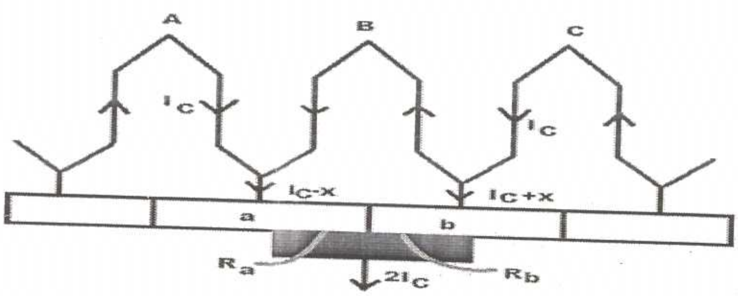
Sub. code – 4031

DC MACHINES

QNO	Scoring Indicators	Split Score	Total Score
I 1	**Basis for Comparison** / **Slip Ring** / **Split Ring** Definition: The slip ring is used for transferring the power between the rotating and stationary structure of an AC machine / The split ring is used for reversing the direction of current. Uses: It is used in AC machine. / It is used in DC machine. Design: Continuous Ring / The ring is split into two or more parts. Application: It supplies power from an AC generator to the AC motor. / For supplying pulsating voltage to the DC motor. Any two	1+1	2
2	The critical field resistance is defined as the maximum field circuit resistance(for a given speed) with which the shunt generator would excite. The shunt generator will build up voltage only if field circuit resistance is less than criticalfield resistance.	2	2
3	The function of equalizer rings are (i) to save the brushes from handling the circulating currents and (ii) to reduce the magnetic flux unbalance that cause sthe potential difference in various parallel paths. Any two	1+1	2
4	1. The flux Φ 2. The voltage across the armature 3. The applied voltage V Any two	1+1	2
5.	1. The power required to test a large machine is small. Thus, this method is an economical and convenient method of testing of DC machines. 2. As the constant loss is known the efficiency can be predetermined at any load.	1+1	2
II 1	PART –B Let P = Number of poles of the generator Φ = Flux produced by each pole in webers (Wb) N = Speed of armature in r.p.m. Z = Total Number of Armature Conductors A = Number of parallel paths in which the 'Z' number of conductors are divided So A = P for lap type of winding A = 2 for wave type of winding Now e.m.f. gets induced in the conductor according to Faraday's law of electromagnetic induction. Hence average value of e.m.f. induced in each armature conductor is, e = Rate of cutting the flux = dΦ/dt Now consider one revolution of conductor. In one revolution, conductor will cut total flux produced by all the poles i.e. Φ x P. While time required to complete one revolution is	2 6	6

2

	60/N seconds as speed is N r.p.m. $\therefore \quad e = \frac{\phi P}{\frac{60}{N}} = \phi P \frac{N}{60}$ This is the e.m.f. induced in one conductor. Now the conductors in one parallel path are always in series. There are total Z conductor with A parallel paths, hence Z/A number of conductors are always in series and e.m.f. remains same across all the parallel paths. $\therefore$ Total e.m.f. can be expressed as, $E = \phi P \frac{N}{60} \times \frac{Z}{A}$ volts This is nothing but the e.m.f. equation of a d.c. generator. So $\boxed{E = \frac{\phi PNZ}{60\ A} \quad \text{e.m.f. equation}}$ $E = \frac{\phi NZ}{60}$ for lap type as A = P $E = \frac{\phi PNZ}{120}$ for wave type as A = 2	2 2	
2	1. In lap winding, the coil is lap back to the succeeding coil whereas in the case of the wave winding the coil are connected in the wave shape. 2. In lap winding, the end of the armature coil is connected to the adjacent commutator segment, whereas is wave winding the end of the armature coil is placed in the commutator segment which is placed apart. 3. In lap winding the number of parallel paths is equal to the total number of poles of the coil and in the wave winding the number of parallel paths is always equal to two. 4. The lap winding is also called parallel winding because their coils are connected in parallel whereas in the wave winding the coils are connected in series and hence it is called series winding. 5. The emf of the lap winding is less as compared to wave winding. 6. The lap winding requires equaliser for the better commutation. The wave winding requires the dummy coil for giving the mechanical balance to the armature. 7. In lap winding, the number of brushes is equal to the number of parallel paths whereas in wave winding the number of brushes is two. 8. The efficiency of the lap winding is less as compared to the wave winding. 9. The simplex and duplex are the types of lap windings. In simplex winding, the number of parallel paths is equal to the pole, in duplex winding the pole is twice to that of a parallel path, whereas the progressive and the retrogressive are the types of the wave windings. 10. The winding cost of the lap winding is more than the wave winding because it requires more conductor. 11. The lap winding is used in low voltage, high current machines, whereas the wave winding is used in high voltage, low current machines. Any six	6x1= 6	6
3	**1.** There must be some residual magnetism in the generator poles.		

	2. For the given direction of rotation, the shunt field coils should be correctly connected to the armature *i.e.* they should be so connected that the induced current reinforces the e.m.f. produced initially due to residual magnetism. **3.** If excited on open circuit, its shunt field resistance should be less than the critical resistance (which can be found from its *O.C.C.*) **4.** The generator speed should be greater than critical speed	6	6
4	There are three main methods of improving commutation. These are 1. Resistance commutation 2. E.M.F. commutation **Resistance Commutation** In this method of commutation we use high electrical resistance brushes for getting spark less commutation. This can be obtained by replacing low resistance copper brushes with high resistance carbon brushes. The current IC from the coil C may reach to the brush in two ways in the commutation period. One path is direct through the commutator segment b and to the brush and the 2nd path is first through the short-circuit coil B and then through the commutator segment a and to the brush. When the brush resistance is low, then the current IC from coil C will follow the shortest path, i.e. the 1st path as its electrical resistance is comparatively low because it is shorter than the 2nd path. When high resistance brushes are used, then as the brush moves towards the commutator segments, the contact area of the brush and the segment b decreases and contact area with the segment a increases. Now, as the electrical resistance is inversely proportional to the contact area of then resistance Rb will increase and Ra will decrease as the brush moves. Then the current will prefer the 2nd path to reach to the brush. Thus by this method of improving commutation, the quick reversal of current will occur in the desired direction.  **E.M.F. Commutation** The main reason of the delay of the current reversing time in the short circuit coil during commutation period is the inductive property of the coil. In this type of commutation, the reactance voltage produced by the coil due to its inductive property, is neutralized by producing a reversing emf in the short circuit coil during commutation period. Reactance Voltage: The voltage rise in the short circuit coil due to inductive property of the coil, which opposes the current reversal in it during the commutation period, is called the reactance voltage. We can produce reversing emf in two ways	3 3	6

	1. By brush shifting. 2. By using inter-poles or commutating poles.		
5	Now at the starting instant the speed of the motor is zero, (N = 0). As speed is zero, there can not be any back e.m.f. as $E_b \alpha$ N and N is zero at start. $\therefore$ E_b at start = 0 The voltage equation of a d.c. motor is, $V = E_b + I_a R_a$ So at start, $V = I_a R_a$ as $E_b = 0$ $\therefore$ $I_a = V/Ra$ .... at start Generally motor is switched on with normal voltage and as armature resistance is very small, the armature current at start is very high. So at start, motor is showing a tendency to draw an armature current which is 15 to 20 times more than the full load current. Such high current drawn by the armature at start is highly objectionable for the following reasons : 1. In a constant voltage system, such high inrush of current may cause tremendous line voltage fluctuations. This may affect the performance of the other equipments connected to the same line. 2. Such excessively high armature current, blows out the fuses. 3. If motor fails to start due to some problems with the field winding, then a large armature current flowing for a longer time may burn the insulation of the armature winding. 4. As the starting armature current is 10 to 15 times more than the full load current, the torque developed which is proportional to the I_a will also be 10 to 15 times, assuming shunt motor operation. So due to such high torque, the shaft and other accessories are thus subjected to large mechanical stresses. These stresses may cause permanent mechanical damage to the motor. To restrict this high starting armature current, a variable resistance is connected in series with the armature at start. This resistance is called starter or a starting resistance. So starter is basically a current limiting device. In the beginning the entire resistance is in the series with the armature and then gradually cut off as motor gathers speed, producing the back e.m.f.	6	6

6	**Losses In A Rotating DC Machine**
	▪ Copper losses
	  ▪ Armature Cu loss
	  ▪ Field Cu loss
	  ▪ Loss due to brush contact resistance
	▪ Iron Losses
	  ▪ Hysteresis loss
	  ▪ Eddy current loss
	▪ Mechanical losses
	  ▪ Friction loss
	  ▪ Windage loss
		2
		2
		2
			6

7	DC series motor :- .Series motors have high starting torque.so they are used where very high starting torque required. The motor has very wide use in traction purpos. As in case of traction the engine has to carry a heavy loads of luggage or boggies from stopping condition in such cases only this motor can be used efficiently.In Series motor its torque is inversely proportional to its speed. So when speed is zero the torque is max and as speed approaches the torque decreases . So both became stable when they balance each other Some other purposes of DC series motors are cranes, machine tools , pumps blowers ,trolley cars,conveyors etc.	6	6

III a

An electrical generator is a machine which converts mechanical energy (or power) into electrical energy (or power).The energy conversion is based on the principle of the production of dynamically (or due to motion) induced e.m.f.whenever a conductor cuts magnetic flux, dynamically induced e.m.f. is produced in it according to Faraday's Laws of Electromagnetic Induction. This e.m.f. causes a current to flow if the conductor circuit is closed. Hence, two basic *essential parts of an electrical dc generator are (i) a magnetic field and (ii) a conductor or conductors* which can so move as to cut the flux In Fig.is shown a single-turn rectangular copper coil ABCD rotating about its own axis in a magnetic field provided by either permanent magnet is or electromagnets. The two ends of the coil are joined to two slip-rings 'a' and 'b' which are insulated from each other and from the central shaft. Two collecting brushes (of carbon or copper) press against the slip-rings. Their function is to collect the current induced in the coil and to convey it to the external load resistance R. The rotating coil may be called 'armature' and the magnets as 'field magnets'.

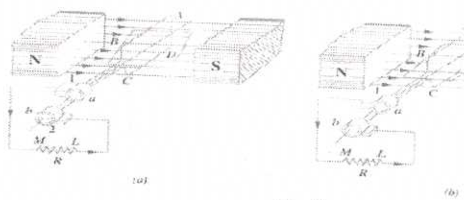


Fig.0

DC Generator Working:

Imagine the coil to be rotating in clock-wise direction (Fig.1). As the coil assumes successive positions in the field, the flux linked with it changes. Hence, an e.m.f. is induced in it which is proportional to the rate of change of flux linkages (e = NdΦdt). When the plane of the coil is at right angles to lines of flux i.e. when it is in position, 1, then flux linked with the coil is maximum but rate of change of flux linkages is minimum. It is so because in this position, the coil sides AB and CD do not cut or shear the flux, rather they slide along them i.e. they move parallel to them. Hence, there is no induced e.m.f. in the coil. Let us take this no-e.m.f. or vertical position of the coil as the starting position. The angle of rotation or time will be measured from this position.

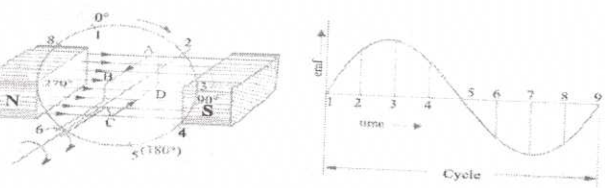


Fig.1

As the coil continues rotating further, the rate of change of flux linkages (and hence induced e.m.f. in it) increases, till position 3 is reached where θ = 90°. Here, the coil plane is

horizontal i.e. parallel to the lines of flux. As seen, the flux linked with the coil is minimum but rate of change of flux linkages is maximum. Hence, maximum e.m.f. is induced in the coil when in this position
(Fig.1).

In the next quarter revolution i.e. from 90° to 180°, the flux linked with the coil gradually increases but the rate of change of flux linkages decreases. Hence, the induced e.m.f. decreases gradually till in position 5 of the coil, it is reduced to zero value. So, we find that in the first half revolution of the coil, no (or minimum) e.m.f. is induced in it when in position 1, maximum when in position 3 and no e.m.f. when in position 5. The direction of this induced e.m.f. can be found by applying Fleming's Right-hand rule which gives its direction from A to B and C to D. Hence, the direction of current flow is ABMLCD (Fig.0). The current through the load resistance R flows from M to L during the first half revolution of the coil.

In the next half revolution i.e. from 180° to 360°, the variations in the magnitude of e.m.f. are similar to those in the first half revolution. Its value is maximum when coil is in position 7 and minimum when in position 1. But it will be found that the direction of the induced current is from D to C and B to A as shown in Fig.1. Hence, the path of current flow is along DCLMBA which is just the reverse of the previous direction of flow. Therefore, we find that the current which we obtain from such a simple generator reverses its direction after every half revolution. Such a current undergoing periodic reversals is known as alternating current. It is, obviously, different from a direct current which continuously flows in one and the same direction.

It should be noted that alternating current not only reverses its direction, it does not even keep its magnitude constant while flowing in any one direction. The two half-cycles may be called positive and negative half-cycles respectively (Fig.1). For making the flow of current unidirectional in the external circuit, the slip-rings are replaced

Figures &waveform — 2+1

explanation — 4

7

b P=8
Z=500
0=.05Wb
N=1200rpm
In lap winding,induced emf=E= $\Phi ZP/60A$ — 4

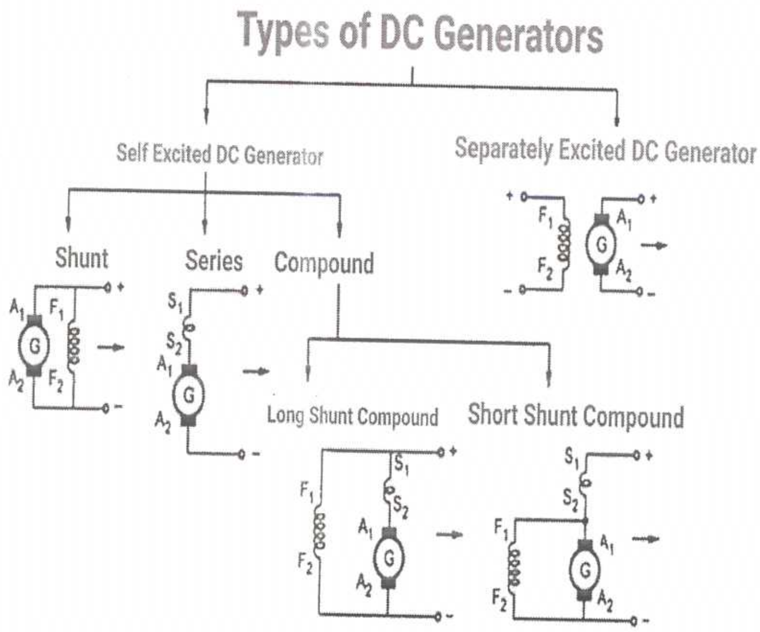
$$= \frac{.05 \times 500 \times 1200 \times 8}{60 \times 8} = 500V$$

In wave winding,
E=500V
P=8
A=2
Z=500
N= Ex60Xa/$_{\phi ZP}$ — 4

8

$$= \frac{500 \times 60 \times 2}{.05 \times 500 \times 8} = 300 \text{ rpm}$$

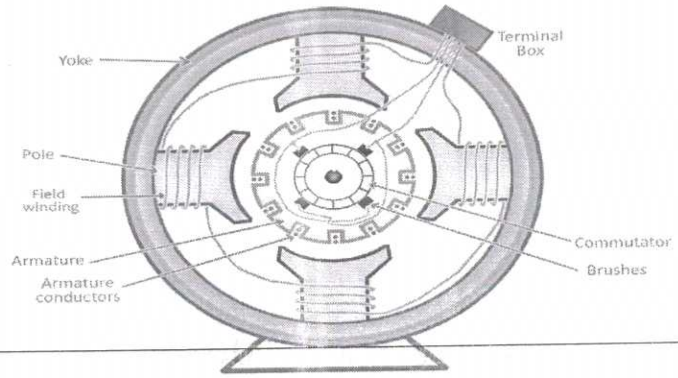
b



Or DC generators classification explanation

7 7

Or Construction Of DC Generators — ~~is~~ ~~Wor~~



The above figure shows constructional details of a simple **4-pole DCGenerator**. Basic constructional parts of a DC machine are described below.

1. **Yoke:** The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.
2. **Poles and pole shoes:** Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.
3. **Field winding:** They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.
4. **Armature core:** Armature core is the rotor of a dc machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.
5. **Armature winding:** It is usually a former wound copper coil which rests in armature slots. The armature conductors are insulated from each other and also from the armature core. Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.
6. **Commutator and brushes:** Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors. A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

3 - fig
5 - exp.
8

Figure 3
Explanation 5

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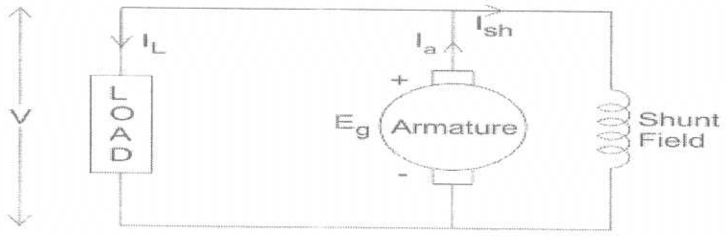


Shunt Wound Generator

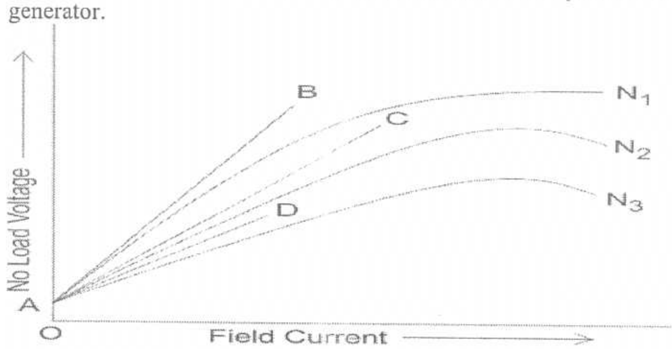
Magnetic or Open Circuit Characteristic of Shunt Wound DC Generator

OCC is the curve drawn between shunt field current($I_{sh\ or\ If}$) and the no load voltage (E_0). For a given excitation current or field current, the emf generated at no load E_0 varies in proportionally with the rotational speed of the armature. Here in the diagram the magnetic characteristic curve for various speeds are drawn.

Due to residual magnetism the curves start from a point A slightly up from the origin O. The upper portions of the curves are bend due to saturation. The external load resistanceof the machine needs to be maintained greater than its critical value otherwise the machine will not excite or will stop running if it is already in motion. AB, AC and AD are the slops which give critical resistances at speeds N_1, N_2 and N_3. Here, $N_1 > N_2 > N_3$.

Critical Load Resistance of Shunt Wound DC Generator

This is the minimum external load resistance which is required to excite the shunt wound generator.



Magnetic or Open Circuit Characteristic

Figure
Explanation
</td>
<td>4
3</td>
<td>7</td>
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The effect of armature flux on the main field flux is called as **armature reaction.**

The **effect of armature reaction** is explained in the figure below.
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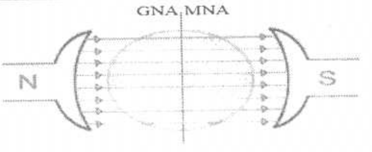
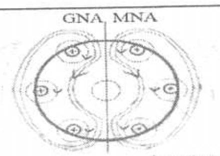
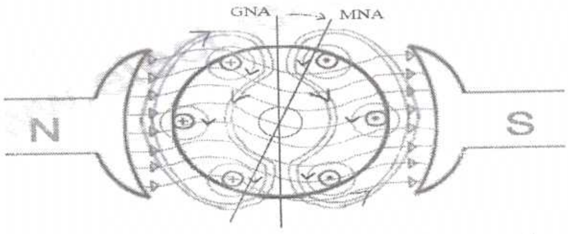


Main field flux



Armature Flux



Distortion of main field flux due to armature flux - Armature reaction

Consider, no current is flowing in the armature conductors and only the field winding is energized (as shown in the first diagram.. In this case, magnetic flux lines of the field poles are uniform and symmetrical to the polar axis. The Magnetic Neutral Axis coincides with the Geometric Neutral Axis

The second diagram shows armature flux lines due to the armature current. Field poles are de-energised.

when a DC machine is running, both the fluxes (flux due to the armature conductors and flux due to the field winding) will be present at a time. The armature flux superimposes with the main field flux and, hence, disturbs the main field flux (as shown in third figure the of above image). This effect is called as **armature reaction in DC machines**.

The Effects are

1. Armature reaction weakens the main flux. In case of a dc generator, weakening of the main flux reduces the generated voltage. 4
2. Armature reaction distorts the main flux, hence the position of M.N.A. gets shifted (M.N.A. is perpendicular to the flux lines of main field flux). Brushes should be placed on the M.N.A., otherwise, it will lead to sparking at the surface of brushes. So, due to armature reaction, it is hard to determine the exact position of the MNA 4 8

Figure 4
Explanation 4

VI a

Applications of DC Generators.

Sc

This type of DC generators are generally more expensive than self-excited DC generators because of their requirement of separate excitation source. Because of that their applications are restricted. They are generally used where the use of self-excited generators are unsatisfactory.

1. They are generally used for testing purpose in the laboratories.
2. Separately excited generators operate in a stable condition with any variation in field excitation. So they are used as supply source of DC motors, whose speeds are to be controlled for various applications. Example- Ward Leonard Systems of speed control.

Applications of Shunt Wound DC Generators

The application of shunt generators is very much restricted for its dropping voltage characteristic. They are used to supply power to the apparatus situated very close to its position. These type of DC generators generally give constant terminal voltage for small distance operation with the help of field regulators from no load to full load.

1. They are used for general lighting.
2. They are used to charge battery because they can be made to give constant output voltage.
3. They are used for giving the excitation to the alternators.
4. They are also used for small power supply (such as a portable generator).

Applications of Series Wound DC Generators

These types of generators are restricted for the use of power supply because of their increasing terminal oltage characteristic with the increase in load current from no load to full load. We can clearly see this characteristic from the characteristic curve of series wound generator. They give constant current in the dropping portion of the characteristic curve.

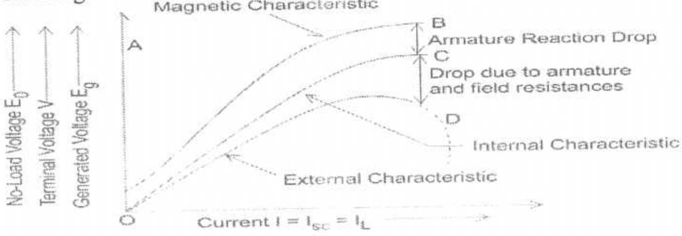
1. They are used for supplying field excitation current in DC locomotives for regenerative breaking.
2. This types of generators are used as boosters to compensate the voltage drop in the feeder in various types of distribution systems such as railway service.
3. In series arc lightening this type of generators are mainly used.

Applications of Compound Wound DC Generators

The compound wound DC generators are most widely used because of its compensating property.

1. Cumulative compound wound generators are generally used for lighting, power supply purpose and for heavy power services because of their constant voltage property. They are mainly made over compounded.
2. Cumulative compound wound generators are also used for driving a motor.
3. For small distance operation, such as power supply for hotels, offices, homes and lodges, the flat compounded generators are generally used.
4. The differential compound wound generators, because of their large

7 | 7

	demagnetization armature reaction, are used for arc welding where huge voltage drop and constant current is required.			
b	**Internal Characteristic of Series Wound DC Generator** The **internal characteristic** curve gives the relation between voltage generated in the armature and the load current. This curve is obtained by subtracting the drop due to the demagnetizing effect of armature reaction from the no load voltage. So, the actual generated voltage (E_g) will be less than the no load voltage (E_0). That is why the curve is slightly dropping from the open circuit characteristic curve. Here in the diagram below OC curve is showing the internal characteristic or total characteristic of the series wound DC generator. **External Characteristic of Series Wound DC Generator** The external characteristic curve shows the variation of terminal voltage (V) with the load current (I_L). Terminal voltage of this type of generator is obtained by subtracting the ohomic drop due to armature resistance (R_a) and series field resistance (R_{sc}) from the actually generated voltage (E_g). Terminal voltage $V = E_g - I(R_a + R_{sc})$ The external characteristic curve lies below the internal characteristic curve because the value of terminal voltage is less than the generated voltage. Here in the figure OD curve is showing the external characteristic of the series wound DC generator.  Characteristic Curves of Series Wound DC Generators	Internal Characteristics External Characteristics	4 4	8

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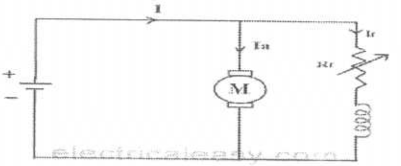
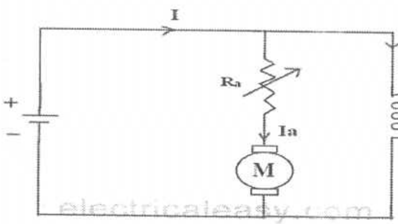
Speed Control Of Shunt Motor

1. Flux Control Method



It is already explained above that the **speed of a dc motor** is inversely proportional to the flux per pole. Thus by decreasing the flux, speed can be increased and vice versa.
To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux. In shunt motors, as field current is relatively very small, Ish2R loss is small. Therefore, this method is quite efficient. Though speed can be increased above the rated value by reducing flux with this method, it puts a limit to maximum speed as weakening of field flux beyond a limit will adversely affect the commutation.

2. Armature Control Method



Speed of a dc motor is directly proportional to the back emf Eb and Eb = V - IaRa. That means, when supply voltage V and the armature resistance Ra are kept constant, then the speed is directly proportional to armature current Ia. Thus, if we add resistance in series with the armature, Ia decreases and, hence, the speed also decreases. Greater the resistance in series with the armature, greater the decrease in speed.

3. Voltage Control Method

In this method, the shunt field is connected to a fixed exciting voltage and armature is supplied with different voltages. Voltage across armature is changed with the help of suitable switchgear. The speed is approximately proportional to the voltage across the armature.

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<tr><td>b</td><td>

Since the flux remains constant, the speed formula becomes $N_2/N_1 = E_{b2}/E_{b1}$

(i) Full-load torque

$N_1 = 600$rpm;

$E_{b1} = V - I_{a1}R_{a1} = 250 - 20 \times 0.5 = 240V$

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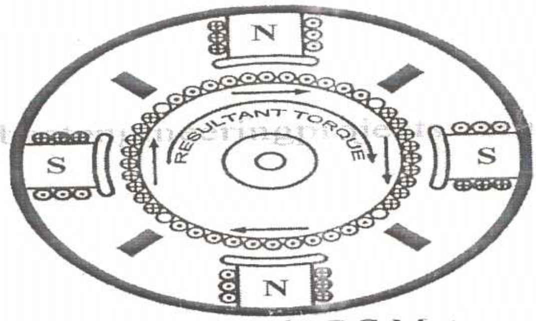
</table>

	$T\ \alpha\ \phi I_a\ \alpha\ I_a$ (ϕ is constant) $T_2/T_1 = I_{a2}/I_{a1}$ since $T_2=T_1$; $I_{a2}=I_{a1}= 20A$ $E_{b2} = V-I_{a2}R_{a2}=250-20x1.5=220V$ $N_2/100=220/240$; $N_2= 600x220/240= 550rpm$ (ii) Half the full-load torque $T_2/T_1=I_{a2}/I_{a1}$ or $T_1\frac{1}{2}/T_1 = I_{a2}/20$; $I_{a2}= 10A$; $E_{b2} = 250-10x1.5=235V$ $N_2/600= 235/240$; $N_2= 600x235/240= 587.5rpm$	4 4	8
VIII a	Working Principle of DC Motor An electric motor converts electrical energy into mechanical energy.Its action based on the principle that when a current carrying conductor is placed in a magnetic field, mechanical force is experienced on the conductor, the direction of which is given by Fleming's left hand rule (also called motor rule) and hence the conductor moves in the direction of force. The magnitude of the mechanical force experienced on the conductor is given by F=BIl newtons where B is the field strength is teslas (Wb/m^2), I is the current flowing through the conductor in amperes and l is the length of conductor in metres. When the motor is connected to the dc supply mains, a direct current passes through the brushes and commutator it is converted into ac so that the group of conductors under successive field poles carry currents in the opposite directions, as shown Fig. 1 Also the direction of current in the individual conductors reverses as they pass away from the influence of one pole to that of the next.  Figure 1: 4-Pole DC Motor In Fig. 1, a 4-pole dc motor is shown when the field and armature circuits are connected across dc supply mains. Let the current armature conductors be outwards under the N-poles (shown by dots) and inwards under S-poles (shown by crosses). By applying Fleming's left hand rule, the direction of force on each conductor can be determined.. From Fig.1. it is observed that each conductor experiences a force which tends to rotate the motor armature in clockwise direction. These forces collectively produce a driven torque.	fig-3 expl.-4 7	7
b	A **3 point starter** is a device that helps in the starting and running of a DC shunt motor or compound wound DC motor . It's due to the presence of back emf (Eb), which plays a critical role in governing the operation of the motor. The back emf develops as the motor armature starts to rotate in presence of the magnetic field, by generating action and counters the supply voltage. Hence the back emf at the starting of the motor is zero, but it develops gradually as the motor		

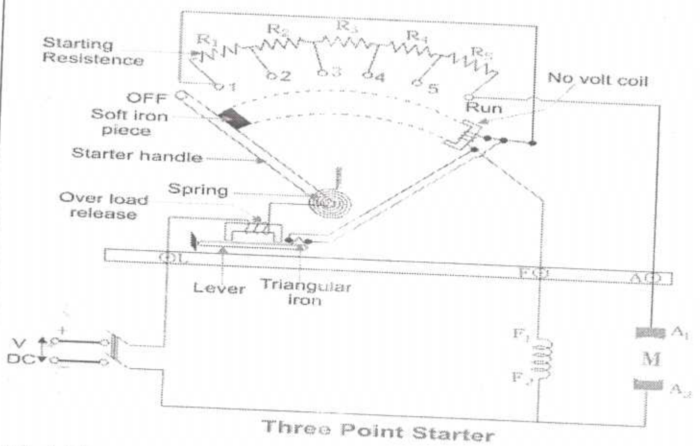
gathers speed.
The general motor emf equation is:

$$E = E_b + I_a . R_a$$

Where E=Supply Voltage; Eb=Back EMF; Ia=Armature Current; and Ra=Armature Resistance. Since at starting Eb = 0, then E = Ia.Ra. Hence we can rearrange for the armature current Ia:

$$\therefore \ I_a = \frac{E}{R_a}$$

We can see from the above equation that the current will be dangerously high at starting (as the armature resistance Ra is small). This is why it's important that we make use of a device like the **3 point starter** to limit the starting current to acceptably low value.



3 Point Starter Diagram

Construction of 3 Point Starter

Construction wise a starter is a variable resistance, integrated into the number of sections as shown in the figure beside. The contact points of these sections are called studs and are shown separately as **OFF, 1, 2, 3, 4, 5, RUN**. Other than that there are three main points, referred to as

1. 'L' Line terminal (Connected to positive of supply)
2. 'A' Armature terminal (Connected to the armature winding)
3. 'F' Field terminal (Connected to the field winding)

And from there it gets the name 3 point starter. Now studying the **construction of 3 point starter** in further details reveals that the point 'L' is connected to an electromagnet called overload release (OLR) as shown in the figure. The other end of OLR is connected to the lower end of conducting lever of starter handle where spring is also attached with it, and the starter handle also contains a soft iron piece housed on it. This handle is free to move to the other side RUN against the force of the spring. This spring brings back the handle to its original OFF position under the influence of its own force. Another parallel path is derived from the stud '1', given to another electromagnet called No Volt Coil (NVC) which is further connected to terminal 'F.' The starting resistance at starting is entirely in series with the armature. The OLR and NVC act as the two protecting devices of the starter.

Working of Three Point Starter

To start with the handle is in the OFF position when the supply to the DC motor is switched on. Then handle is slowly moved against the spring force to make contact with stud No. 1. At this point, field winding of the shunt or the compound motor gets supply through the parallel path provided to starting the resistance, through No Voltage Coil. While entire starting resistance comes in series with the armature. The high starting armature current thus gets limited as the current equation at this stage becomes:

$$I_a = \frac{E}{(R_a + R_{st})}$$

As the handle is moved further, it goes on making contact with studs 2, 3, 4, etc., thus gradually cutting off the series resistance from the armature circuit as the motor gathers speed. Finally, when the starter handle is in 'RUN' position, the entire starting resistance is eliminated, and the motor runs with normal speed.

No Voltage Coil

The supply to the field winding is derived through no voltage coil. So when field current flows, the NVC is magnetized. Now when the handle is in the 'RUN' position, a soft iron piece is connected to the handle and gets attracted by the magnetic force produced by NVC, because of flow of current through it. The NVC is designed in such a way that it holds the handle in 'RUN' position against the force of the spring as long as supply is given to the motor. Thus NVC holds the handle in the 'RUN' position and hence also called **hold on coil**.

Now when there is any kind of supply failure, the current flow through NVC is affected and it immediately loses its magnetic property and is unable to keep the soft iron piece on the handle, attracted. At this point under the action of the spring force, the handle comes back to OFF position, opening the circuit and thus switching off the motor. So due to the combination of NVC and the spring, the starter handle always comes back to OFF position whenever there is any supply problem. Thus it also acts as a protective device safeguarding the motor from any kind of abnormality

Figure – 4
Working – 4

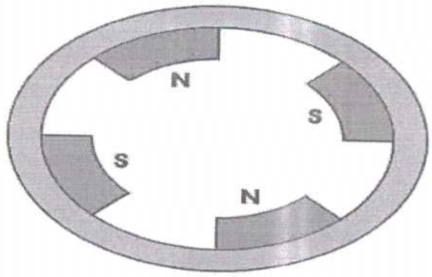
4
4 | 8

IX a

A **Permanent Magnet DC motor** (or **PMDC motor**) is a type of DC motor that uses a permanent magnet to create the magnetic field required for the operation of a DC motor. As the magnetic field strength of a permanent magnet is fixed it cannot be controlled externally, field control of this type of DC motor cannot be possible. Thus permanent magnet DC motor is used where there is no need to control the speed of the motor (which is usually done by controlling the magnetic field). Small fractional and sub-fractional KW motors are often constructed using a permanent magnet.

Construction of Permanent Magnet DC Motor or PMDC Motor

The field poles of this motor are essentially made of permanent magnet. A **PMDC motor** mainly consists of two parts. A stator and an armature. Here the stator which is a steel cylinder. The magnets are mounted in the inner periphery of this cylinder.



The permanent magnets are mounted in such a way that the N-pole and S-pole of each magnet are alternatively faced towards armature as shown in the figure . That means, if N-pole of one magnet is faced towards armature then S-pole of very next magnet is faced towards armature. In addition to holding the magnet on its inner periphery, the steel cylindrical stator also serves as low reluctance return path for the magnetic flux. Although field coil is not required in permanent magnet DC motor but still it is sometimes found that they are used along with permanent magnet. This is because if permanent magnets lose their strength, these lost magnetic strengths can be compensated by field excitation through these field coils. Generally, rare earth hard magnetic materials are used in these permanent magnet.

The rotor of a PMDC motor is similar to other DC motor. The rotor or armature of permanent magnet DC motor also consists of core, windings and commutator. Armature core is made of number of varnish insulated, slotted circular lamination of steel sheets. By fixing these circular steel sheets one by one, a cylindrical shaped slotted armature core is formed. The varnish insulated laminated steel sheets are used to reduce eddy current loss in armature of permanent magnet DC motor. These slots on the outer periphery of the armature core are used for housing armature conductors in them. The armature conductors are connected in a suitable manner which gives rise to armature winding. The end terminals of the winding are connected to the commutator segments placed on the motor shaft. Like other DC motor, carbon or graphite brushes are placed with spring pressure on the commutator segments to supply current to the armature.

Working Principle of Permanent Magnet DC Motor or PMDC Motor

The working principle of PMDC motor is similar to the general working principle of DC motor. When a carrying conductor comes inside a magnetic field, a mechanical force will be experienced by the conductor and the direction of this force is governed by Fleming's left hand rule. As in a permanent magnet DC motor, the armature is placed inside the magnetic field of permanent magnet; the armature rotates in the direction of the generated force. Here each conductor of the armature experiences the mechanical force F = B.I.L Newton where, B is the magnetic field strength in Tesla (weber / m2), I is the current in Ampere flowing through that conductor and L is length of the conductor in metre comes under the magnetic field. Each conductor of the armature experiences a force and the compilation of those forces produces a torque, which tends to rotate the armature.

Construction	3	7
Working	4	

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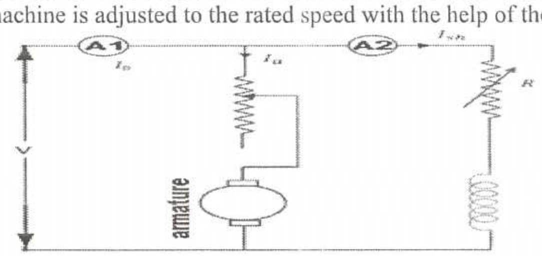
4</td><td>7</td></tr>
<tr><td>b</td><td>

This method is an indirect method of testing a DC machine. It is named after Sir James Swinburne. **Swinburne's test** is the most commonly used and simplest method of testing of shunt and compound wound DC machines which have constant flux. In this test the efficiency of the machine at any load is pre-determined. We can run the machine as a motor or as a generator. In this method of testing no load losses are measured separately and eventually we can determine the efficiency.

The circuit connection for **Swinburne's test** is shown in figure below. The speed of the machine is adjusted to the rated speed with the help of the shunt regulator R .



Calculation of Efficiency

Let, I_0 is the no load current (it can be measured by ammeter A_1)
I_{sh} is the shunt field current (it can be measured by ammeter A_2)

Then, no load armature current $=(I_0 - I_{sh})$

Also let, V is the supply voltage. Therefore, No load power input = VI_0 watts.

In **Swinburne's test** no load power input is only required to supply the losses. The losses occur in the machine mainly are:

- Iron losses in the core
- Friction and windings losses
- Armature copper loss.

Since the no load mechanical output of the machine is zero in Swinburne's test, the no load input power is only used to supply the losses.

The value of armature copper loss $=(I_0 - I_{sh})^2 R_a$

Here, R_a is the armature resistance.

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8</td><td>8</td></tr>
</table>

Now, no to get the constant losses we have to subtract the armature copper loss from the no load power input.

Then, $Constant\ losses\ W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

After calculating the no load constant losses now we can determine the efficiency at any load.

Let, I is the load current at which we have to calculate the efficiency of the machine.

Then, armature current (I_a) will be ($I - I_{sh}$), when the machine is motoring.

And $I_a = (I + I_{sh})$, when the machine is generating.

Calculation of Efficiency When the Machine is Motoring on Load 2

Power input = VI

Armature copper loss, $P_{CU} = I^2 R_a = (I - I_{sh})^2 R_a$

Constant losses, $W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

$Total\ losses = P_{CU} + W_C$

∴ Efficiency of the motor:

$$\eta_m = \frac{output}{input} = \frac{input\ -\ losses}{input} = \frac{VI\ -\ (P_CU + W_C)}{VI}$$

Calculation of Efficiency When the Machine is Generating on Load 2

Power input = VI

Armature copper loss, $P_{CU} = I_2 R_a = (I + I_{sh})^2 R_a$

Constant losses, $W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

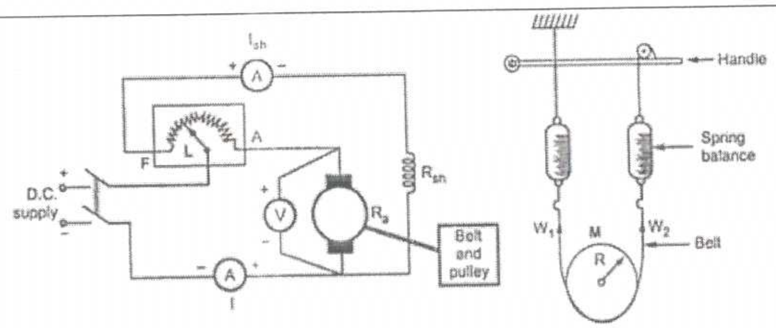
$Total\ losses = P_{CU} + W_C$

∴ Efficiency of the generator:

$$\eta_g = \frac{output}{input} = \frac{input\ -\ losses}{input} = \frac{VI\ -\ (P_CU\ +\ W_C)}{VI}$$

X a **Procedure of Direct loading or brake test On DC Shunt Motor**

1. By adjusting the handle of the pulley take different readings of the spring balance.
2. The tension in the belt can be adjusted using the handle. The tension in kg can be obtained from the spring balance readings.
3. Adjusting the load step by step till full load, number of readings can be obtained.By increasing the load is slowly, adjust to get rated load current.
4. The power developed gets wasted against the friction between belt and shaft. Due to the braking action of belt the test is called brake test.
5. The speed can be measured by tachometer. Thus all the motor characteristics can be plotted.

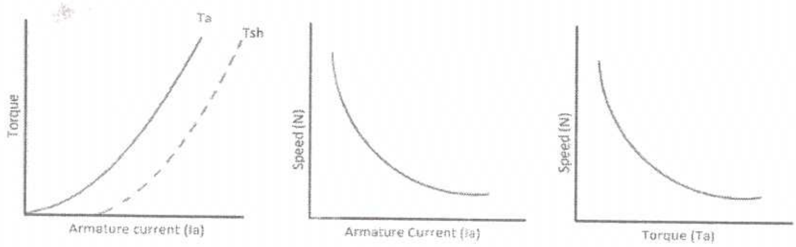
	 (a) Experimental setup (b) Belt and pulley arrangement You can refer figure for the experimental setup for performing brake test on a d.c. shunt motor,belt & pulley arrangement mounted on the shaft of the motor. Calculation Of Brake Test On DC Shunt Motor Let R (or) r= Radius of pulley in meters N = Speed in r.p.m. S1 = Spring balance reading on tight side in kg S2 = Spring balance reading on slack side in kg So net pull on the belt due to friction at the pulley is the difference between the two spring balance readings. Net pull on the rope = (S1-S2) kg = (S1-S2) X 9.81 newtons As radius r and speed N are known, the shaft torque developed Tsh = Net pull X R=(S1-S2) X 9.81 X r =Srg Hence the output power can be obtained as,Say speed of the pulley is N r.p.m., then,The above equation shows the output power of dc shunt motor in brake test. Now let, V = Voltage applied in volts I = Total line current drawn in amps. As we know V,I are input parameters of dc motors in brake test.then, Pin=V.I Watts .....(3) Efficiency (η)=Output/Input $\text{Output power} = \frac{2\pi N T_{sh}}{60} = \frac{2\pi N \times (W-S) \times 9.81 \times r}{60}$ watts	7 dia-3 exp-4	7
b	**Characteristics Of DC Series Motors** **Torque Vs. Armature Current (Ta-Ia)** This characteristic is also known as **electrical characteristic**. torque is directly proportional to the product of armature current and field flux, Ta ∝ ϕ.Ia. In DC series motors, field winding is connected in series with the armature, i.e. Ia = If. Therefore, before magnetic saturation of the field, flux ϕ is directly proportional to Ia. Hence, before magnetic saturation Ta α Ia2. Therefore, the Ta-Ia curve is parabola for smaller values of Ia. After magnetic saturation of the field poles, flux ϕ is independent of armature current Ia.	3	

Therefore, the torque varies proportionally to Ia only, T ∝ Ia.Therefore, after magnetic saturation, Ta-Ia curve becomes a straight line.
The shaft torque (Tsh) is less than armature torque (Ta) due to stray losses. Hence, the curve Tsh vs Ia lies slightly lower. 8
In DC series motors, (prior to magnetic saturation) torque increases as the square of armature current, these motors are used where high starting torque is required.

Speed Vs. Armature Current (N-Ia)

N ∝ Eb/ϕ
For small load current (and hence for small armature current) change in back emf Eb is small and it may be neglected. Hence, for small currents speed is inversely proportional to ϕ. 3
As we know, flux is directly proportional to Ia, speed is inversely proportional to Ia.
Therefore, when armature current is very small the speed becomes dangerously high. That is **why a series motor should never be started without some mechanical load**.
But, at heavy loads, armature current Ia is large. And hence, speed is low which results in decreased back emf Eb. Due to decreased Eb, more armature current is allowed.

Speed Vs. Torque (N-Ta)
This characteristic is also called as **mechanical characteristic**. From the above two **characteristics of DC series motor**, it can be found that when speed is high, torque is low and vice versa. 2



Characteristics of DC series motor