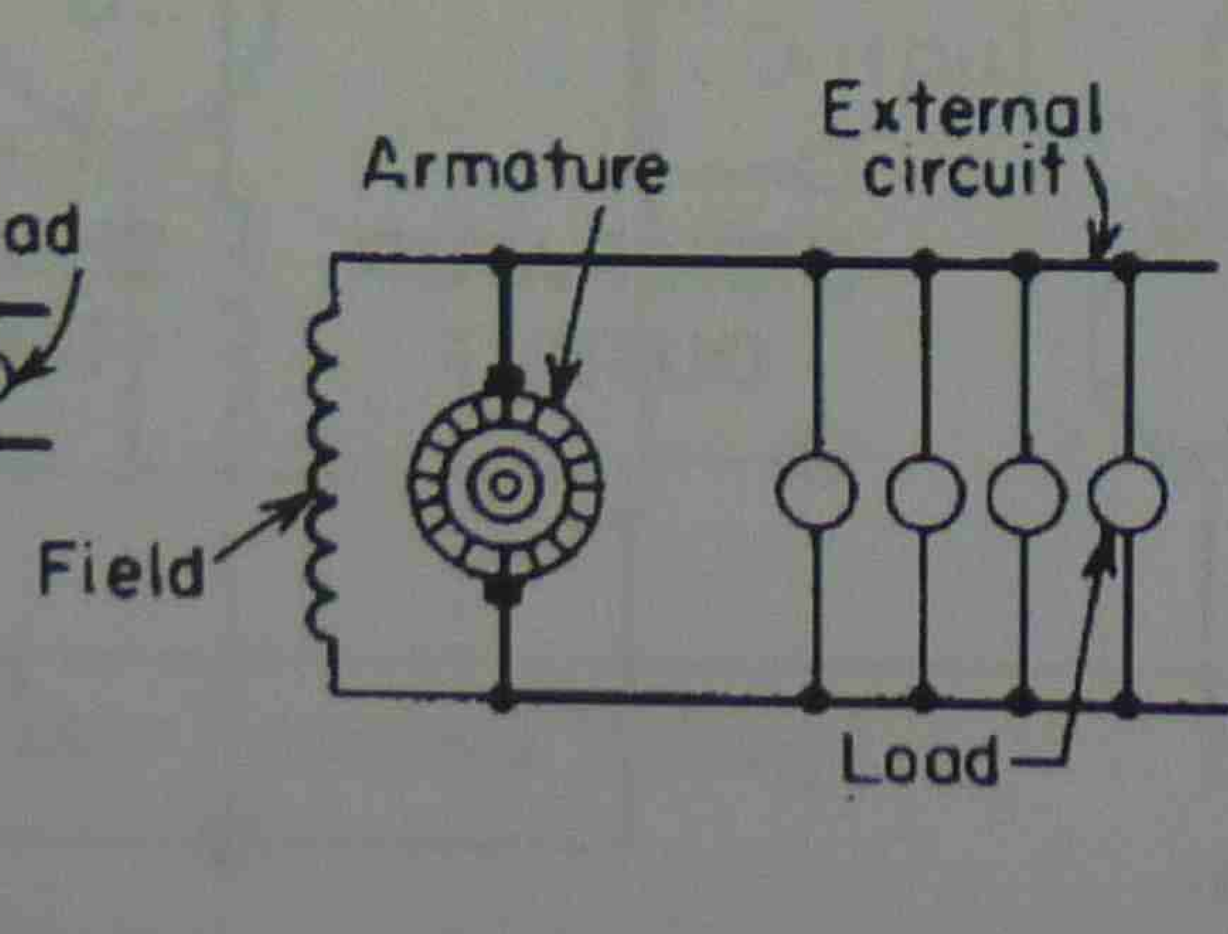
Q13.Sketch & write the equation for (a) shunt generator (b) Short shunt compound generator (c) Series motor (d) Shunt motor



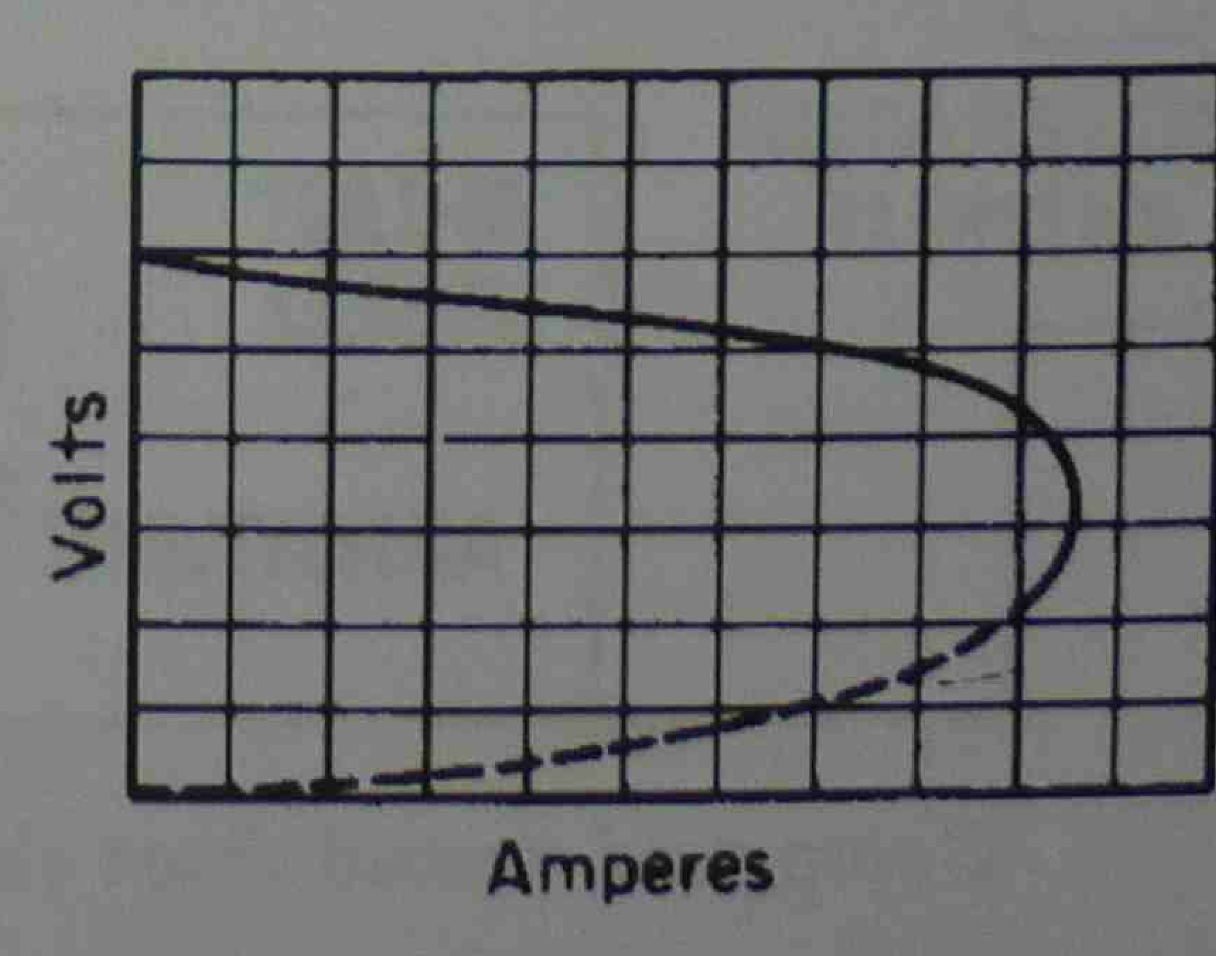
Series generator.



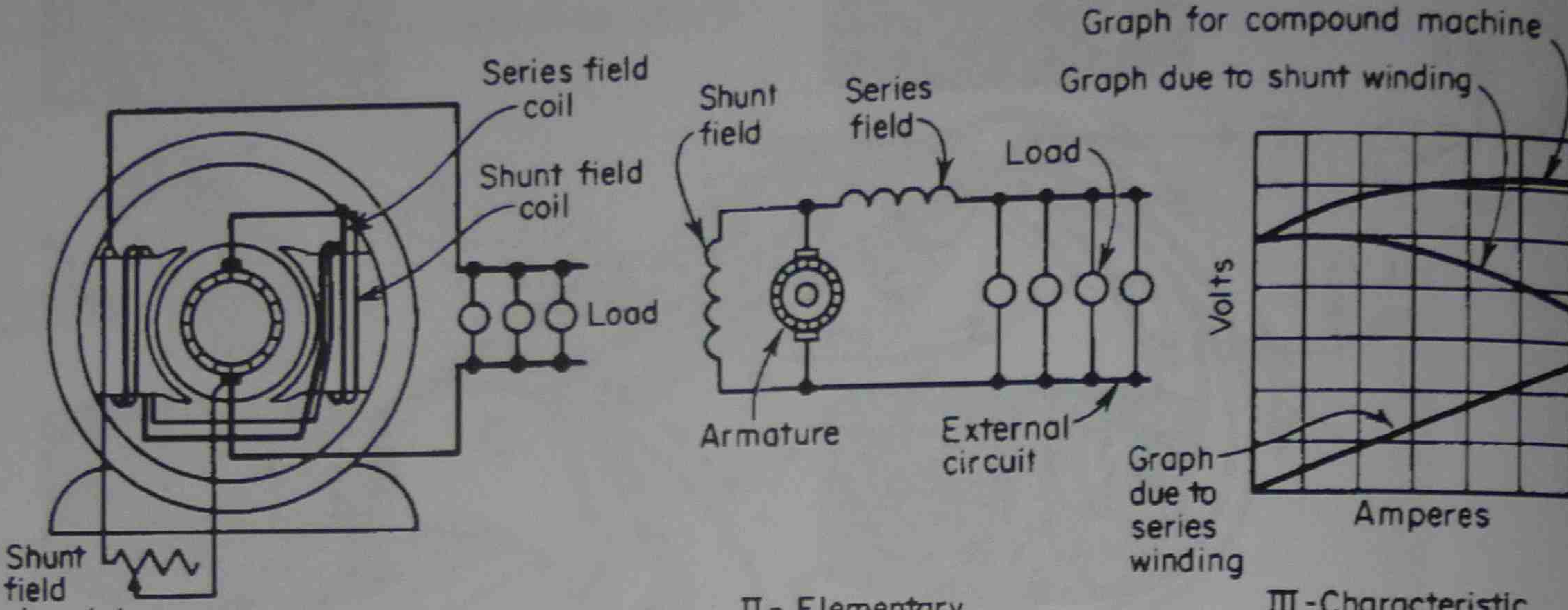
I- Diagram



II- Elementary

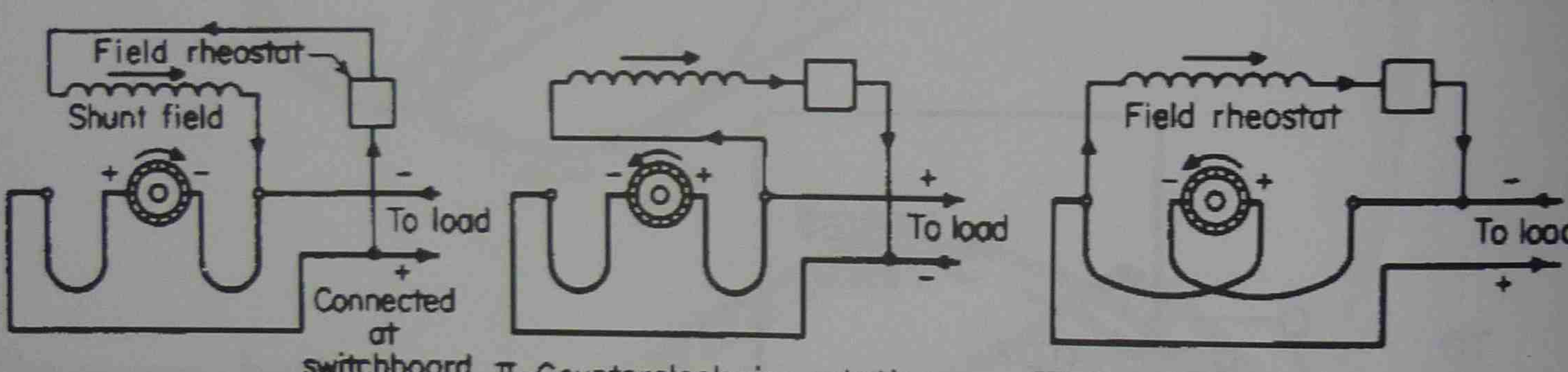


Shunt generator



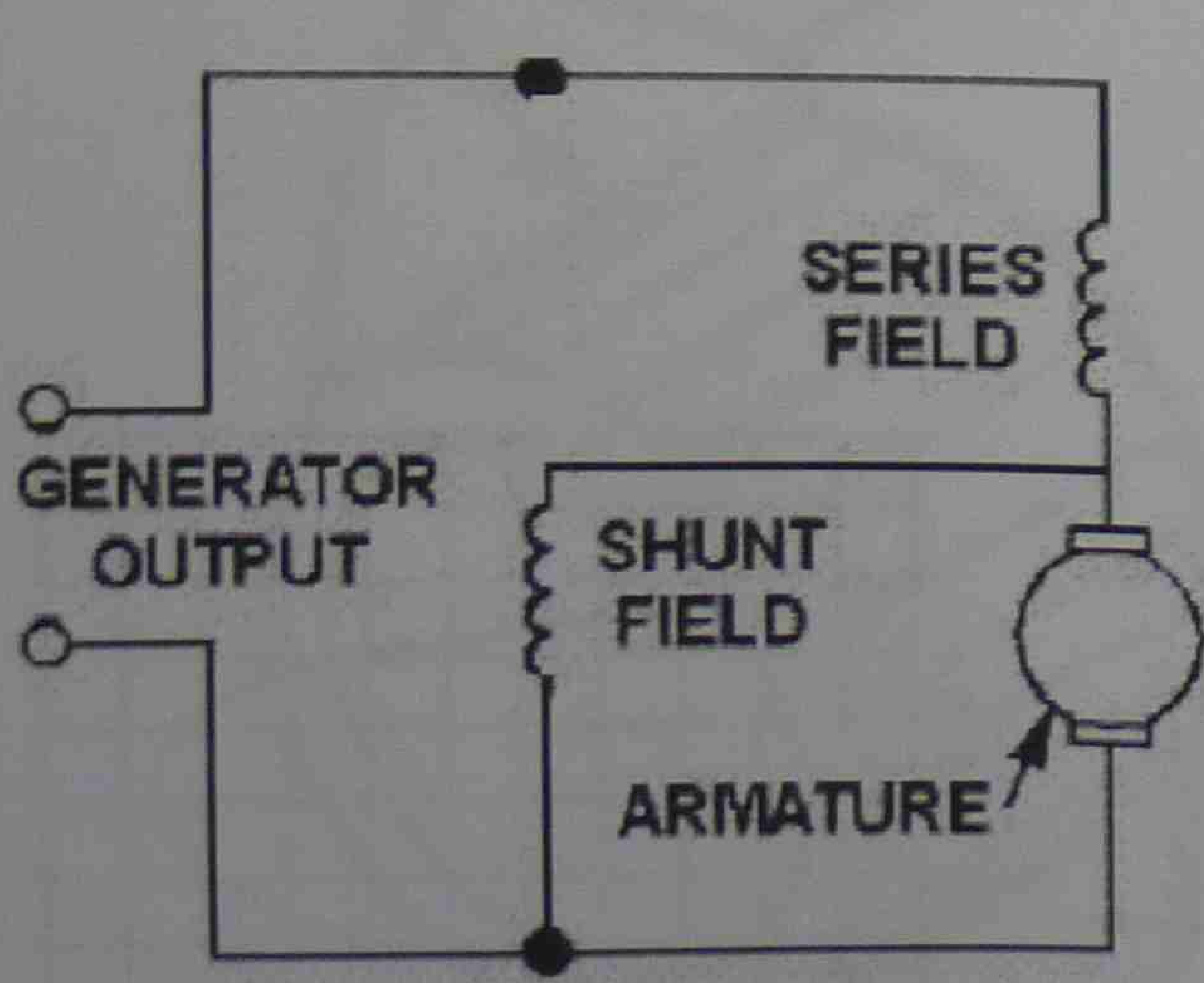
I - Diagram   II - Elementary circuit   III - Characteristic graph

Compound generator

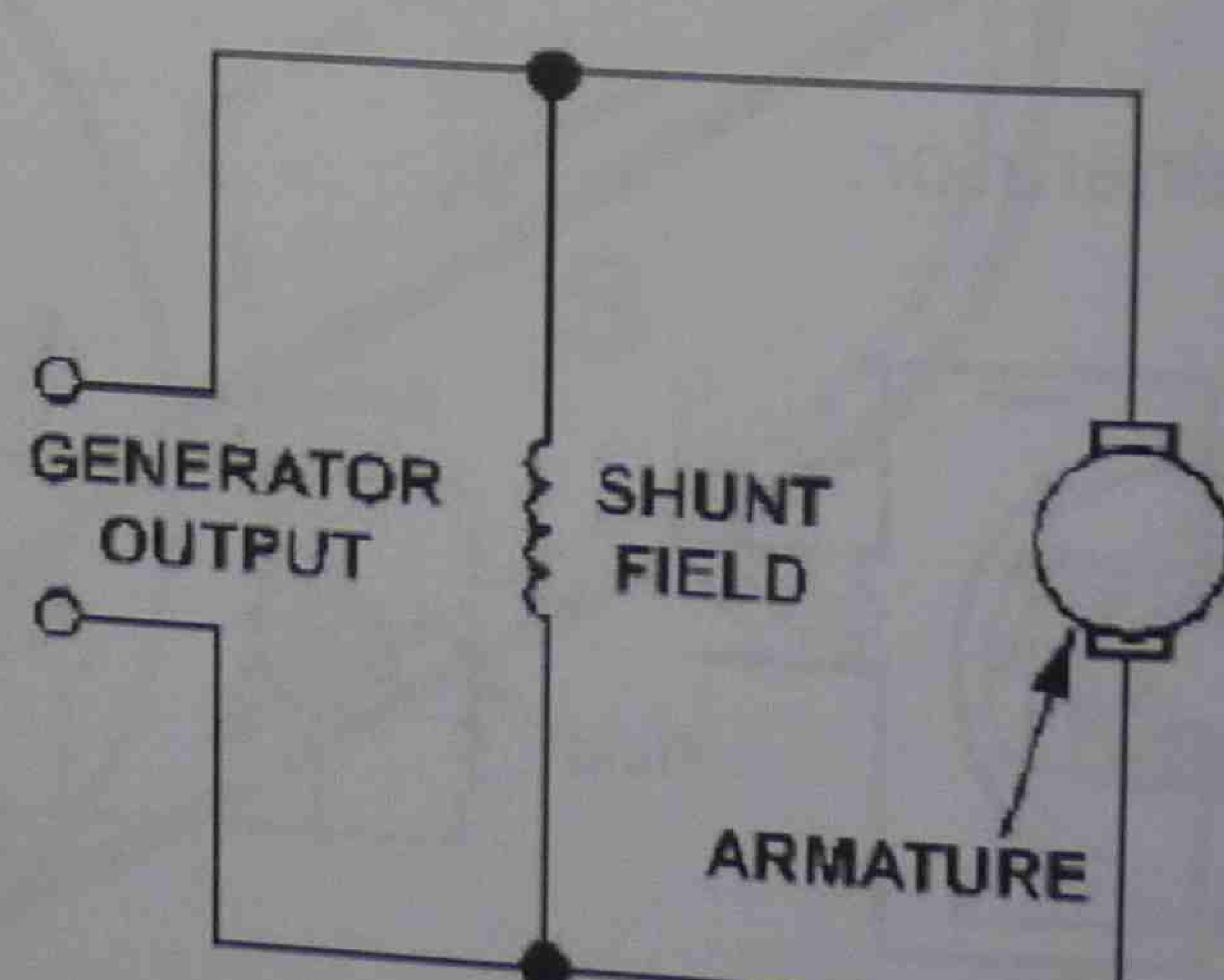


I - Clockwise rotation   II - Counterclockwise rotation (Line wire polarity reversed)   III - Counterclockwise rotation (Armature leads reversed)

direction of a shunt machine.



Compound wound short shunt



The steady-state operation of a loaded generator is described by the equations:

$V_T = R_F I_F$

$I_A = I_L + I_F$:

From these equations,

$R_A I_L = E_A \square (R_A + R_F) I_F$

That is, the $R_A I_L$ is the voltage gap between the no load voltage and the voltage drop across R_A and R_F caused by the field current I_F

Q14.Write the generated emf equation for generator and motor.

Generator E.M.F Equation

Let

Φ = flux/pole in weber

Z = total number of armture conductors

= No.of slots x No.of conductors/slot

P = No.of generator poles

A = No.of parallel paths in armature

N = armature rotation in revolutions per minute (r.p.m)

E = e.m.f induced in any parallel path in armature

Generated e.m.f Eg = e.m.f generated in any one of the parallel paths i.e E.

Average e.m.f geneated /conductor = **$d\Phi/dt$** volt (n=1)

Now, flux cut/conductor in one revolution **$d\Phi = \Phi P$** Wb

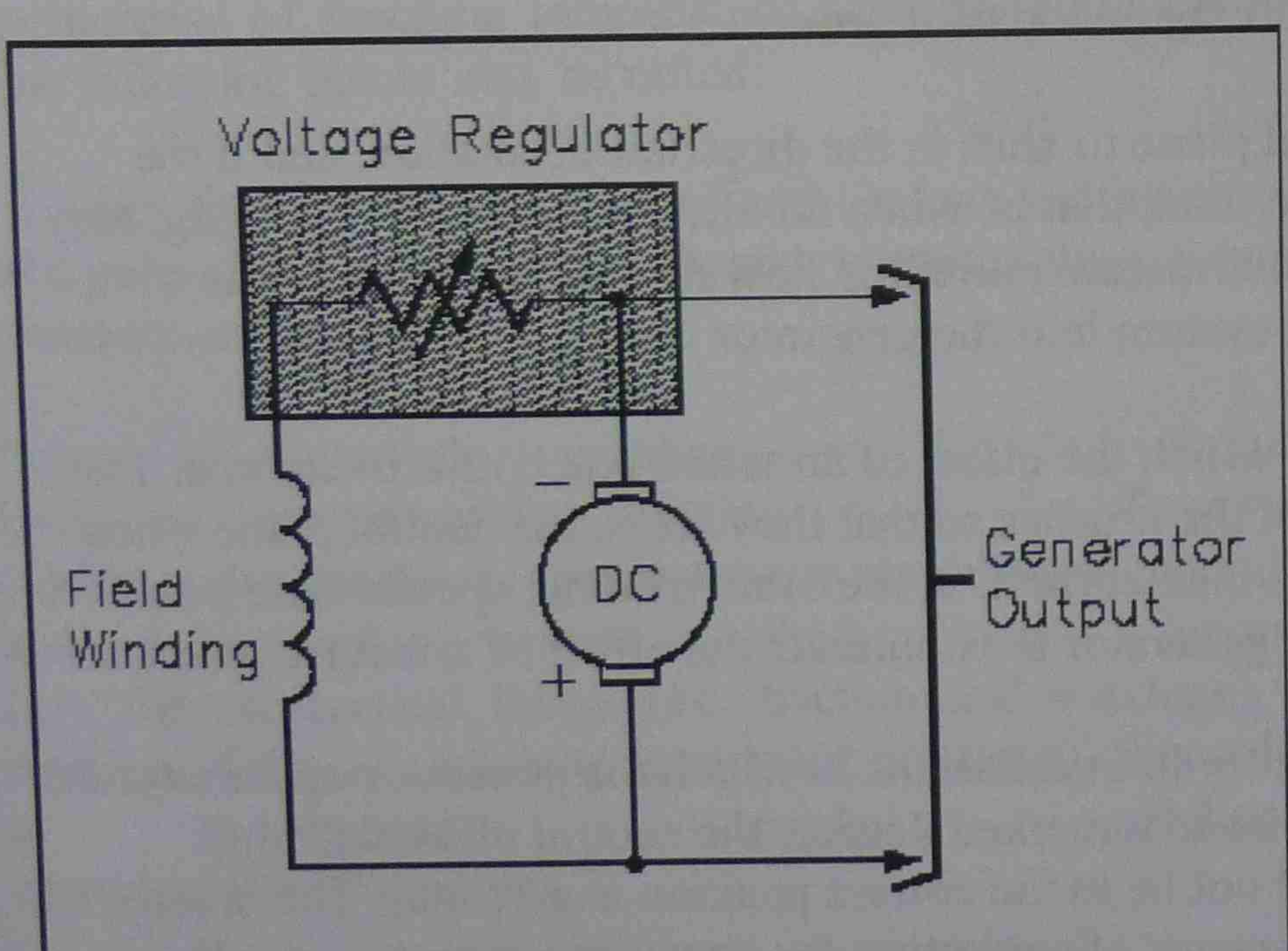
No.of revolutions/second = N/60

Time for one revolution, **dt = 60/N** second

Hence, according to Faraday's Laws of Electroagnetic Induction,

E.M.F generated/conductor is

$$\frac{d\varnothing}{dt} = \frac{\varnothing PN}{60}$$



Varying Generator Terminal Voltage

$$E_g = \frac{\varnothing ZN}{60} \times \left(\frac{P}{A}\right) \text{ volt}$$

Q15.Explain the magnetic action of armature field distortion

A commutator is a rotary electrical switch in certain types of electric motors or electrical generators that periodically reverses the current direction between the rotor and the external circuit. In a motor, it applies power to the best location on the rotor, and in a generator, picks off power similarly. As a switch, it has exceptionally long life, considering the number of circuit makes and breaks that occur in normal operation.

Q17.Explain the methods to reduce the armature reaction.

All current-carrying conductors produce magnetic fields. The magnetic field produced by current in the armature of a dc generator affects the flux pattern and distorts the main field. This distortion causes a shift in the neutral plane, which affects commutation. This change in the neutral plane and the reaction of the magnetic field is called armature reaction.

Since an armature is wound with coils of wire, a magnetic field is set up in the armature whenever a current flows in the coils. This field is at right angles to the generator field, and is called cross magnetization of the armature. The effect of the armature field is to distort the generator field and shift the neutral plane. The neutral plane is the position where the armature windings are moving parallel to the magnetic flux lines. This effect is known as armature reaction and is proportional to the current flowing in the armature coils.

The brushes of a generator must be set in the neutral plane; that is, they must contact segments of the commutator that are connected to armature coils having no induced emf. If the brushes were contacting commutator segments outside the neutral plane, they would short-circuit "live" coils and cause arcing and loss of power.

Armature reaction causes the neutral plane to shift in the direction of rotation, and if the brushes are in the neutral plane at no load, that is, when no armature current is flowing, they will not be in the neutral plane when armature current is flowing. For this reason it is desirable to incorporate a corrective system into the generator design.

These are two principal methods by which the effect of armature reaction is overcome. The first method is to shift the position of the brushes so that they are in the neutral plane when the generator is producing its normal load current. in the other method, special field poles, called interpoles, are installed in the generator to counteract the effect of armature reaction.

The brush-setting method is satisfactory in installations in which the generator operates under a fairly constant load. If the load varies to a marked degree, the neutral plane will shift proportionately, and the brushes will not be in the correct position at all times. The brush-setting method is the most common means of correcting for armature reaction in small generators (those producing approximately 1000 W or less). Larger generators require the use of interpoles.

Q20.Explain the voltage of self induction

The property of self-inductance is a particular form of electromagnetic induction. Self inductance is defined as the induction of a voltage in a current-carrying wire when the current in the wire itself is changing. In the case of self-inductance, the magnetic field created by a changing current in the circuit itself induces a voltage in the same circuit. Therefore, the voltage is self-induced.

Q21.Sketch the power flow diagram in dc machine.

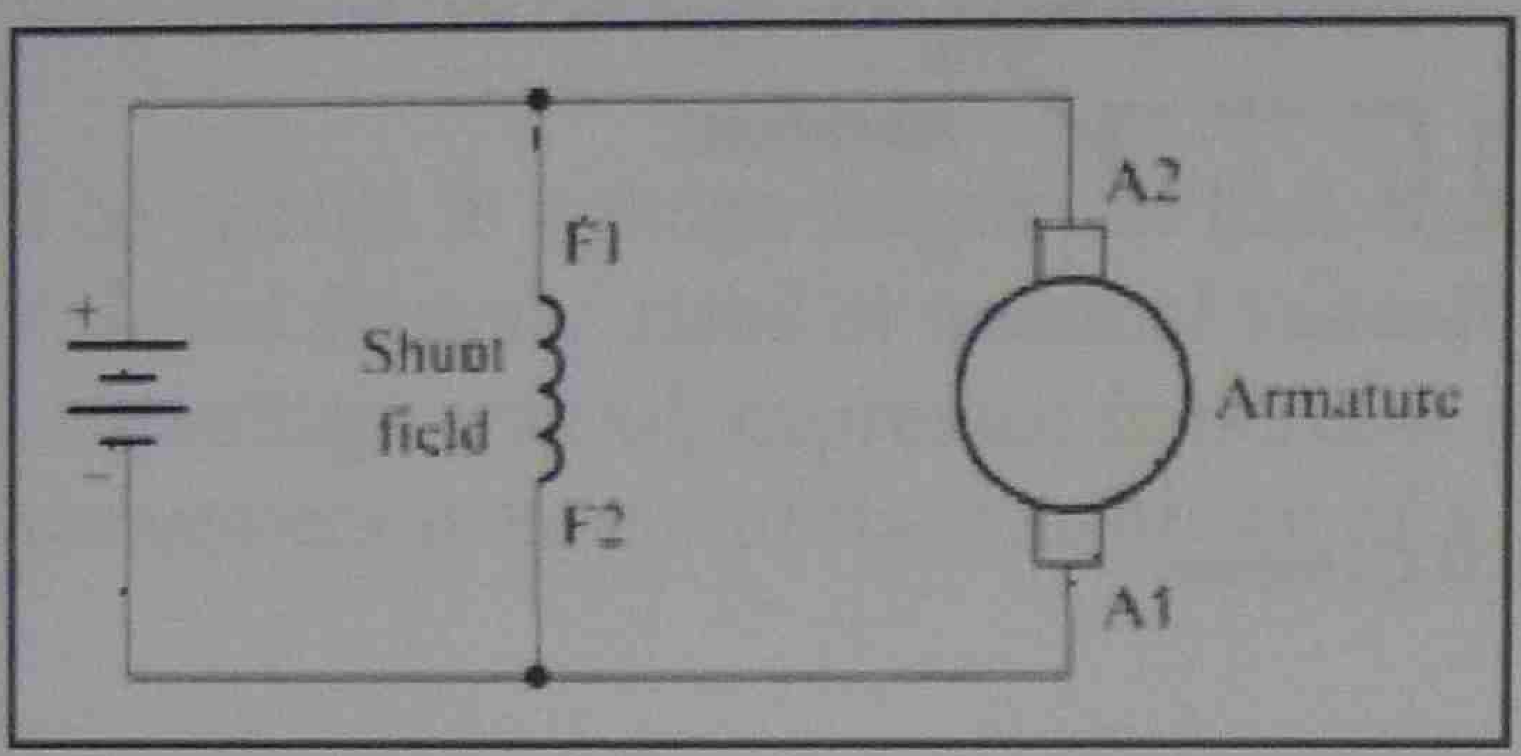


Diagram of DC shunt motor. Notice the shunt coil is identified as a coil of fine wire with many turns that is connected in parallel (shunt) with the armature.

Q22.Describe the losses and efficiency in dc motor.

The losses occurring in a d.c. motor are the same as in a d.c. generator (i) copper losses (ii) Iron losses or magnetic losses (iii) mechanical losses As in a generator, these losses cause (a) an increase of machine temperature and (b) reduction in the efficiency of the d.c. motor. The following points may be noted:

(i) Apart from armature Cu loss, field Cu loss and brush contact loss, Cu losses also occur in interpoles (commutating poles) and compensating windings. Since these windings carry armature current (I_a),

Loss in interpole winding = $I_a^2 \times$ Resistance of interpole winding
Loss in compensating winding = $I_a^2 \times$ Resistance of compensating winding
(ii) Since d.c. machines (generators or motors) are generally operated at constant flux density and constant speed, the iron losses are nearly constant.
(iii) The mechanical losses (i.e. friction and windage) vary as the cube of the speed of rotation of the d.c. machine (generator or motor). Since d.c. machines are generally operated at constant speed, mechanical losses are considered to be constant.

This proposes the effective technique for estimating efficiency of existing three-phase inductionmotors in the field. This technique focuses on the efficiency of motors without the need for removing the motors and without the need for measuring the output power or

torque. This paper describes the use of a few sets of data (voltage, current, power, speed)
measured from the motor (on-site) coupled with the genetic algorithms for evaluating the
motor parameters instead of using the no-load and blocked rotor test results.
Once these parameters are known it is possible to obtain the estimated efficiency of the
motor. To illustrate how well the estimated efficiency match that of the calculated obtained
from the standard evaluations, the results of various induction motors rating 10 up to 100 hp
are presented. Test results indicate that this proposed technique has a high accuracy, and
then it could be suitable for conducting on-site energy audits of existing motors in order to
support a decision to replace operating motors with a higher-efficiency model.

Q24.Sketch the power flow diagram of dc generator

Q25.Sketch the power flow diagram of dc motor.

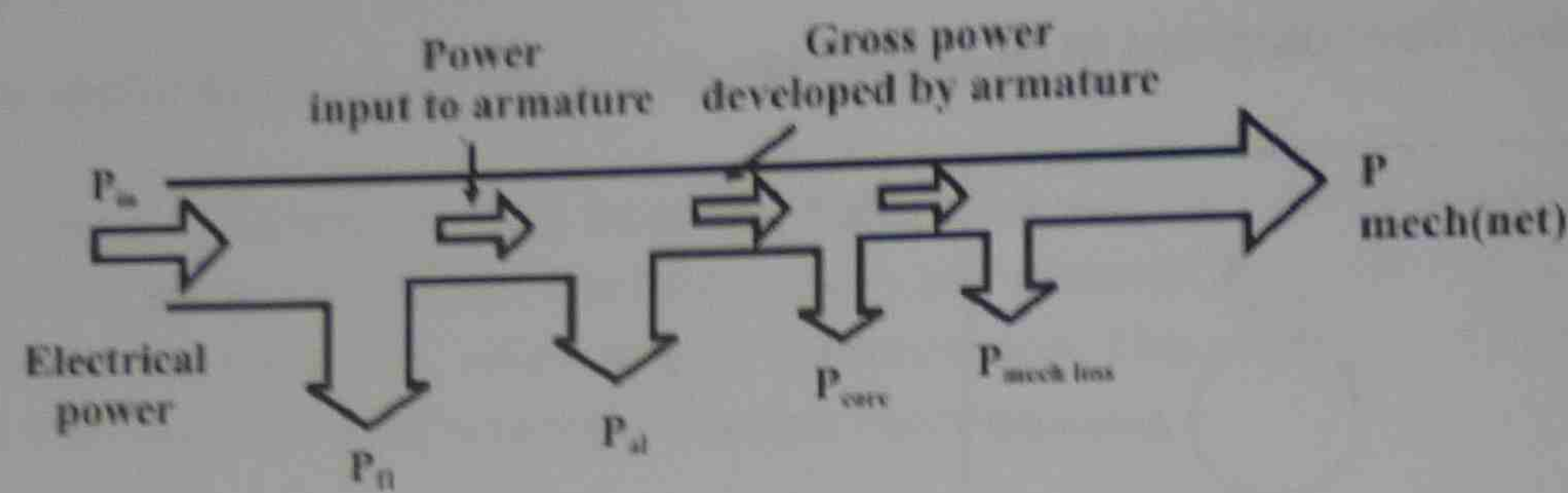


Fig. 40.1: Power flow diagram of a D.C. motor

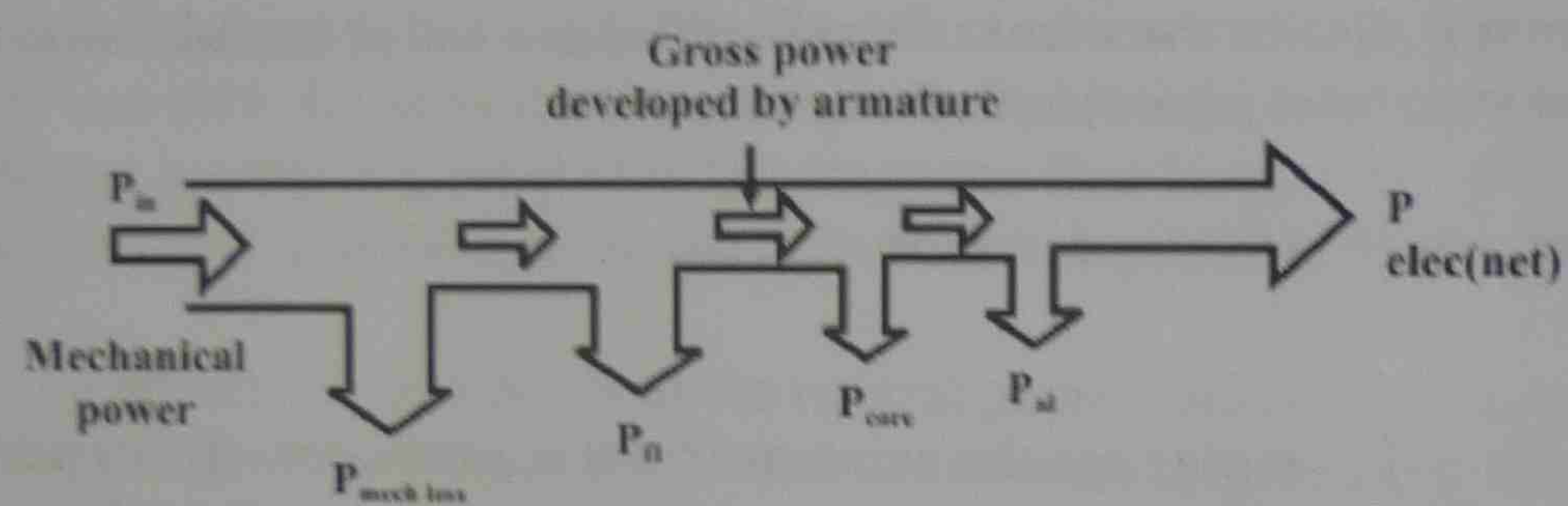


Fig. 40.2: Power flow diagram of a D.C. generator

Q26.Explain maximum efficiency

Many engines and power plants burn fuel, converting part of the heat energy so generated into more useful forms such as electricity or mechanical work. In practise there are losses due to friction, leakage, and so forth. But even in the most ideal case, as we have hinted above, the Second Law places constraints on the maximum efficieny that can be attained.

Q28.Explain machine temperature rise.

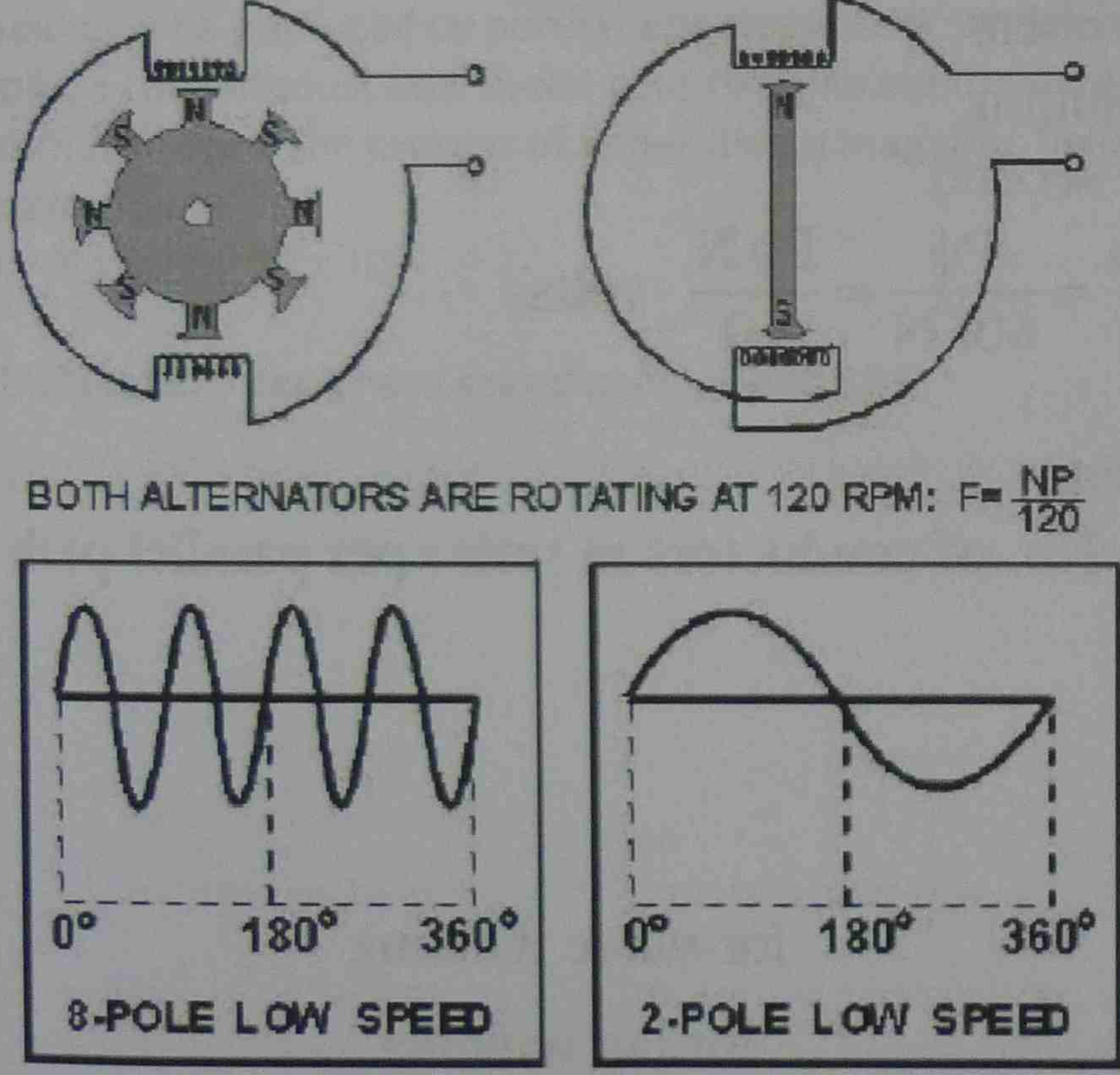
Whenever a wire carries electrical current, its temperature will increase due to the resistance of the wire. One important factor of this temperature rise is the influence it has on the insulation system of an electrical machine, such as an alternator. The hotter the wire, the shorter the life expectancy of the insulation, and of course the machine itself. This article will explain some standards and considerations regarding alternator temperature rise.

Q30.Analyze the power losses in dc machine.

The power ratings of the drive systems used in cyclic duty applications such as flying-die and cut-to-length shears are dictated by the thermal considerations associated with the losses produced by the machine during an operation cycle and the specified production rate. Since speed and torque are both transient functions with no steady-state operating point for such systems, a study was conducted to determine an expression that would describe these losses for a DC machine as a function of its operating speed and torque. A multiple regression technique was applied to the data collected from a set of sample machines for this purpose. Starting with the analysis of individual expressions for each of the components of losses in a DC machine, two regression models are presented. The first, based on a sample size of ten machines, provides an expression for the determination of operating point losses at any specified speed and torque per unit of rated machine losses (at rated speed and torque). The second model, based on data on 64 machines, provides an expression for the determination of rated losses in percent of machine power rating as a function of rated motor speed in r/min, armature volume in cubic units (DSQL), and percent armature droop. Mean estimates are also presented for the determination of percent droop and armature volume for a range of power ratings from 50 hp to 800 hp machines.

Q32.Explain percentage voltage regulation.

The change in voltage magnitude that occurs when the load (at a specified power factor) is reduced from the rated or nominal value to zero, with no intentional manual readjustment of any voltage control, expressed in percent of nominal full-load voltage. Voltage regulation is a convenient measure of the sensitivity of a device to changes in loading.



Q33(a)

$$\frac{E_{nL} - E_{fL}}{E_{fL}} \times 100 = \text{Percent of regulation}$$

$$\frac{250-220}{220} \times 100 = 13.6\%$$

500/520 x 100 = 96%

Q34.Sketch the generator loading circuit for shunt generator

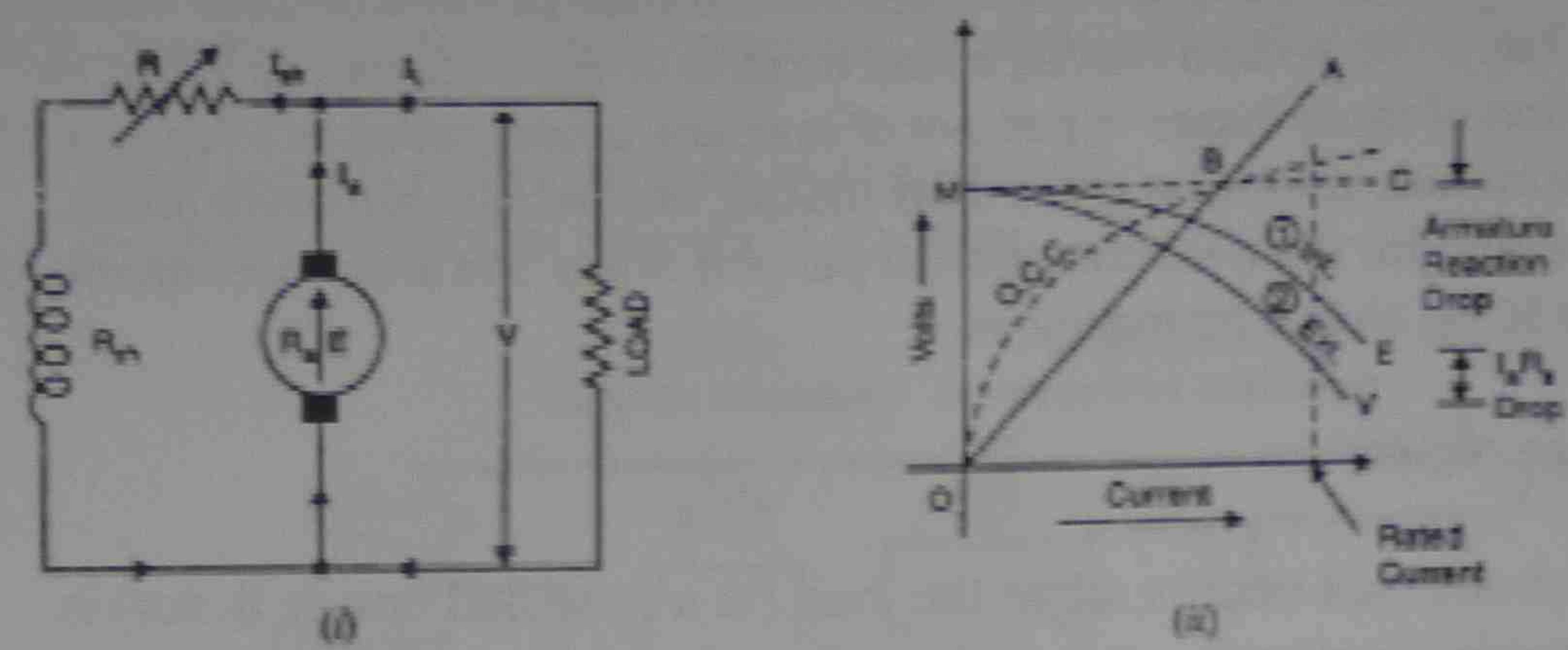


Fig. (3.9)

Q35.Write the generated emf equation.

Flux cut by one conductor in one revolution of the armature,

$$d\phi = P\phi \text{ webers}$$

Time taken to complete one revolution,

$$dt = 60/N \text{ second}$$

$$\text{e.m.f generated/conductor} = \frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60} \text{ volts}$$

e.m.f. of generator,

$$E_g = \text{e.m.f. per parallel path}$$

$$= (\text{e.m.f/conductor}) \times \text{No. of conductors in series per parallel path}$$

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

$$\therefore \quad E_g = \frac{P\phi ZN}{60\,A}$$

where $A = 2$ for-wave winding

$= P$ for lap winding

Q36.Write transfer function of dc shunt generator and write the equation for generated voltage.

Permanent magnet DC motors are commonly used to provide rotary (or linear) motion to a variety of electromechanical devices and servo systems. In most applications the speed or position of the shaft of these motors must be accurately controlled. In order to design such velocity and position control systems it is necessary to obtain, analytically or experimentally, a mathematical model for the motor or system to be controlled. If the system is predominantly linear a suitable model is given by its Transfer Function. In the previous laboratory experiment some parameters of the Motor Board, including DC motor + amplifier, tachogenerator and potentiometer transfer functions were identified. In this lab, students will design an experiment to identify the "dynamic characteristics" (e.g. the time constants) of the DC motor transfer function.

AC voltage may be increased or decreased with a transformer. Use of a higher voltage leads to significantly more efficient transmission of power. The power losses in a conductor are a product of the square of the current and the resistance of the conductor, described by the formula

$$P_L = I^2 R.$$

This means that when transmitting a fixed power on a given wire, if the current is doubled, the power loss will be four times greater.

The power transmitted is equal to the product of the current and the voltage (assuming no phase difference); that is,

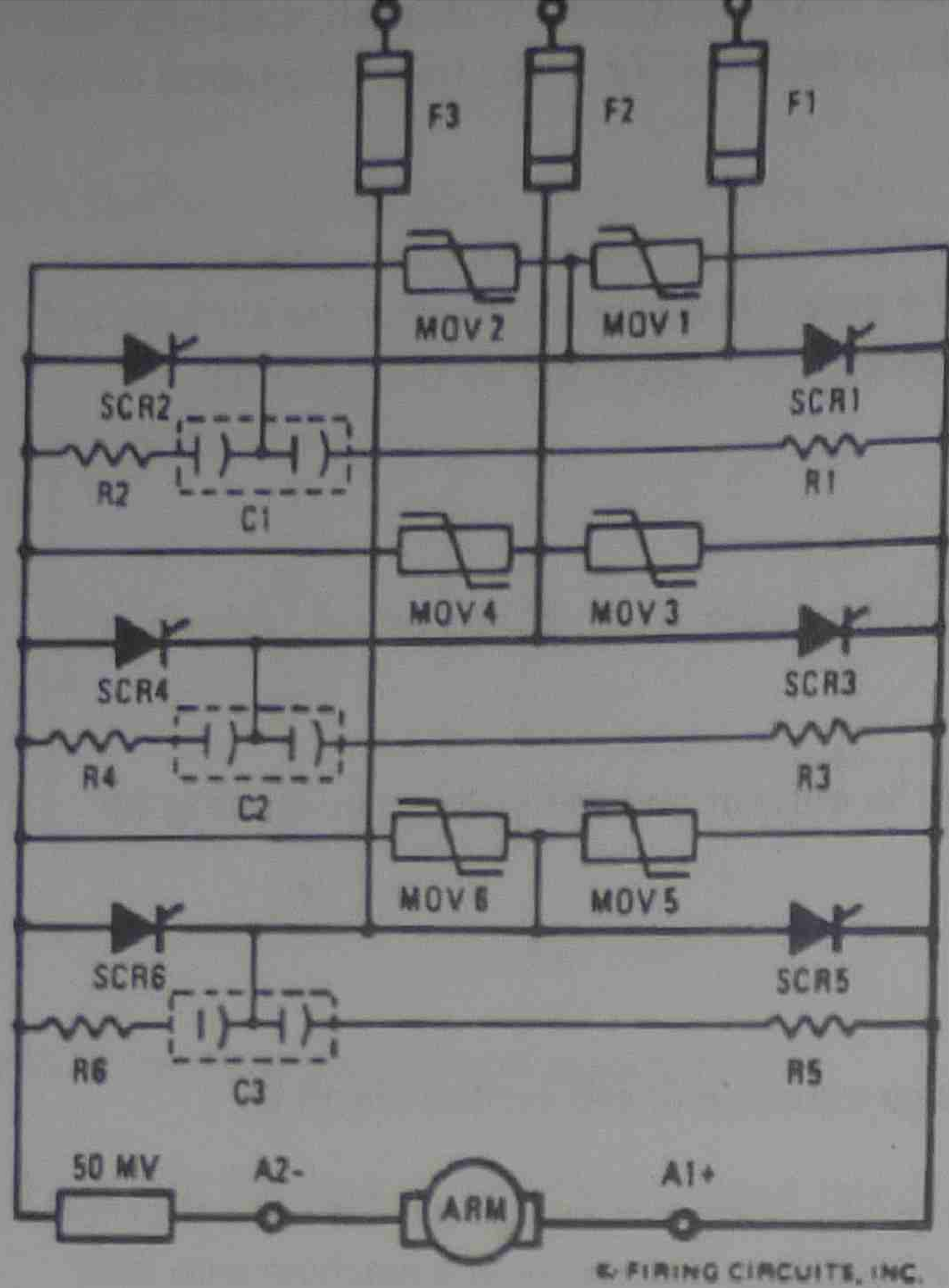
$$P_T = IV.$$

Q37.Write the transfer function and generated voltage equation of self excited machine.

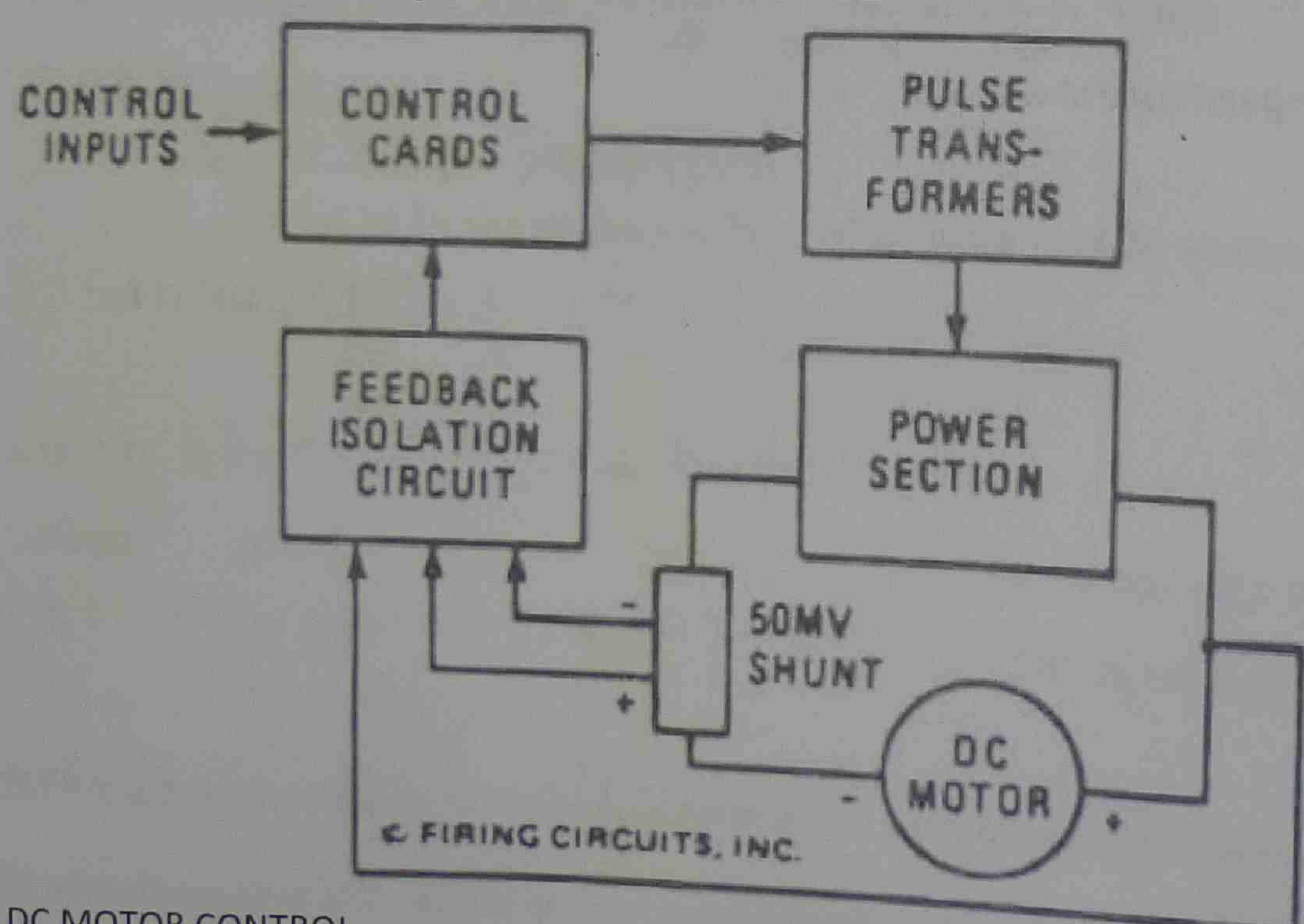
An electric generator or electric motor consists of a rotor spinning in a magnetic field. The magnetic field may be produced by permanent magnets or by field coils. In the case of a machine with field coils, a current must flow in the coils to generate the field, otherwise no power is transferred to or from the rotor. The process of generating a magnetic field by means of an electric current is called ***excitation***.

$e = N \times (d\Phi / dt) \times 10^{-8}$

Q42.Sketch three phase speed control with SCR



Q43.Sketch the block diagram of SCR controlled motor.



DC MOTOR CONTROL.
SIMPLIFIED BLOCK DIAGRAM

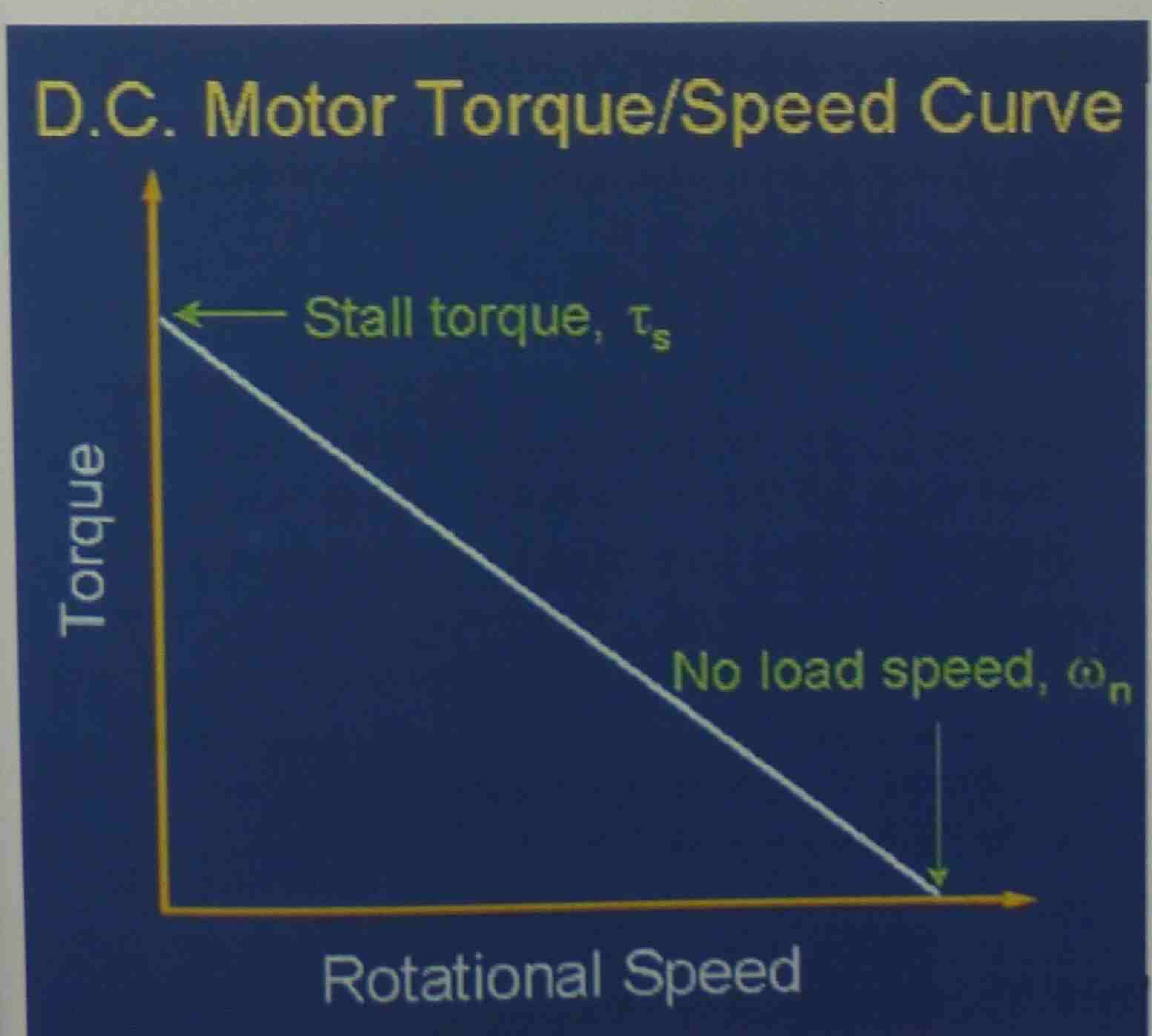
Q44.What are the effects of ripples.

The **ripple effect** is a term used to describe a situation where, like the ever expanding ripples across water when an object is dropped into it, an effect from an initial state can be followed outwards incrementally.

Ripple is undesirable in many electronic applications for a variety of reasons:

- The ripple frequency and its harmonics are within the audio band and will therefore be audible on equipment such as radio receivers, equipment for playing recordings and professional studio equipment.
- The ripple frequency is within television video bandwidth. Analogue TV receivers will exhibit a pattern of moving wavy lines if too much ripple is present.
- The presence of ripple can reduce the resolution of electronic test and measurement instruments. On an oscilloscope it will manifest itself as a visible pattern on screen.
- Within digital circuits, it reduces the threshold, as does any form of supply rail noise, at which logic circuits give incorrect outputs and data is corrupted.
- High-amplitude ripple currents shorten the life of electrolytic capacitors

Q45.Sketch the torque-speed relationship curve and write the equation

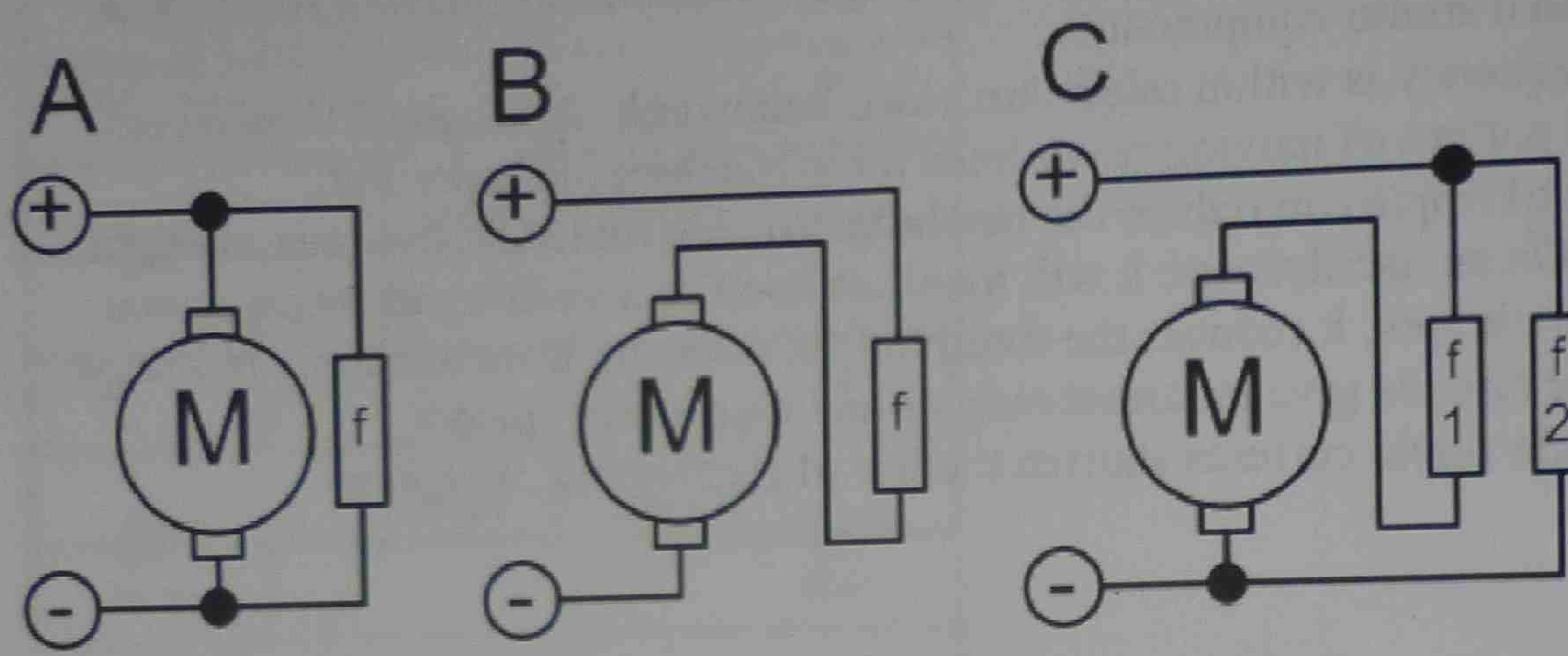


T motor = Ts – W Ts / Wn

Q47 + Q48. What is the duty cycle?

The duty cycle of a machine refers to how long it can keep operating before it needs a rest, or what percentage of the time it's designed to be in use. For instance, a machine gun might only be able to fire continuously for 100 rounds before it needs to be allowed to cool.

Q49.Sketch 4 points dc motor starter



A: shunt

B: series

C: compound

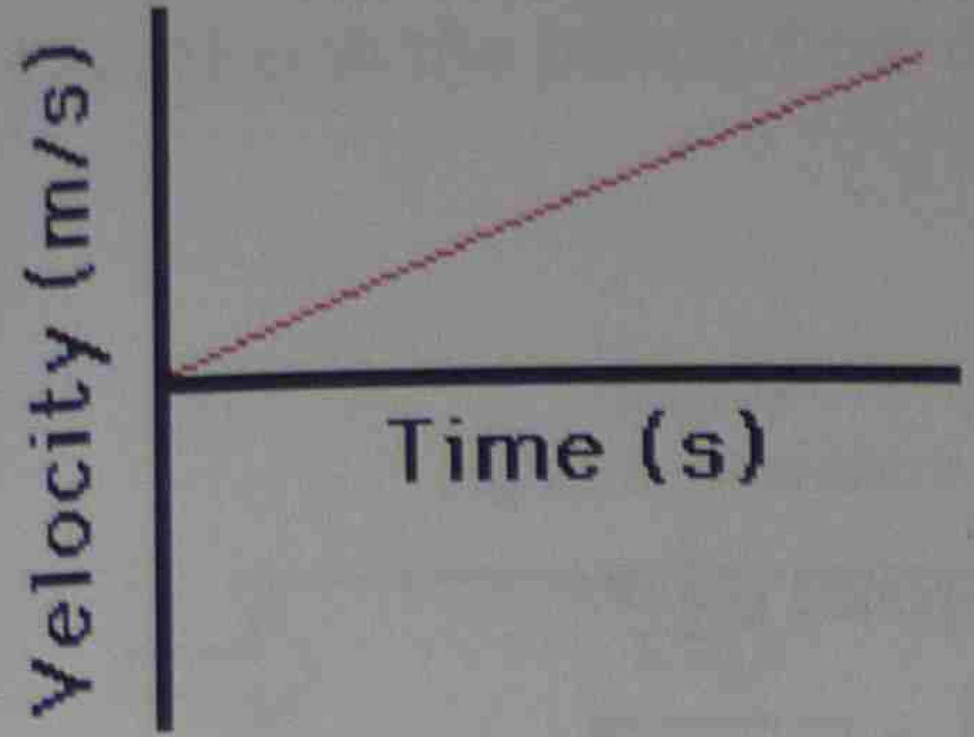
f = field coil

Q51.Express the types of dc motor starters

- circuit making and breaking conditions,
- type of load (squirrel cage motor, brush motor, resistor),
- conditions in which making and breaking take place (motor running, motor stalled, starting process, counter-current breaking, etc.).

DC motor starters combine a controller (most often a contactor) with overload protection, allowing a motor or motor-controlled equipment to be turned on and off. There are many different types of products. Multi-speed DC motor starters are designed to be operated at a constant frequency and voltage. Reduced voltage starters (RVS) also change speeds, but use motor windings that can be reconnected to form different numbers of poles. Reducing or reversing DC motor starters are designed for applications which must avoid overload conditions, or which need to avoid unnecessary wear and tear on equipment. There are five main types of reduced voltage starters: primary resistor, autotransformer, part winding, wye delta, and solid state. Full voltage, non-reversing DC motor starters have an overload relay and two contactors. These contactors are mechanically and electrically interlocked. Manual DC motor starters are also commonly available. They connect the incoming power directly to the motor, and are well-suited for squirrel-cage motors.

Q52.Sketch armature current and time graph, speed and time graph.



Q54.Sketch 4 points starter

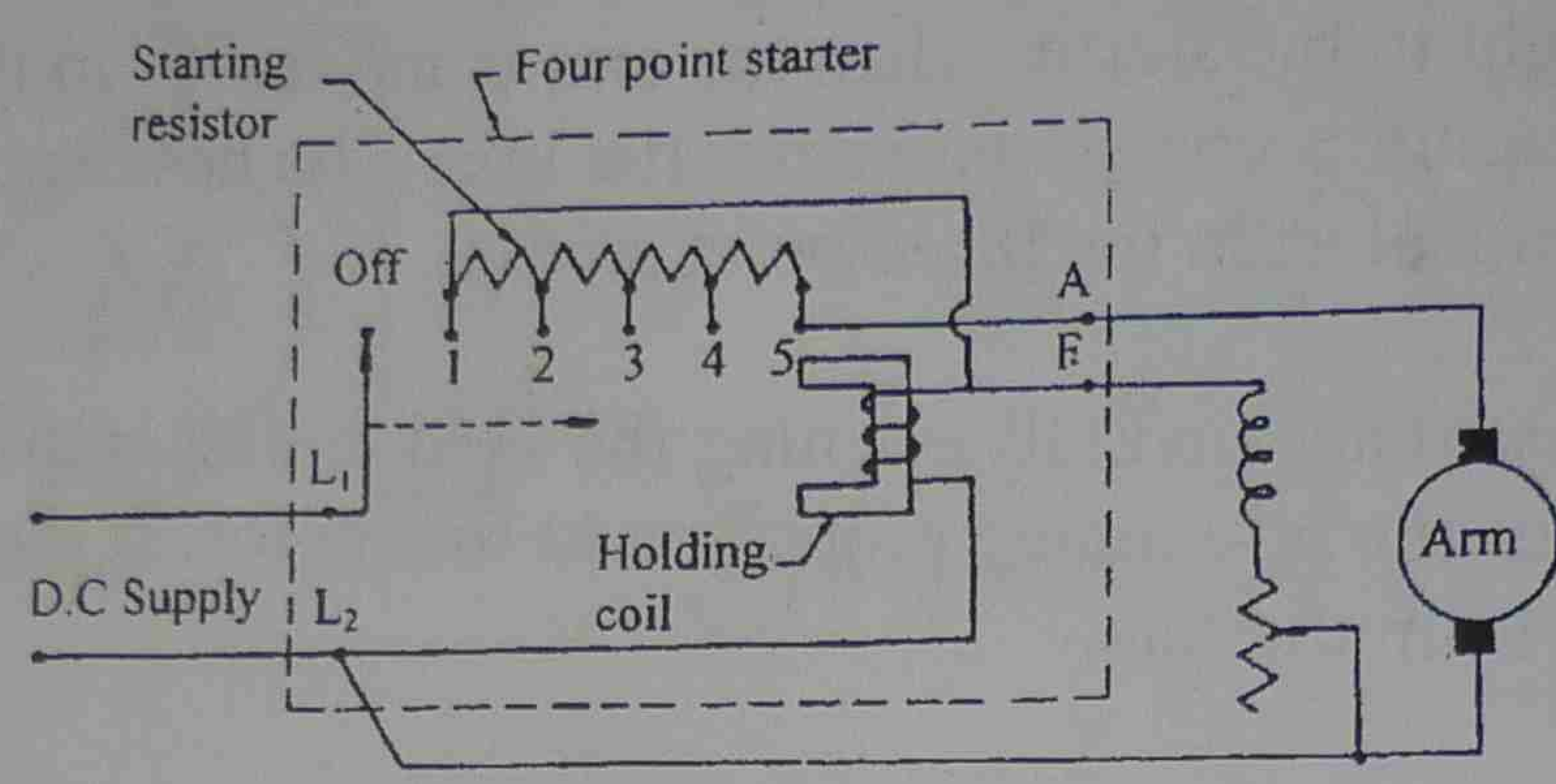
The four-point starter eliminates the drawback of the three-point starter. In addition to the same three points that were in use with the three-point starter, the other side of the line, L1, is the fourth point brought to the starter when the arm is moved from the "Off" position. The coil of the holding magnet is connected across the line. The holding magnet and starting resistors function identical as in the three-point starter.

- The possibility of accidentally opening the field circuit is quite remote. The four-point starter provides the no-voltage protection to the motor. If the power fails, the motor is disconnected from the line.

- There are two standard types of motor starter for shunt and compound motors. These are:

  (i) Three-point type; and (ii) Four-point type.

Three-point starter. The starter has three terminals L, F and A. if it is desired that the speed of the motor is controlled, a field rheostat is added as shown in Fig 1.26.



(a)

When the motor is at rest, the starter arm is held in the OFF position by a strong spiral spring.

Starting of motor:

- In order to *start the motor*, one hand is held on the handle of the open main switch while the starter arm is moved to the first stud with the other hand; then the main switch is closed. If all the wiring is correct and the armature is free to turn, the motor will start.
- After the armature has accelerated sufficiently on the first stud, the starter arm is slowly moved to studs 2, 3, 4 etc. until the arm rests firmly against the iron poles of the *holding coil* electromagnet. The entire starting process should take from 5 to 10 seconds. In the final position, the electromagnetic pull exerted by the holding coil will be greater than the force exerted by the spiral spring. *Should there be a power failure or should the field circuit be opened accidentally, the starter arm will fall back to its OFF position.* This function of starter is particularly important because:

  (i) if the power fails and starter arm is not restored to the OFF position, the motor might be damaged should the power, come on again; and

Q56.Sketch the power flow diagram of dc generator

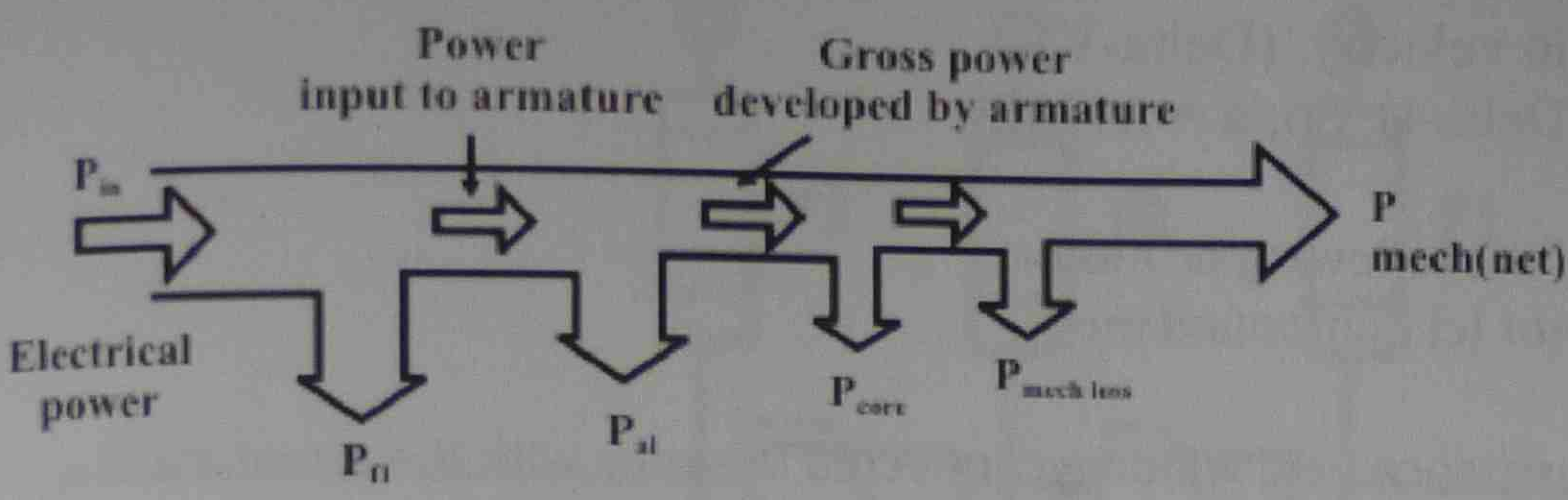
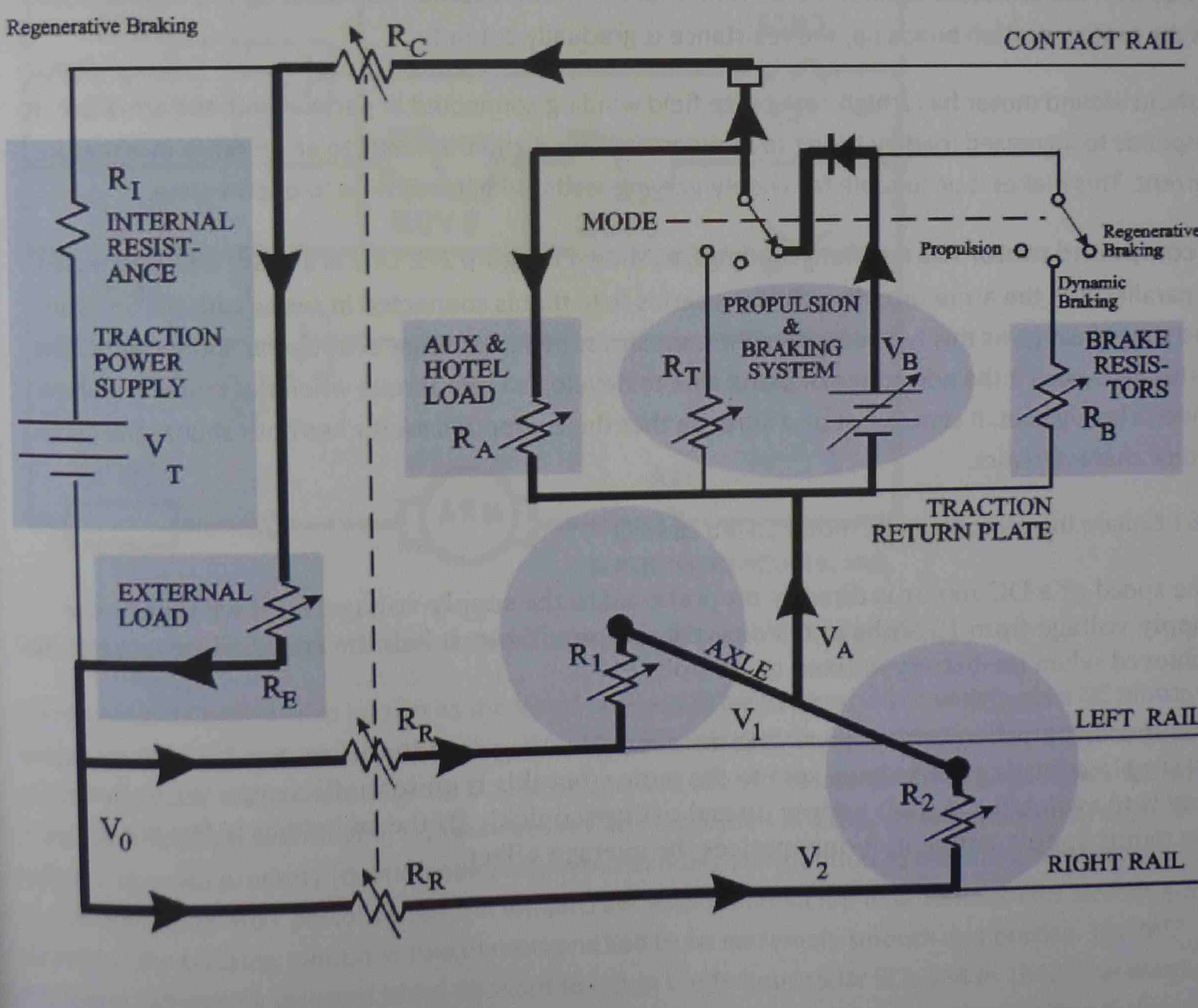


Fig. 40.1: Power flow diagram of a D.C. motor

Q59.Explain dynamic braking with sketch.

Dynamic braking is the use of the electric traction motors of a railroad vehicle as generators when slowing the Locomotive. It is termed rheostatic if the generated electrical power is dissipated as heat in brake grid resistors, and regenerative if the power is returned to the supply line. Dynamic braking lowers the wear of friction-based braking components, and additionally regeneration can also lower energy consumption.



Q61.Write the formula to calculate the acceleration time.

a = **F/m**, where ***F*** is the net force applied to a mass, **m**. Acceleration is also the change in velocity, (Delta-V), divided by the change in time, (Delta-t). So, **a** = **Δv/Δt**.

Q62.Describe the characteristics of the following dc motors.
(a) Series motor (b) Shunt motor (c) Compound motor

A series wound motor has a low-resistance field winding connected in series with the armature. It responds to increased load by slowing down and this reduces the armature current and minimises the risk of overheating. Series wound motors were widely used as traction motors in rail transport of every kind, but are being phased out in favour of AC induction motors supplied through solid state inverters. The counter-EMF aids the armature resistance to limit the current through the armature. When power is first applied to a motor, the armature does not rotate. At that instant, the counter-EMF is zero and the only factor limiting the armature current is the armature resistance. Usually the armature resistance of a motor is less than 1 Ω; therefore the current through the armature would be very large when the power is applied. Therefore the need arises for an additional resistance in series with the armature to limit the current until the motor rotation can build up the counter-EMF. As the motor rotation builds up, the resistance is gradually cut out.

A shunt wound motor has a high-resistance field winding connected in parallel with the armature. It responds to increased load by trying to maintain its speed and this leads to an increase in armature current. This makes it unsuitable for widely-varying loads, which may lead to overheating.

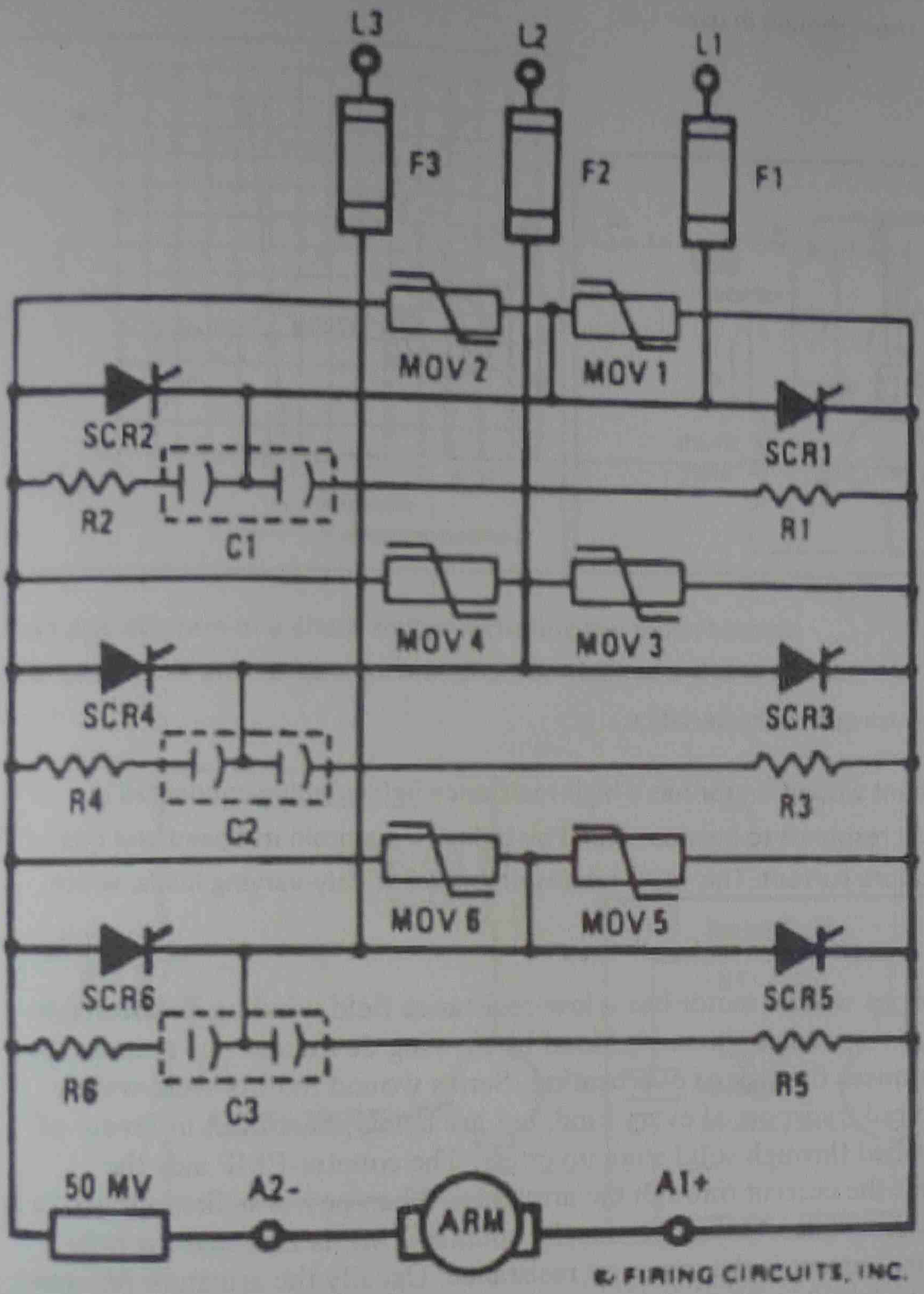
A compound motor has two field windings, as shown in figure 2-5. One is a shunt field connected in parallel with the armature; the other is a series field that is connected in series with the armature. The shunt field gives this type of motor the constant speed advantage of a regular shunt motor. The series field gives it the advantage of being able to develop a large torque when the motor is started under a heavy load. It should not be a surprise that the compound motor has both shunt- and series-motor characteristics.

Q63.Explain the principle of dc motor speed control

The speed of a DC motor is directly proportional to the supply voltage, so if we reduce the supply voltage from 12 Volts to 6 Volts, the motor will run at half the speed. How can this be achieved when the battery is fixed at 12 Volts?

The speed controller works by varying the average voltage sent to the motor. It could do this by simply adjusting the voltage sent to the motor, but this is quite inefficient to do. A better way is to switch the motor's supply on and off very quickly. If the switching is fast enough, the motor doesn't notice it, it only notices the average effect.

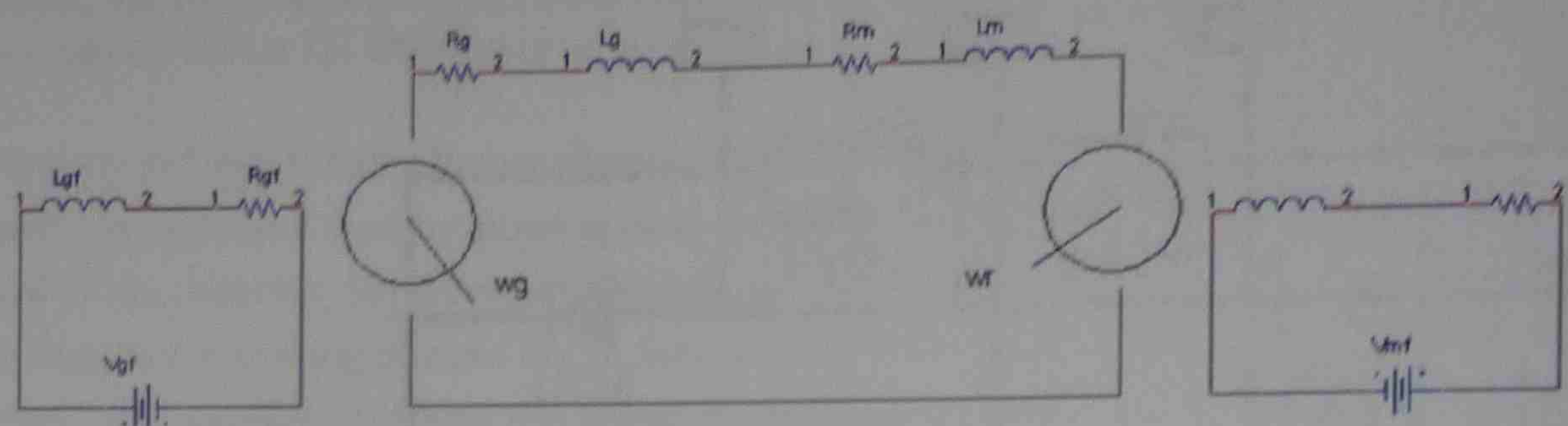
Q64.Sketch the block diagram of SCR controlled motor



Q65.Sketch the ward Leonard system speed control and explain it's operation

Ward Leonard Control, also known as the Ward Leonard Drive System, was a widely used DC motor speed control system introduced by Harry Ward Leonard in 1891. In early 1900s, the control system of Ward Leonard was adopted by the U.S. Navy and also used in passenger lift of large mines. It also provided a solution to a moving sidewalk at the Paris Exposition of 1900, where many others had failed to operate properly.[citation needed] An outstanding contribution to the war effort was the use of Ward-Leonard Control systems in antiaircraft radars. Connected to automatic anti-aircraft gun directors, the tracking motion in two dimensions had to be extremely smooth and precise. The MIT Radiation Laboratory selected Ward-Leonard to equip the famous radar SCR-584 in 1942. The Ward Leonard control system was widely used for elevators until thyristor drives became availble in the

1980s, because it offered smooth speed control and consistent torque. Many Ward Leonard control systems and variations on them remain in use.



Q66.Explain dc motor speed-torque characteristics.

Shunt wound motor: A shunt wound motor has a high-resistance field winding connected in parallel with the armature. It responds to increased load by trying to maintain its speed and this leads to an increase in armature current. This makes it unsuitable for widely-varying loads, which may lead to overheating.

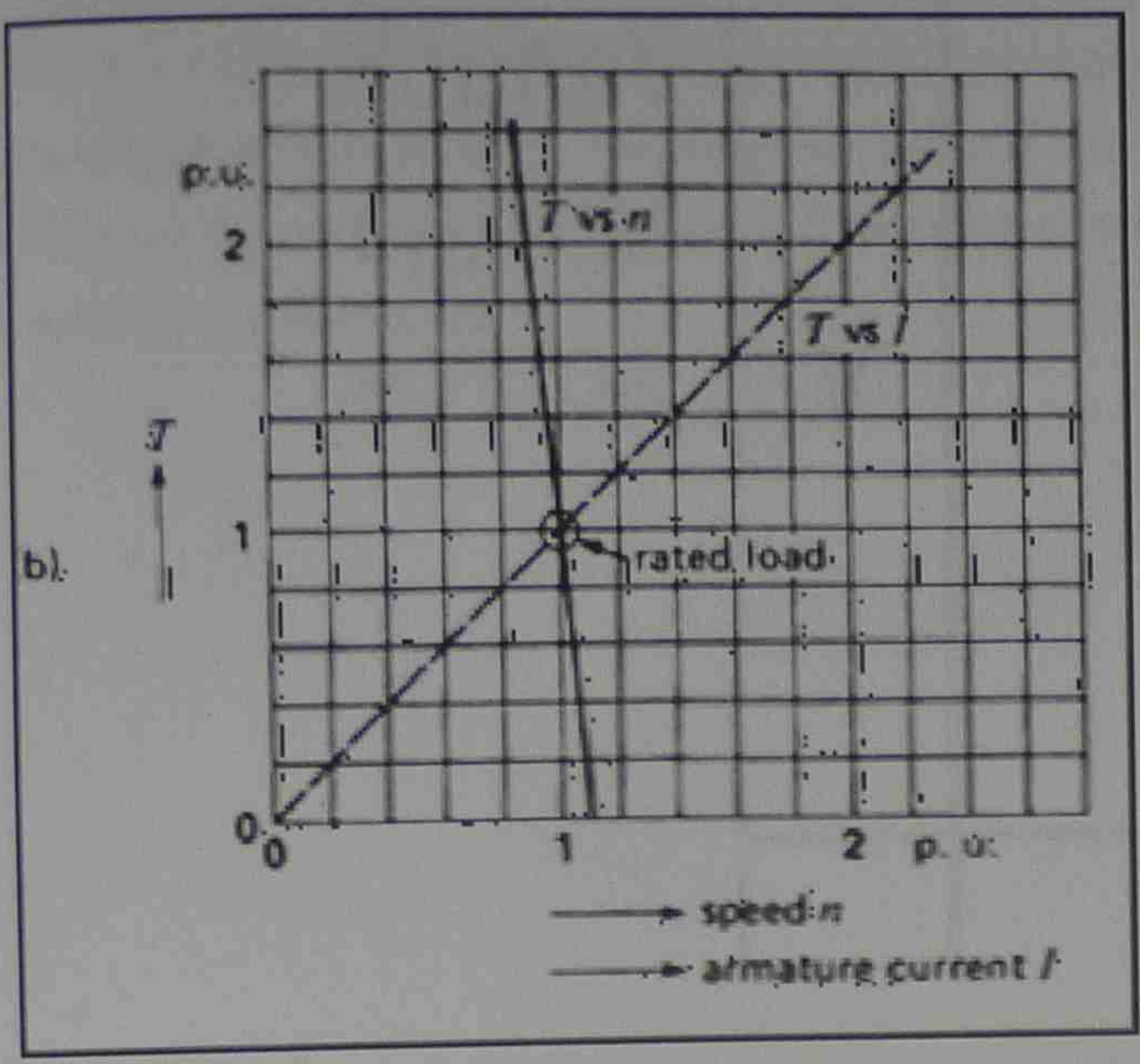
Series wound motor: A series wound motor has a low-resistance field winding connected in series with the armature. It responds to increased load by slowing down and this reduces the armature current and minimises the risk of overheating. Series wound motors were widely used as traction motors in rail transport of every kind, but are being phased out in favour of AC induction motors supplied through solid state inverters. The counter-EMF aids the armature resistance to limit the current through the armature. When power is first applied to a motor, the armature does not rotate. At that instant, the counter-EMF is zero and the only factor limiting the armature current is the armature resistance. Usually the armature resistance of a motor is less than 1 Ω; therefore the current through the armature would be very large when the power is applied. Therefore the need arises for an additional resistance in series with the armature to limit the current until the motor rotation can build up the counter-EMF. As the motor rotation builds up, the resistance is gradually cut out.

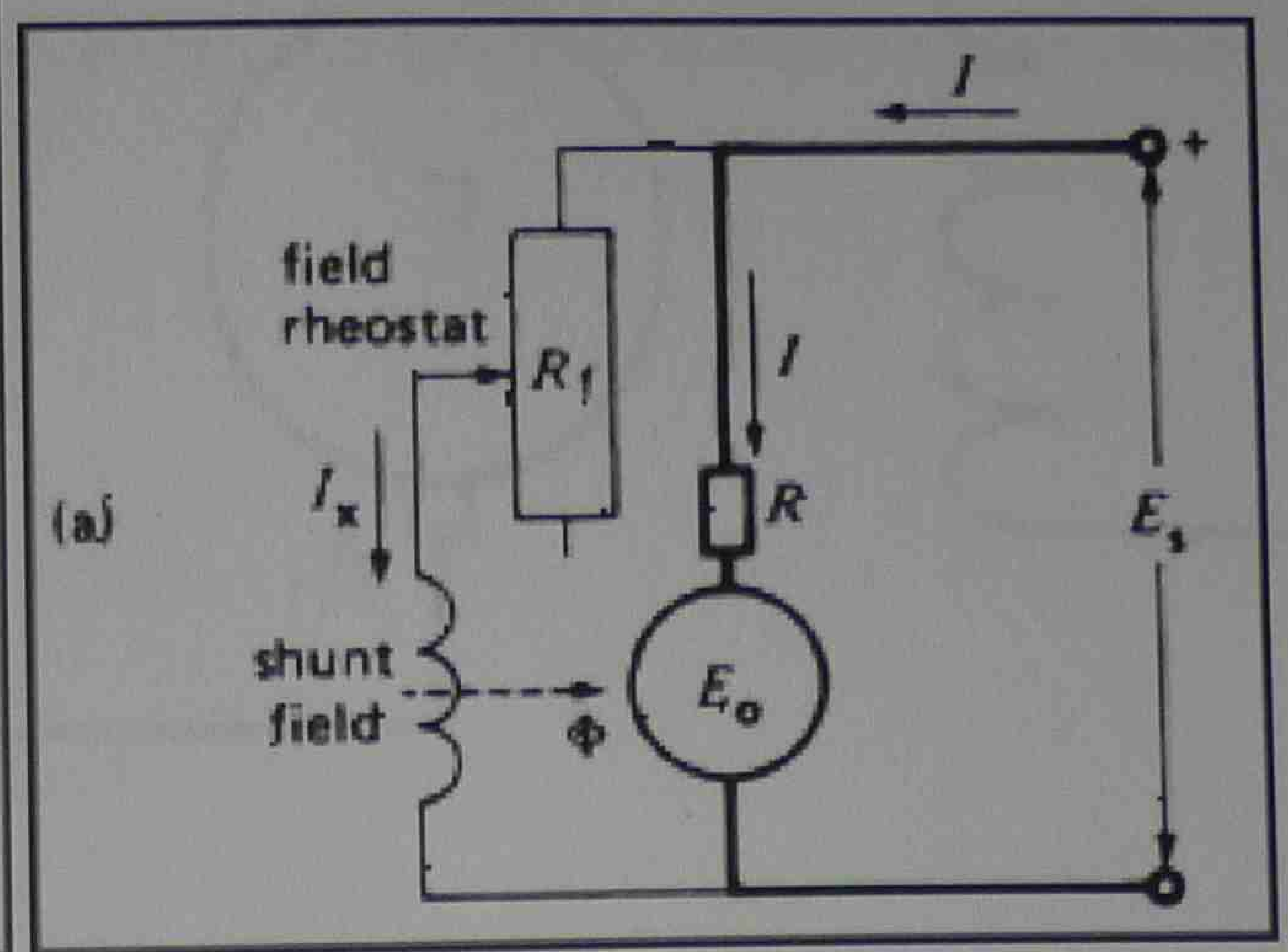
The output speed torque charateristic is the most notable characteristic of series wound d.c. motors. The speed being almost entirely dependent on the torque required to drive the load. This suits large inertial loads as the speed will drop until the motor slowly starts to rotate & these motors have a very high stalling torque.

Permanent magnet motor

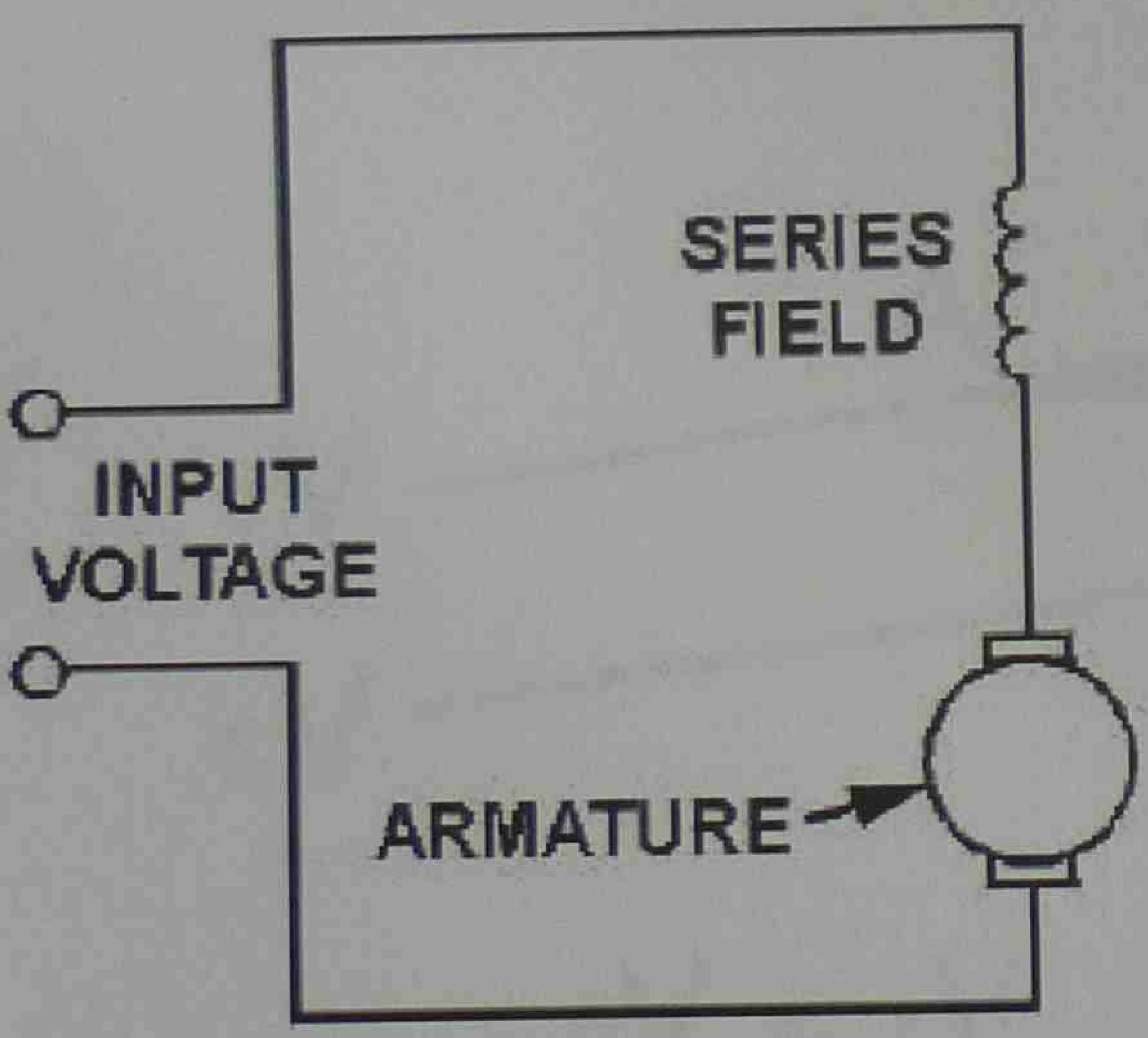
A permanent magnet DC motor is characterized by its locked rotor (stall) torque and its no-load angular velocity (speed).

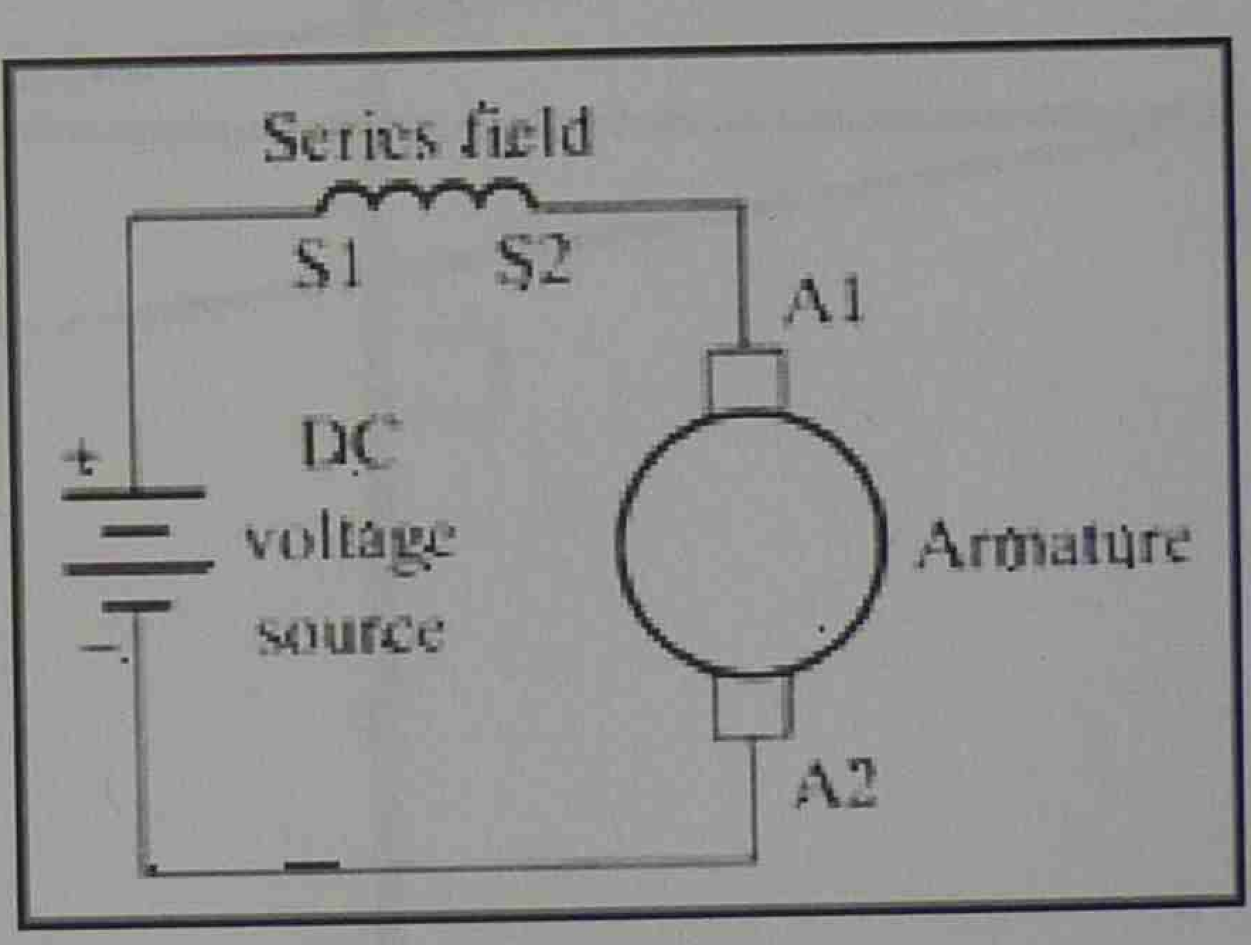
Q68.Sketch dc motor torque and speed relationship graph for (a) shunt motor (b) series motor





Schematic diagram of a shunt motor including the field rheostat
b. Torque-speed and torque-current characteristic of a shunt motor.

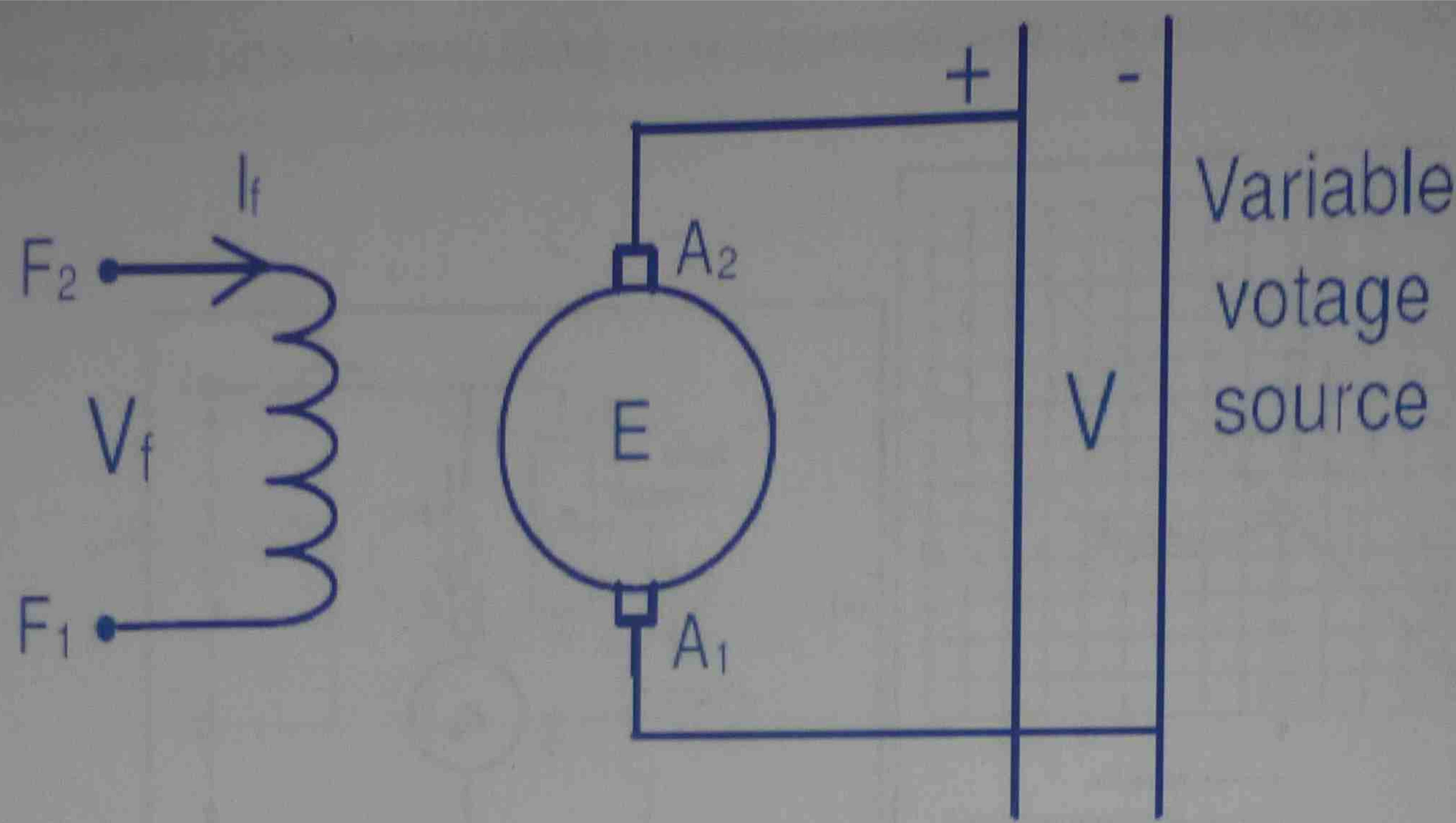




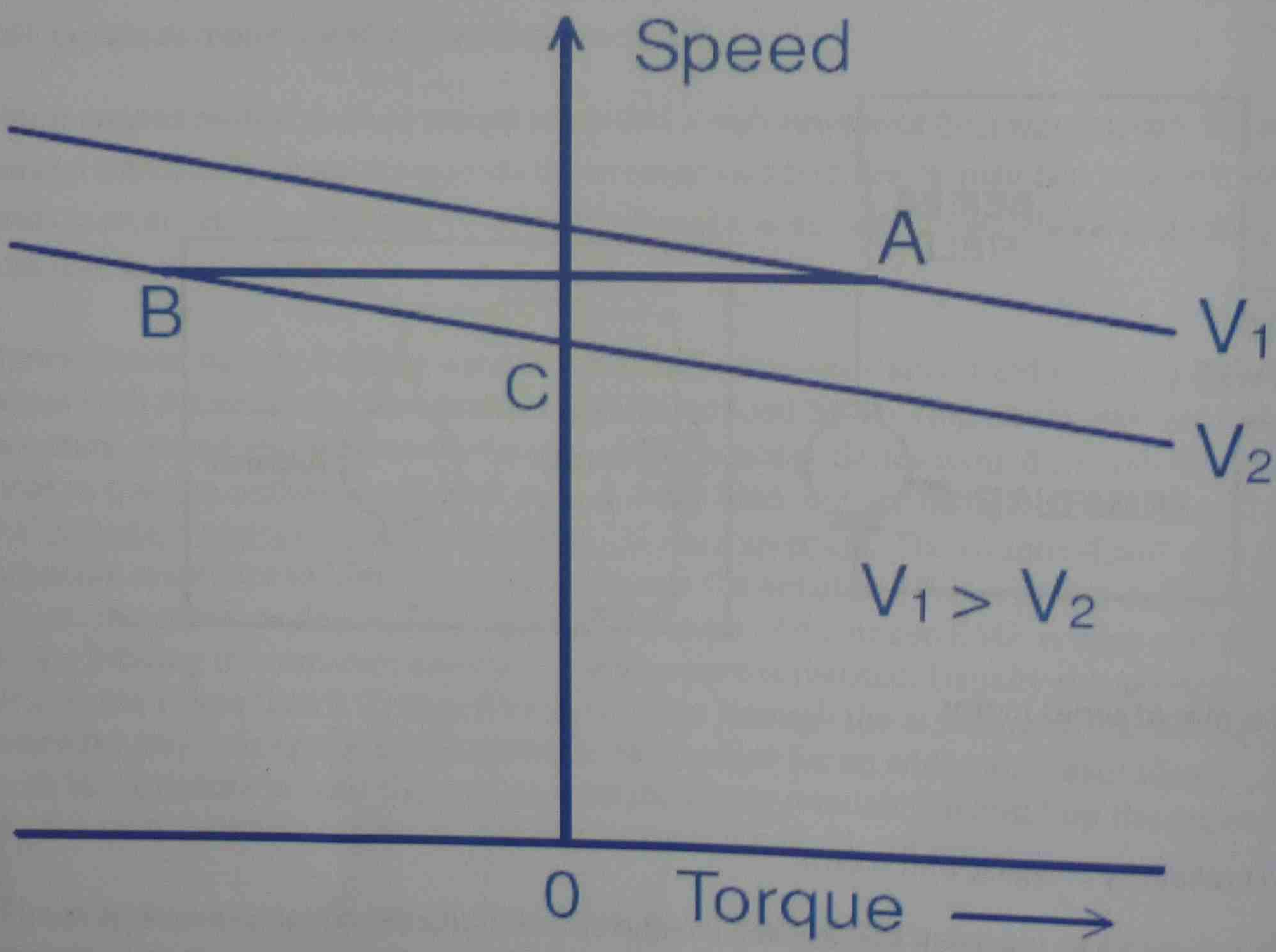
Electrical diagram of series motor

Q70.Explain braking by plugging with sketch

In regenerative braking as the name suggests the energy recovered from the rotating masses is fed back into the d.c. power source. Thus this type of braking improves the energy efficiency of the machine. The armature current can be made to reverse for a constant voltage operation by increase in speed/excitation only. Increase in speed does not result in braking and the increase in excitation is feasible only over a small range, which may be of the order of 10 to 15%. Hence the best method for obtaining the regenerative braking is to operate, the machine on a variable voltage supply. As the voltage is continuously pulled below the value of the induced emf the speed steadily comes down. The field current is held constant by means of separate excitation.



(a)Physical connection



(b)Characteristics

Figure 51: Regenerative braking of a shunt machine