222 09-11-23 DG NOV23

SCHEME OF VALUATION

(Scoring indicators) - QID: 1510230046 (1)

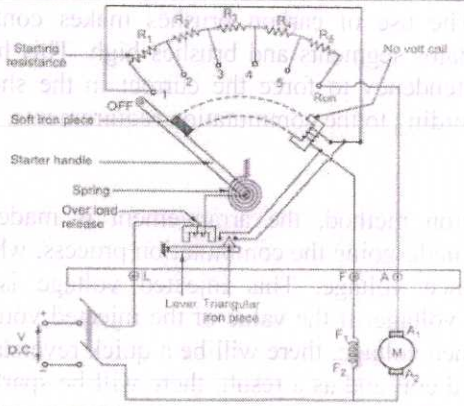
Revision (2015)
Couse Title: DC machines

Course code: 4031

PART A

Q No	Scoring indicator	Split up score	Sub total	Total
I.1	Critical resistance is the resistance value at which a part can operate at full rated power and full rated voltage. For a DC generator, critical resistance is the maximum field circuit resistance for which the generator would excite.	1+1	2	
I.2	The armature magnetic field has two effects: (i) It demagnetises or weakens the main flux and (ii) It cross-magnetises or distorts it.	1+1	2	
I.3	In DC machines, maximum efficiency occurs when variable losses are equal to constant losses.		2	
I.4	The yoke acts as path for the magnetic flux. It also provides mechanical support and shape to the dc machine.	1+1	2	
I.5	PMDC motors are mainly used in automobiles to operate windshield wipers and washers, to raise the lower windows, to drive blowers for heaters and air conditioners etc. They are also used in computer drives. These types of motors are also used in toy industries [Any two]	1+1	2	
				10

PART B

Q No	Scoring indicator	Split up score	Sub total	Total
II.1		4+2	6	

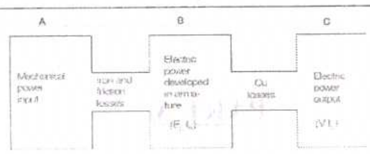
<table>
<tr><td>II.2</td><td>31.3. Advantages of Swinburne's Test
1. It is convenient and economical because power required to test a large machine is small i.e. only no-load input power.
2. The efficiency can be predetermined at any load because constant-losses are known.
31.4. Main Disadvantages
1. No account is taken of the change in iron losses from no-load to full-load. At full-load, due to armature reaction, flux is distorted which increases the iron losses in some cases by as much as 50%.
2. As the test is on no-load, it is impossible to know whether commutation would be satisfactory at full-load and whether the temperature rise would be within the specified limits.</td><td>3+3</td><td>6</td><td></td></tr>
<tr><td>III.3</td><td>

Fig. 2.56
(i) Mechanical efficiency
$\eta_m = \frac{B}{A} = \frac{E_g I_a}{\text{Mechanical power input}}$
(ii) Electrical efficiency
$\eta_e = \frac{C}{B} = \frac{V I_L}{E_g I_a}$
(iii) Commercial or overall efficiency
$\eta_c = \frac{C}{A} = \frac{V I_L}{\text{Mechanical power input}}$
Clearly, $\eta_c = \eta_m \times \eta_e$
Unless otherwise stated, commercial efficiency is always understood.
Now, commercial efficiency, $\eta_c = \frac{C}{A} = \frac{\text{output}}{\text{input}} = \frac{\text{input} - \text{losses}}{\text{input}}$</td><td>4+2</td><td>6</td><td></td></tr>
<tr><td>II.4</td><td>Flux cut by one conductor in one revolution of the armature,
$d\phi = P\phi$ webers
Time taken to complete one revolution,
$dt = 60/N$ second
e.m.f. generated/conductor $= \frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60}$ volts
e.m.f. of generator, E_g = e.m.f. per parallel path
= (e.m.f./conductor) × No. of conductors in series per parallel path
$= \frac{P\phi N}{60} \times \frac{Z}{A}$
$\therefore \quad E_g = \frac{P\phi Z N}{60\,A}$
where $A = 2$ ... for wave winding
$= P$ ... for lap winding</td><td></td><td>6</td><td></td></tr>
<tr><td>II.5</td><td>There are three methods for improving commutation in a DC generator: Resistance commutation, Voltage commutation, Compensating windings.
Compensating windings balance the armature flux, which eliminates the effect of armature reaction and flashover.

Resistance Commutation
The Resistance Commutation method uses carbon brushes for improving commutation. The use of carbon brushes makes contact resistance between commutator segments and brushes high. This high contact resistance has the tendency to force the current in the short-circuited coil to change according to the commutation requirements.

Voltage Commutation
In the Voltage Commutation method, the arrangement is made to induce a voltage in the coil undergoing the commutation process, which will neutralize the reactance voltage. This injected voltage is in opposition to the reactance voltage. If the value of the injected voltage is made equal to the reactance voltage, there will be a quick reversal of current in the short-circuited coil and as a result, there will be sparkles commutation.

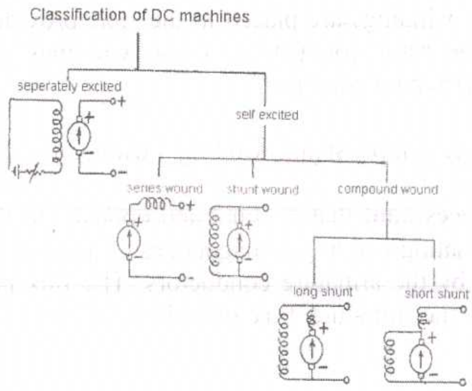
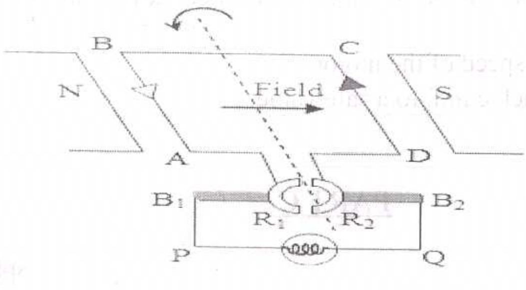
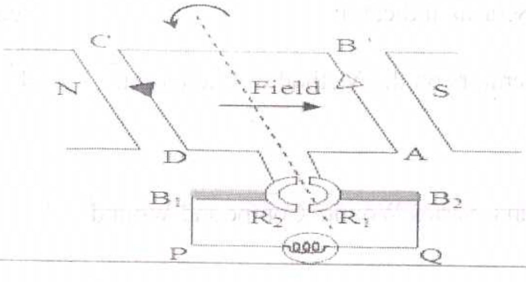
Compensating Windings

The most efficient method of eliminating the problem of armature reaction and flashover by balancing the armature mmf is the</td><td>2+2+2</td><td>6</td><td></td></tr>
</table>

	compensating windings. The windings are placed in the slots provided in pole faces parallel to the rotor conductors. These windings are connected in series with the armature windings. The direction of currents in the compensating winding must be opposite to that in the armature winding just below the pole faces. Thus, compensating winding produces mmf that is equal and opposite to the armature MMF. The compensating winding demagnetizes or neutralizes the armature flux produced by the armature conductors. The flux per pole is then undisturbed by the armature flux regardless of the load conditions.			
II.6	Parallel operation of DC generators has several advantages, including: Cost effectiveness Smooth supply of power Increased reliability Easier maintenance Increased total capacity Essential conditions for parallel operation of DC generators include: Same drooping voltage characteristics Same voltage rating Same percentage voltage regulation	3+3	6	
II.7	Starters are necessary for DC motors because they protect the motor from damage during startup. Starters provide external resistance to the motor, which limits the current to an acceptable level. Starters are necessary for DC motors because: • When starting a DC motor, the back emf is zero. • If rated voltage is applied without a starter, the starting current will be dangerously high. • This high current can cause mechanical stress and heat the windings, resulting in damage. • Starters allow a DC motor or motor-controlled device to be turned on or off. • Starters restrict the speed of the motor. • Starters limit the back e.m.f. to a safe value.	6*1	6	

PART C

Q No	Scoring indicator	Split up score	Sub total	Total
III.(a)	Classification of DC Generators on the Method of Excitation: Permanent Magnet Separately Excited Self- Excited: Shunt Wound, Series Wound, Compound Wound	4+4	8	

				
III.(b)	$E = \phi ZNP/60A = (0.01*60*6*1000*6)/(60*2)$ As It is wave wound, $A = 2$ $E = 180$ V Equations - 2 Calculations - 4 Result - 1	2+4+1	7	
IV.(a)	DC generators' primary function is to convert mechanical energy into electrical energy. DC generators generate electricity using the principle of Faraday's law of electromagnetic induction. When a conductor is placed in a varying magnetic field, an electromotive force gets induced within the conductor. This induced e.m.f magnitude is measured using the equation of the electromotive force of a generator. If the conductor is provided with a closed path, the induced current will circulate within the closed path. In this generator, field coils will generate an electromagnetic field as well as the armature conductors are turned into the field. Therefore, an electromagnetically induced electromotive force (e.m.f) will be generated within the armature conductors.  	4+4	8	

<table>
<tr><td>IV.(b)</td><td>Given that it's a 4-pole generator, $N = 600$ rpm, and $A = 600$ conductors, we need to find ϕ and f.

The pole-arc to pole pitch ratio (f) is given as 0.7. So, $f = 0.7$.

The pole shoe bore is given as 42 cm, and the length of the pole shoe is 10 cm. The pole pitch (y) is the sum of the bore and twice the length of the pole shoe

$y = 42 + 2 \times 10 = 62\,\mathrm{cm}$

Now, ϕ can be calculated as:

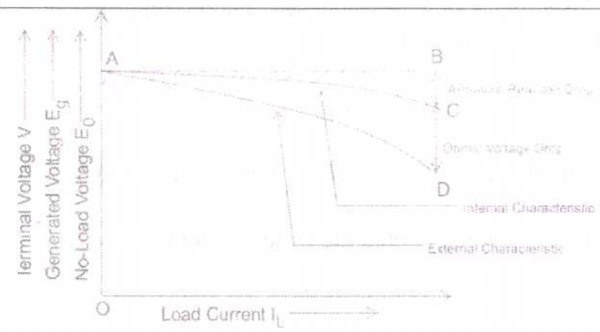
$\phi = \frac{\pi \times \mathrm{Bore}}{2}$

$\phi = \frac{\pi \times 42}{2}$

$\phi = 65.973\,\mathrm{cm}$

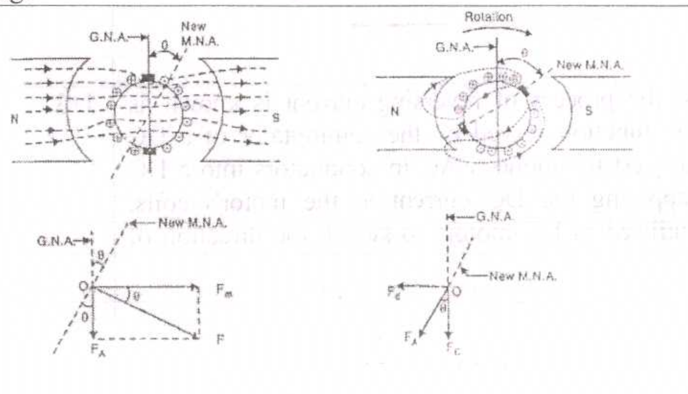
Now, plug in the values into the formula:

$B_{\mathrm{mean}} = \frac{300}{4.44 \times 0.7 \times 600 \times 65.973 \times 600}$

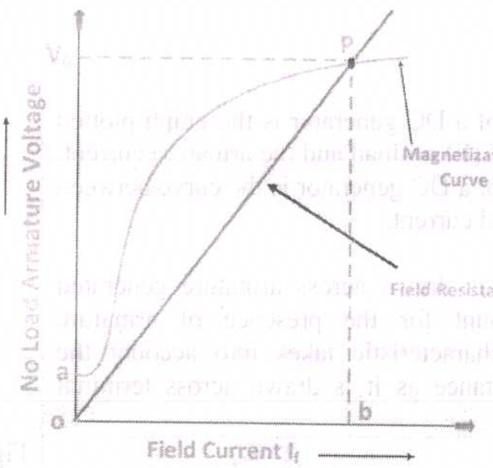
$B_{\mathrm{mean}} \approx 0.0023\,\mathrm{T}$</td><td></td><td>7</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>V.(a)</td><td>

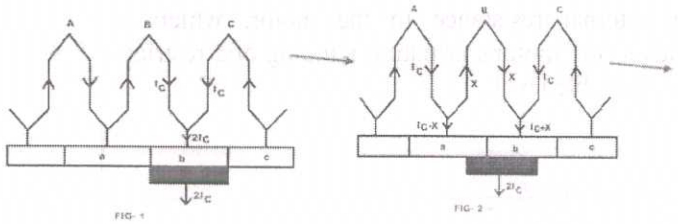
Internal and External Characteristic Curve

The internal characteristic of a DC generator is the graph plotted between the generated EMF (E) on-load and the armature current. The external characteristic of a DC generator is the curve between the terminal voltage and load current.

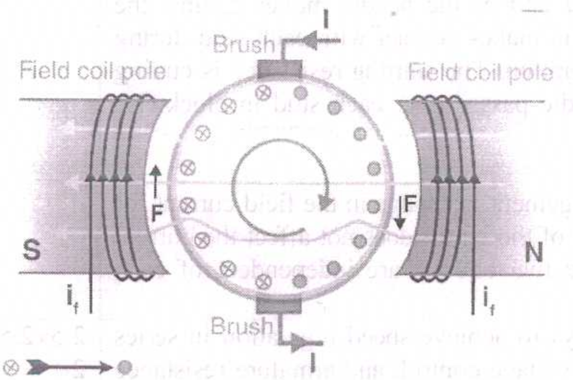
The internal characteristic is drawn across armature generated voltage and doesn't account for the presence of armature resistance. The external characteristic takes into account the presence of armature resistance as it is drawn across terminal voltage</td><td>4+4</td><td>8</td><td></td></tr>
<tr><td>V.(b)</td><td>

Armature reaction is the effect of the magnetic field set up by armature current on the distribution of flux under main poles of a</td><td>Fig – 3
Exp – 4</td><td>7</td><td></td></tr>
</table>

	generator. It has two effects: Demagnetization: The armature magnetic field weakens the main flux. Cross-magnetization: The armature magnetic field distorts the main flux. The effects of armature reaction include: Reduced generated voltage in a DC generator Shifted position of M.N.A. Reduced overall flux density in the machine The MNA axis is the axis in which the value of induced MEF becomes zero. The GNA divides the armature core into two equal parts.			
VI.(a)	The open circuit characteristic (OCC) of a self-excited DC generator is a curve that shows the relationship between the generated emf at no load (E0) and the field current (If) at a constant speed. The OCC is also known as the magnetization characteristic or no-load saturation curve. The OCC is plotted by gradually increasing the field current while the generator is running at no load and a constant speed. The corresponding terminal voltage is recorded. The OCC is the same for all types of generators, whether they are separately excited or self-excited. The OCC is typically plotted alongside the synchronous impedance curve. 	4+4	8	
VI.(b)	In DC machines, the process of reversing current is known as commutation. The function served by the commutator of a DC generator is to convert the induced AC in conductors into a DC output. Before applying the DC current to the motor's coils, commutation is utilised in DC motors to switch the direction of the current.	4+3	7	

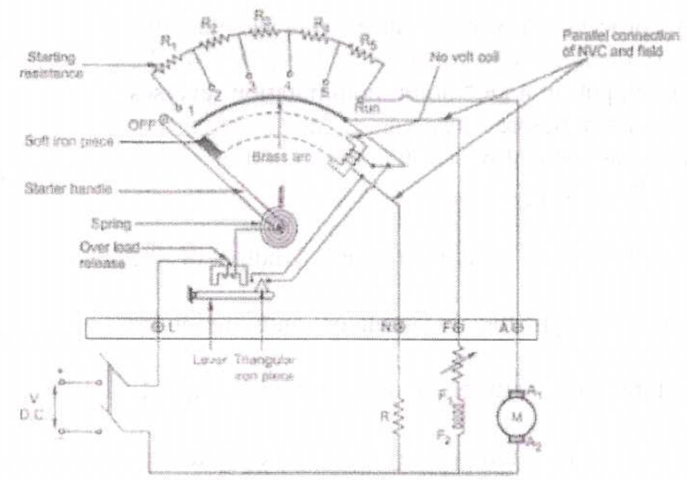
<table>
<tr><td></td><td>

Commutation is the process of reversing current in a DC machine. In a DC generator, commutation converts induced AC in the conductors to a DC output. In a DC motor, commutation reverses the direction of DC current before it's applied to the motor's coils. Commutation is the most critical part of the design and operation of any DC machine. It works by:

Generating alternating current in the armature winding of the machine
Passing the current through the commutator and stationary brushes
Rotating the armature coils between a negative brush and its succeeding positive brush
Reversing the direction of the current away from the commutator segments</td><td></td><td></td><td></td></tr>
<tr><td>VII.(a)</td><td>A DC motor is an electrical machine which converts electrical energy into mechanical energy. The basic working principle of the DC motor is that whenever a current carrying conductor places in the magnetic field, it experiences a mechanical force.
If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other, and first finger represents the direction of the magnetic field, the second finger represents the direction of the current, then the thumb represents the direction of the force experienced by the current carrying conductor.


Production of torque in a DC motor</td><td>4+4</td><td>8</td><td></td></tr>
<tr><td>VII.b</td><td>Starters are necessary to start DC motors because they protect the motor from damage that can be caused by high current and torque during startup.

When a DC motor is at rest, it has zero back EMF (electromotive force) and draws a very high current. This high current can damage the motor windings, and it can also cause the power</td><td>4+3</td><td>7</td><td></td></tr>
</table>

	supply to trip or overload. Starters provide external resistance to the motor, which is connected in series to the motor's armature winding and restricts the current to an acceptable level. Starters also: Restrict the speed of the motor Limit the back e.m.f. to a safe value Limit the starting current to a safe value			
VIII.a	 Four Point Starter The one end of the armature coil is connected to the terminal A and of the shunt field winding to the terminal F. The other ends of the armature and the shunt field windings are directly connected to the negative terminal of the supply. The no-volt trip coil (NVC) is connected directly across the line with a current limiting resistor R in series. The NVC is also known as under-voltage protection of the motor. One end of the handle is connected to the terminal L through the overload trip coil (OLC) and the other end of the handle moves against the force of control spring and makes contact with each stud during the starting period of operation. The starting resistance is cutting out gradually as the handle passes over each stud in clockwise direction. Therefore, with this arrangement, a change in the field current for the variation of the speed of the motor does not affect the current through the NVC, as the two circuits are independent of each other.	4+4	8	
VIII.b	There are three main ways to achieve speed regulation in series DC motors–flux control, voltage control, and armature resistance control. 1. Flux Control Method In the flux control method, a rheostat (a type of variable resistor) is connected in series with the field windings. The purpose of this component is to increase the series resistance in the windings which will reduce the flux, consequently increasing the motor's	2.5+2.5+2	7	

<table>
<tr><td></td><td>speed.

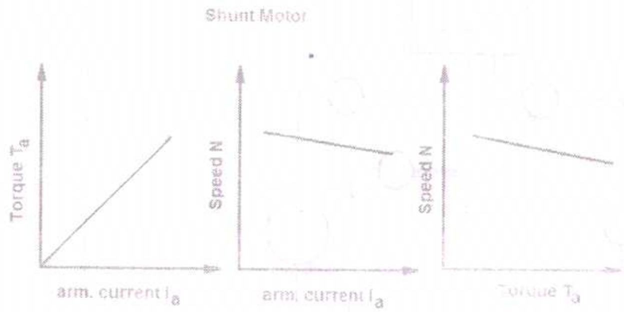
2. Voltage Regulation Method

The variable regulation method is typically used in shunt dc motors. There are, again, two ways to achieve voltage regulation control:

Connecting the shunt field to a fixed exciting voltage while supplying the armature with different voltages (aka multiple voltage control)

Varying the voltage supplied to the armature (aka the Ward Leonard method)

3. Armature Resistance Control Method

The armature resistance control is based on the principle that the speed of the motor is directly proportional to the back EMF. So, if the supply voltage and the armature resistance are kept at a constant value, the speed of the motor will be directly proportional to the armature current.</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>IX.a</td><td>

The torque and armature current characteristic is also known as the electrical characteristics of the motor.

The mechanical characteristic curve of a DC shunt motor represents the relationship between the motor speed and the torque it produces under different load conditions</td><td>4+4</td><td>8</td><td></td></tr>
<tr><td>IX.b</td><td>2.30 CONDITION FOR MAXIMUM EFFICIENCY

The efficiency of a d.c. generator is not constant but varies with load. Consider a shunt generator delivering a load current I_L at a terminal voltage V.

Generator output $= VI_L$
Generator input $=$ Output + Losses
$= VI_L +$ Variable losses + Constant losses
$= VI_L + I_a^2 R_a + W_C$
$= VI_L + (I_L + I_{sh})^2 R_a + W_C$ $[\because I_a = I_L + I_{sh}]$

The shunt field current I_{sh} is generally small as compared to I_L and, therefore, can be neglected
$\therefore$ Generator input $= VI_L + I_L^2 R_a + W_C$

Now $\eta = \frac{\text{output}}{\text{input}} = \frac{VI_L}{VI_L + I_L^2 R_a + W_C}$
$= \frac{1}{1 + \left(\frac{I_L R_a}{V} + \frac{W_C}{VI_L}\right)}$

The efficiency will be maximum when the denominator of eq. (i) is minimum i.e.,
$\frac{d}{dI_L}\left(\frac{I_L R_a}{V} + \frac{W_C}{VI_L}\right) = 0$</td><td></td><td>7</td><td></td></tr>
</table>

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

$$\frac{d}{dI}\left(1 + \frac{I\,R_a}{V} + \frac{W_c}{V\,I}\right) = 0$$

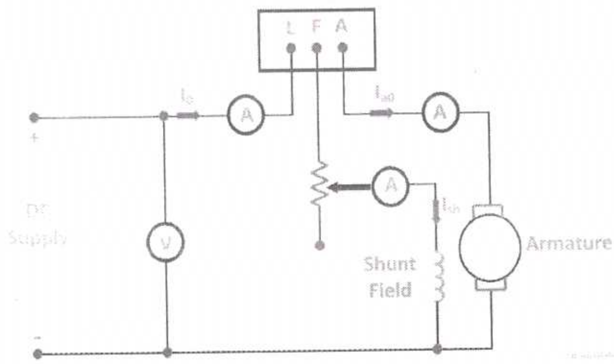
$$0 + \frac{R_a}{V} + \frac{W_c}{V\,I^2} = 0$$

$$or\ \ I^2\,R_a = W_c$$

</td><td></td><td></td><td></td></tr>
<tr><td>X.a</td><td>

The Swinburne test is an indirect method for determining the efficiency of DC motors. In this test, the DC machine is run as a motor at no-load and the losses of the machine are determined. Once the losses of the machine are known, its efficiency at any desired load can be determined in advance.

The Swinburne test works by:
Finding the no-load losses experimentally
Estimating additional losses from the rated motor data
Finding the heated resistance, allowing a temperature rise of 50°C



Let, supply voltage $= V$ no-load input $= VI_0$ watt
∴ Power input to armature $= V(I_0 - I_{sh})$;   Power input to shunt $= VI_{sh}$
No-load [illegible] to armature supplies the following:
(i) [illegible] (ii) [illegible] friction loss [illegible] (iii) windage loss and
(iv) armature Cu loss, $(I_0 - I_{sh})^2 R_a$ or $I_{a0}^2 R_a$

Efficiency when running as a motor

Input $= VI$,   Armature Cu loss $= I_a^2 R_a = (I - I_{sh})^2 R_a$
Constant losses $= W_c$ ...found above

∴ Total losses $= (I - I_{sh})^2 R_a + W_c$; $\eta_m = \frac{\text{input} - \text{losses}}{\text{input}} = \frac{VI - (I - I_{sh})^2 R_a - W_c}{VI}$

Efficiency when running as a generator

Output $= VI$, Armature Cu loss $= (I + I_{sh})^2 R_a$, Constant loss $= W_c$ ...found above

∴ Total losses $= (I + I_{sh})^2 R_a + W_c$; $\eta_g = \frac{\text{output}}{\text{output} + \text{losses}} = \frac{VI}{VI + (I + I_{sh})^2 R_a + W_c}$

</td><td>5+3</td><td>8</td><td></td></tr>
<tr><td>X.b</td><td>

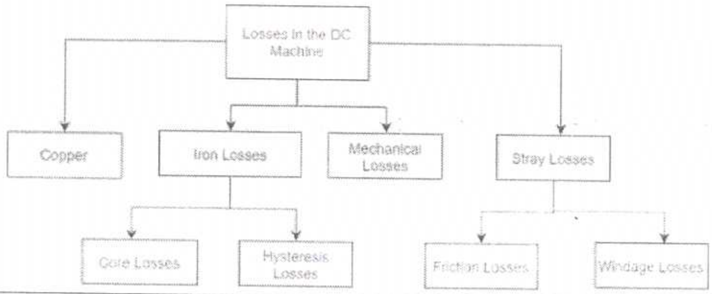
There are five types of losses in a DC motor:

Copper losses: These losses occur in the windings of the DC motor, which are made of copper. The power loss is proportional to the square of the current.
Iron losses: These losses occur in the iron parts of the DC motor.
Mechanical losses: These losses are caused by the movement of the motor.

</td><td>2+2+2+1</td><td>7</td><td></td></tr>
</table>

Brush losses: These losses occur in the brushes of the DC motor.
Stray losses: These losses are difficult to account for and are usually due to inaccuracies in the design and modeling of the machine.

The losses that vary with load are known as variable losses. These include:
Armature copper loss
Series field copper loss



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