Model Question Paper I

DC MACHINES AND TRACTION MOTORS

Time: 3 Hour *Max.Marks: 75*

PART A

I. Answer **all** questions in one word or one sentence. Each question carries 1 mark.

1	State the function of yoke in the dc generator	M 1.01	U
2	Number of parallel paths in a lap wound dc generator are …………………	M 1.04	R
3	List the effects of armature reaction	M 2.01	R
4	Define critical speed of dc shunt generator	M 2.03	R
5	Write voltage equation of a dc shunt motor	M 3.01	R
6	State the purpose of testing in dc machines?	M 3.03	U
7	The dc series motor should never be switched on at no load .State the reason behind this .	M 3.02	U
8	List any two methods of speed control of dc motors	M 4.01	R
9	List any two types of electrical braking used in traction	M 4.04	R

PART B

II. Answer any **eight** questions from the following, each question carries 3 marks.

1	Show the classification of dc generator on the basis of field winding in a schematic diagram	M 1.02	R
2	Determine the generated emf in a lap wound, 4 pole dc generator having useful flux per pole 0.07Wb, 220 armature turns, and runs at 900 rpm.	M 1.03	A
3	Summarize the use of dummy coils in dc generator	M 1.04	U
4	Derive the emf equation of dc generator	M 1.03	U

5	Summarize the conditions necessary for voltage build-up in self-excited dc generators	M 2.03	U
6	Explain the electrical characteristics of a dc series motor	M 3.04	U
7	List general features of traction motors	M 4.02	R
8	Illustrate series parallel control by shunt transition method	M 4.03	U
9	List the demerits of armature resistance control of dc series motor	M 4.01	R
10	List the factors controlling motor speed	M 4.01	R

PART C

Answer ALL questions. Each question carries 7 marks.

III	Label the essential parts of a dc machine in a schematic diagram and write their functions	M 1.01	R
	OR		
IV	Explain the working of single loop generator	M 1.02	U
V	The magnetization curve of a dc shunt generator at 1500 rpm is: (see table below) For this generator find the magnetization curve at 1200 r.p.m.	M 2.03	A
	OR		
VI	Illustrate open circuit characteristics of a dc shunt generator with diagram	M 2.03	U
VII	The magnetization curve of a dc shunt generator at 1500 rpm is: (see table below) For this generator find (i) no load e.m.f. for a total shunt field resistance of 100 Ω (ii) the critical field resistance at 1500 r.p.m.	M 2.03	A
	OR		
VIII	Illustrate commutation in the dc generator with the help of diagrams.	M 2.02	U

Table for V:

I_f(A):	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.0
E_0(V):	6	60	120	172.5	202.5	221	231	237	240

Table for VII:

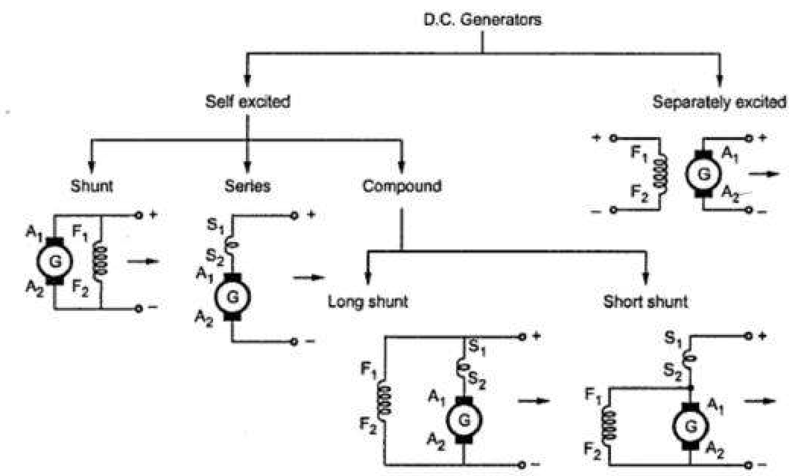
I_f(A):	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.0
E_0(V):	6	60	120	172.5	202.5	221	231	237	240

IX	A 200-V, 14.92 kW dc shunt motor when tested by the Swinburne method gave the following results : Running light: armature current was 6.5 A and field current 2.2 A. With the armature locked, the current was 70 A when a potential difference of 3 V was applied to the brushes. Estimate the efficiency of the motor when working under full-load conditions.	M 3.03	A
	OR		
X	Explain Three point starter with the help of a figure.	M 3.02	U
XI	Define torque in dc motor and compare armature torque and shaft torque	M 3.01	U
	OR		
XII	Explain the electrical and mechanical characteristics of dc shunt motor	M 3.04	U
XIII	Explain series parallel starting of dc traction motor	M 4.03	U
	OR		
XIV	Explain speed control of dc shunt motor by flux control method	M 4.01	U

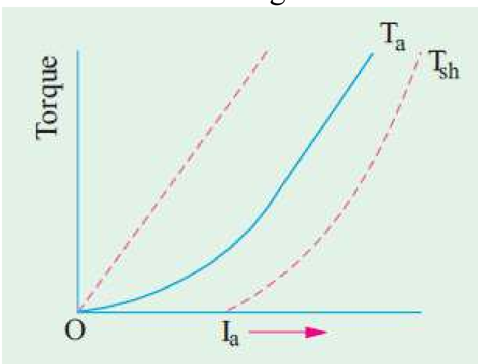
Scoring Indicators

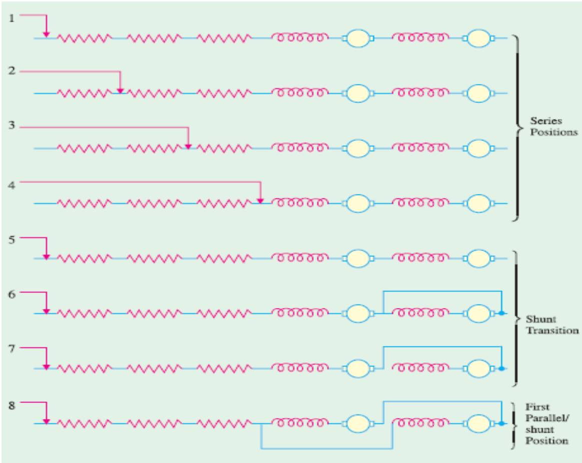
Model Question Paper I

DC MACHINES AND TRACTION MOTORS

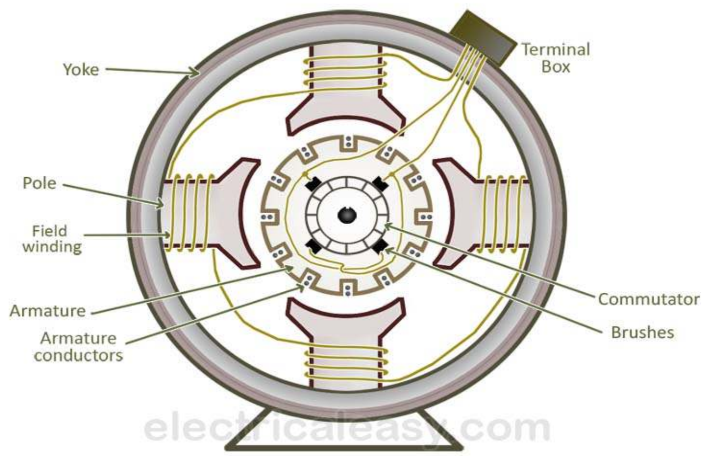
Q No	Scoring Indicators	Split score	Total score
	PART A		
I. 1	Yoke: (i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine. (ii) It carries the magnetic flux produced by the poles.	Any one	1
I. 2	Number of poles (P)	1	1
I. 3	Demagnetising and cross- magnetising effect	0.5+0.5	1
I. 4	Critical speed of a shunt generator is that speed for which the given shunt field resistance represents critical resistance	1	1
I. 5	$V = E_b + I_a R_a$	1	1
I. 6	Testing is performed on dc machines to determine efficiency and power losses	1	1
I. 7	The speed becomes dangerously high	1	1
I. 8	Flux control and armature control	1	1
I. 9	Rheostatic braking and regenerative braking	1	1
	PART B		
II. 1		3	3

II. 2	□□ $= \frac{□□□}{60} \times \frac{□}{□}$ volt $\Phi = 0.07$ N = 900 rpm P = 4 A = P (Lap winding) Z = Armature turns *2 = 220*2 = 440 $Eg = \frac{0.07 \times 440 \times 900}{60} \times \left(\frac{4}{4}\right)$ = 462 volts	3	3
II. 3	These are used with wave-winding and are resorted to when the requirements of the winding are not met by the standard armature punchings available in armature-winding shops. These dummy coils do not influence the electrical characteristics of the winding because they are not connected to the commutator. They are exactly similar to the other coils except that their ends are cut short and taped. They are there simply to provide mechanical balance for the armature because an armature having some slots without windings would be out of balance mechanically.	3	3
II. 4	Generated EMF Equation of a Generator: Let Φ = flux/pole in Weber Z = total number of armature 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 = emf induced in any parallel path in armature Generated emf(Eg) = emf generated in any one of the parallel paths (E). Average emf generated/conductor = dΦ/ *dt* volt (∵ n = 1) Now, flux cut/conductor in one revolution dΦ = ΦP Wb No. of revolutions/second = N/60 ∴ Time for one revolution, dt = 60/N second Hence, according to Faraday’s Laws of Electromagnetic Induction, EMF generated/conductor $= \frac{d\Phi}{dt} = \frac{\phi PN}{60}$ volt No. of conductors (in series) in one path = Z/A In general generated emf $Eg = \frac{\Phi ZN}{60} \times \left(\frac{P}{A}\right)$ volt Where A = 2- for simplex wave winding = P for simplex lap winding	3	3
II. 5	**<u>Necessary for conditions voltage build-up</u>** *list-any three* *3* 1 marks = 3 mark* 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	1+1+1	3

	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. If excited on load, then its shunt field resistance should be more than a certain minimum value of resistance which is given by internal characteristic		
II. 6	**Ta/Ia Characteristic:** We have seen that Ta ∝ ΦIa. In this case, as field windings also carry the armature current, Φ ∝ Ia up to the point of magnetic saturation. Hence, before saturation, Ta ∝ ΦIa and ∴ Ta ∝ Ia^2 After saturation, Φ is almost independent of Ia hence Ta ∝ Ia only. So the characteristic becomes a straight line. 	Fig 2 Exp 1	3
II. 7	**General Features of Traction Motor** *list-any three* *3* 1 marks = 3 mark* Electric Features - High starting torque - Series Speed - Torque characteristic - Simple speed control - Possibility of dynamic/ regenerative braking - Good commutation under rapid fluctuations of supply voltage. Mechanical Features - Robustness and ability to withstand continuous vibrations. - Minimum weight and overall dimensions - Protection against dirt and dust	1+1+1	3
II. 8	**Series Parallel Control by Shunt Transition Method** The various stages involved in this method of series – parallel control are shown in Fig	Fig 2 Exp 1	3

	 In steps 1, 2, 3, 4 the motors are in series and are accelerated by cutting out the Rs in steps. In step 4, motors are in full series. During transition from series to parallel, Rs is reinserted in circuit–step 5. One of the motors is bypassed -step 6 and disconnected from main circuit – step 7. It is then connected in parallel with other motor -step 8, giving 1st parallel position. Rs is again cut-out in steps completely and the motors are placed in full parallel.		
II. 9	**Demerits of armature resistance control** *list-any three* *3* 1 marks = 3 mark* 1. Speed changes with every change in load, because speed variations depend not only on controlling resistance but on load current also. This double dependence makes it impossible to keep the speed sensibly constant on rapidly changing loads. 2. A large amount of power is wasted in the controller resistance. Loss of power is directly proportional to the reduction in speed. Hence, efficiency is decreased. 3. Maximum power developed is diminished in the same ratio as speed. 4. It needs an expensive arrangement for dissipation of heat produced in the controller resistance. 5. It gives speeds below the normal, not above it because armature voltage can be decreased (not increased) by the controller resistance.	1+1+1	3
II.10	**Factors controlling motor speed** *List-any three* *3* 1 marks = 3 mark* The speed of a motor is given by the relation $□ = \frac{□ - □□□□}{□□}\left(\frac{□}{□}\right)$ $= □\frac{□ - □□□□}{□}$ □. □. □	1+1+1	3

<table>
<tr><td></td><td>where Ra = armature circuit resistance.
It is obvious that the speed can be controlled by varying
(i) flux/pole, Φ (Flux Control)
(ii) resistance Ra of armature circuit (Rheostatic Control) and
(iii) applied voltage V (Voltage Control).</td><td></td><td></td></tr>
<tr><td></td><td>PART C</td><td></td><td></td></tr>
<tr><td>III</td><td><u>Essential parts of a dc machine</u>



Yoke:(i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine.
Pole Cores and Pole Shoes: The pole shoes serve two purposes: (i) They spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path. (ii) They support the exciting coils (or field coils)
Pole Coils: The field coils or pole coils, which consist of copper wire or strip, are former-wound for the correct dimension.
Armature Windings: The armature windings are usually former-wound.
Commutator: The functions of the commutator are to facilitate collection of current from the armature conductors, and to convert the alternating current induced in the armature conductors into unidirectional current in the external load circuit.
Brushes and Bearings: The brushes, whose function is to collect current from a commutator, are usually made of carbon or graphite and are in the shape of a rectangular block.</td><td>Fig 4
Exp 3</td><td>7</td></tr>
<tr><td>IV</td><td>Working of single loop generator:
Imagine the coil to be rotating in clock-wise direction (Fig.) 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 ($e = Nd\Phi dt$). 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.</td><td>Fig 3
Exp 4</td><td>7</td></tr>
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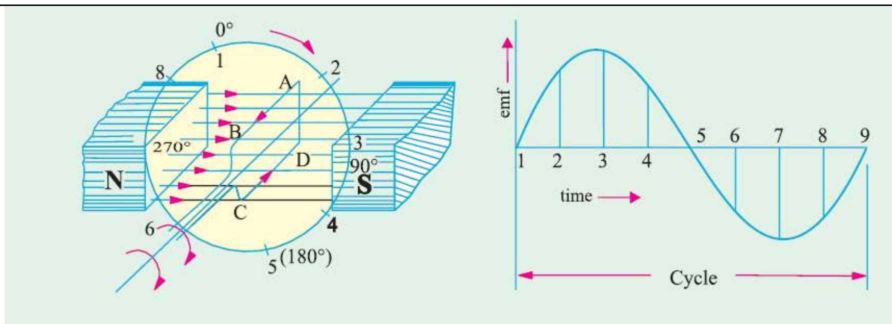

As the coil continues rotating further, the rate of change of flux linkages (and hence induced e.m.f. in it) increases, till position 3 is reached where θ = 90º. Here, the coil plane is horizontal i.e. parallel to the lines of flux. As seen, the flux linked with the coil is minimum but rate of change of flux linkages is maximum. Hence, maximum e.m.f. is induced in the coil when in this position
In the next quarter revolution i.e. from 90º to 180º, 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.
In the next half revolution i.e. from 180º to 360º, the variations in the magnitude of e.m.f. are similar to those in the first half revolution. 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.
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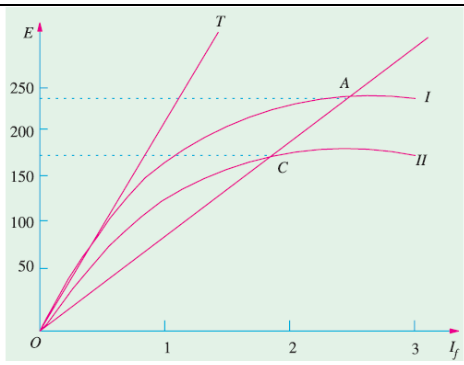
<td>V</td>
<td>


For 1200 r.p.m., the induced voltages for different field currents would be (1200/1500) = 0.8 of those for 1500 r.p.m. The values of these voltages are tabulated below

<table>
<tr><td>$I_f (A)$:</td><td>0</td><td>0.4</td><td>0.8</td><td>1.2</td><td>1.6</td><td>2.0</td><td>2.4</td><td>2.8</td><td>3.0</td></tr>
<tr><td>$E_0 (V)$:</td><td>4.8</td><td>48</td><td>96</td><td>138</td><td>162</td><td>176.8</td><td>184.8</td><td>189.6</td><td>192</td></tr>
</table>

The new magnetisation curve is also plotted in Fig.
</td>
<td>Fig 4
Table 3</td>
<td>7</td>
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<td>VI</td>
<td><u>Open Circuit Characteristic of a D.C. Generator</u>
The field winding of the d.c. generator (series or shunt) is</td>
<td>Fig 4
Exp 3</td>
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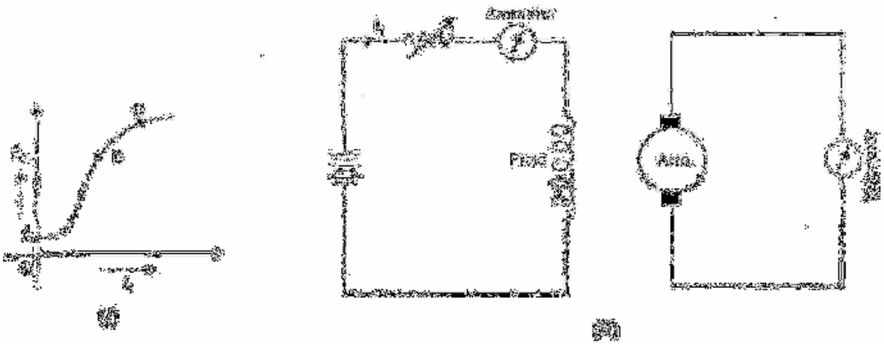
<td>disconnected from the machine and is Separately excited from an external d.c. source as shown in Fig.(ii). The generator is run at fixed speed (i.e., normal speed). The field current (If) is increased from zero in steps and the corresponding values of generated e.m.f. (E0) read off. On plotting the relation between E0 and If, we get the open circuit characteristic as shown in Fig.(i).

The following points may be noted from O.C.C.:
(i) When the field current is zero, there is some generated e.m.f. OA. This is due to the residual magnetism in the field poles.
(ii) Over a fairly wide range of field current (upto point B in the curve), the curve is linear.
(iii) After point B on the curve, the reluctance of iron also comes into picture. Consequently, the curve deviates from linear relationship.
(iv) After point C on the curve, the magnetic saturation of poles begins and E0 tends to level off.</td>
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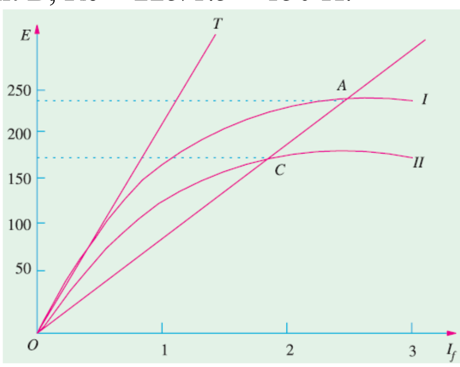
<td>VII</td>
<td>The magnetization curve at 1500 r.p.m. is plotted in fig from the given data.
(i) The 100 Ω resistance line OA is obtained by joining the origin (0, 0) with the point (1A, 100 V). The voltage corresponding to point A is 227.5 V. Hence, no-load voltage to which the generator will build-up is 227.5 V.
(ii) The tangent OT represents the critical resistance at 1500 r.p.m. considering point B, Rc = 225/1.5 = 150 Ω.

</td>
<td>Plot curve I - 3
(i)-2
(ii)– 2</td>
<td>7</td>
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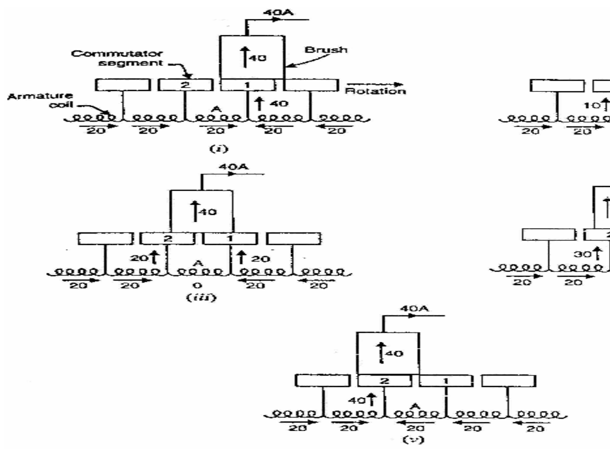
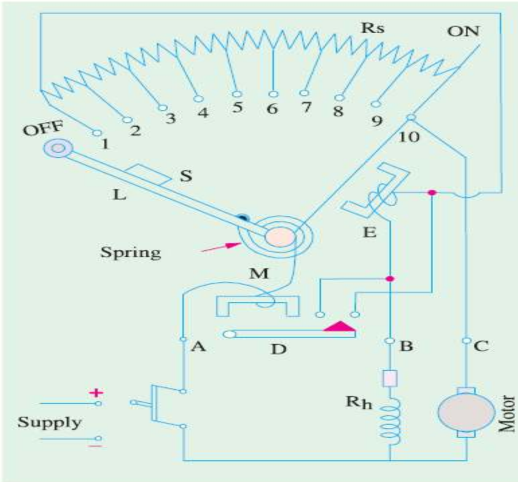
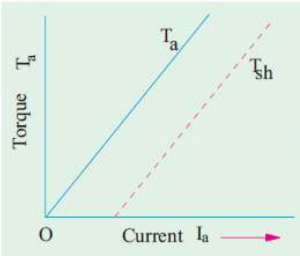
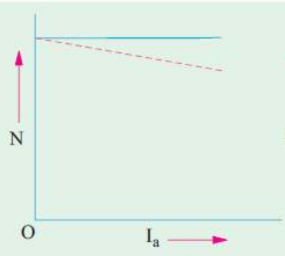
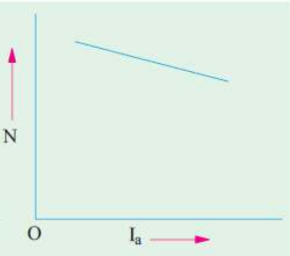
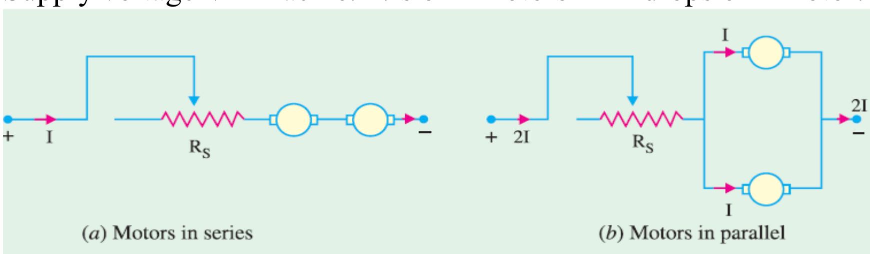
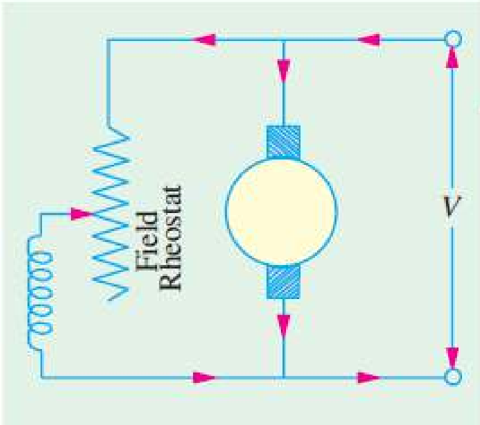
VIII	**<u>Commutation in the dc generator</u>**  (i) In Fig.(i), the brush is in contact with segment 1 of the commutator. The commutator segment 1 conducts a current of 40 A to the brush; 20 A from coil A and 20 A from the adjacent coil as shown. The coil A has yet to undergo commutation. (ii)Fig.(ii) shows the instant when the brush is one-fourth on segment 2 and three-fourth on segment 1. There are now two parallel paths into the brush as long as the short-circuit of coil A exists. For this condition, the resistance of the path through segment 2 is three times the resistance of the path through segment 1. The brush again conducts a current of 40 A; 30 A through segment 1 and 10 A through segment 2. (iii) Fig(iii) shows the instant when the brush is one-half on segment 2 and one-half on segment 1. The brush again conducts 40 A; 20 A through segment 1 and 20 A through segment 2. Note that the current in coil A is zero. (iv) Fig.(iv) shows the instant when the brush is three-fourth on segment 2 and one-fourth on segment 1. The brush conducts a current of 40 A; 30 A through segment 2 and 10 A through segment 1. Note that current in coil A is 10A but in the reverse direction to that before the start of commutation. (v) Fig.(v) shows the instant when the brush is in contact only with segment 2. The brush again conducts 40 A; 20 A from coil A and 20 A from the adjacent coil to coil A. Note that the current in coil A is 20 A but in the reverse direction. Thus the coil A has undergone commutation	Fig 4 Exp 3	7
IX	No-load input current = 6.5 + 2.2 = 8.7 A No-load power input = 200 × 8.7 = 1,740 W No-load input equals Cu losses and stray losses. Field Cu loss = 200 × 2.2 = 440 W Armature Cu loss = $6.5^2 \times 0.04286 = 1.8$ W(Ra = 3/70 = 0.04286 Ω) ∴ Constant losses = 1,740 − 1.8 = 1738 W We will assume that constant losses are the same at full-load also. Let, Ia = full-load armature current	7	7

	F.L. armature Cu loss = 0.04286 Ia^2 W ; Constant losses = 1,738 W F.L. total loss = 1,738 + 0.04286 Ia^2 F.L. output = 14,920 W ; F.L. input = 200 (Ia + 2.2) W We know, input = output + losses or 200 Ia + 440 = 14,920 + 1,738 + 0.04286 Ia^2 or 0.04286 Ia^2 − 200 Ia + 16,218 = 0 ∴ Ia = 82.5 A ∴ Input current = 82.5 + 2.2 = 84.7 A F.L. power input = 200 × 84.7 A = 16,940 W ∴ η= 14,920 × 100/16,940 = 88%		
X	**<u>Three-point Starter</u>** The internal wiring for such a starter is shown in Fig. 30.39. The three terminals of the starting box are marked A, B and C. One line is directly connected to one armature terminal and one field terminal which are tied together. The other line is connected to point A which is further connected to the starting arm L, through the overcurrent (or overload) release M. To start the motor, the main switch is first closed and then the starting arm is slowly moved to the right. As soon as the arm makes contact with stud No. 1, the field circuit is directly connected across the line and at the same time full starting resistance R, is placed in series with the armature. The starting current drawn by the armature = V/(Ra + Rs) where Rs is the starting resistance. As the arm is further moved, the starting resistance is gradually cut out till, when the arm reaches the running position, the resistance is all cut out. The arm moves over the various studs against a strong spring which tends to restore it to OFF position. There is a soft iron piece S attached to the arm which in the full 'ON' or running position is attracted and held by an electromagnet E energised by the shunt current. It is variously known as 'HOLD-ON' coil, LOW VOLTAGE (or NOVOLTAGE) release. It will be seen that as the arm is moved from stud NO. 1 to the last stud, the field current has to travel back through that portion of the starting resistance that has been cut out of the armature circuit. This results is slight decrease of shunt current. But as the value of starting resistance is very small as compared to shunt field resistance, this slight decreases in Ish is negligible.	Fig 4 Exp 3	

	 Fig. 30.39		
XI	**Torque** By the term torque is meant the turning or twisting moment of a force about an axis. It is measured by the product of the force and the radius at which this force acts. Consider a pulley of radius r metre acted upon by a circumferential force of F Newton which causes it to rotate at N r.p.m. Then torque $T = F \times r$ Newton-metre (N - m) **Armature Torque of a Motor** Let Ta be the torque developed by the armature of a motor running at N r.p.s. If Ta is in N/M, then power developed = $Ta \times 2\pi N$ watt …(i) We also know that electrical power converted into mechanical power in the armature = EbIa watt ...(ii) Equating (i) and (ii), we get $Ta \times 2\pi N = EbIa$ ...(iii) Since $Eb = \Phi ZN \times (P/A)$ volt, we have $Ta \times 2\pi N = \Phi ZN (P/A)Ia$ or $Ta = (1/2\pi)\Phi ZI_0 (P/A)$ N-m = 0.159 N newton metre $\therefore$ $Ta = 0.159\ \Phi ZIa \times (P/A)$ N-m **Shaft Torque (Tsh)** The whole of the armature torque, as calculated above, is not available for doing useful work, because a certain percentage of it is required for supplying iron and friction losses in the motor. The torque which is available for doing useful work is known as shaft torque Tsh. It is so called because it is available at the shaft. The motor output is given by Output = $Tsh \times 2\pi N$ Watt provided Tsh is in N-m and N in r.p.s. $\therefore$ Tsh = Output in watts/$2\pi N$ N- m −N in r.p.s = Output in watts/$(2\pi N / 60)$ N-m −N in r.p.m. = $(60/2\pi)$ (output/N) = 9.55(Output/N) N-m.	Definition - 3 Comparison = 4	7
XII	**Characteristics of Shunt Motors** **1. Ta/Ia Characteristic** Assuming Φ to be practically constant (though at heavy loads, φ decreases somewhat due to increased armature reaction) we find that $Ta \propto Ia$. Hence, the electrical characteristic as shown in Fig.	Fig 4 Exp 3	7

	29.17, is practically a straight line through the origin.  Fig. 29.17  Fig. 29.18  Fig. 29.19 **2. N/Ia Characteristic** If Φ is assumed constant, then N ∝ Eb. As Eb is also practically constant, speed is, for most purposes, constant (Fig. 29.18). But strictly speaking, both Eb and Φ decrease with increasing load. However, Eb decreases slightly more than φ so that on the whole, there is some decrease in speed. The drop varies from 5 to 15% of full-load speed, being dependent on saturation, armature reaction and brush position. Hence, the actual speed curve is slightly drooping as shown by the dotted line in Fig. 29.18. But, for all practical purposes, shunt motor is taken as a constant-speed motor. **3. N/Ta Characteristic** can be deduced from (1) and (2) above and is shown in Fig. 29.19.		
XIII	**Series - Parallel Starting** In traction work, 2 or more similar motors are employed. Consider 2 series motors started by series parallel method, which results in saving of energy. **(a) Series operation.** The 2 motors are started in series with the help of Rs. The current during starting is limited to normal rated current ‘I’ per motor. During series operation, current ‘I’ is drawn from supply. Supply voltage V = Back e.m.fs of 2 motors + IR drops of 2 motor.  Fig. 43.29 **(b) Parallel operation.** The motors are switched on in parallel at the instant ‘E’, with Rs reinserted as shown in Fig. 43.29 (b). Current drawn is 2I from supply. When the motors are in full parallel, (Rs = 0 and both the motors are running at rated speed) Supply voltage = V = Normal Back e.m.f. of each motor + IR drop in each motor.	Fig 4 Exp 3	7
XIV	<u>**Variation of Flux or Flux Control Method**</u> It is seen that N ∝ 1/Φ. By decreasing the flux, the speed can be increased and vice versa. Hence, the name flux or field control	Fig 4 Exp 3	7

	method. The flux of a d.c. motor can be changed by changing Ish with help of a shunt field rheostat. Since Ish is relatively small, shunt field rheostat has to carry only a small current, which means I^2R loss is small, so that rheostat is small in size. This method is, therefore, very efficient. In non-interpolar machine, the speed can be increased by this method in the ratio 2 : 1. Any further weakening of flux Φ adversely affects the communication and hence puts a limit to the maximum speed obtainable with the method. In machines fitted with interpoles, a ratio of maximum to minimum speed of 6 : 1 is fairly common. 		

Module wise question analysis

Question No	Module				No of questions
	I	**II**	**III**	**IV**	
Part A (1 Mark)	2	2	3	2	9
Part B (3 Marks)	4	1	1	4	10
Part C (7 Marks)	2	4	4	2	12
Total questions	**8**	**7**	**8**	**8**	**31**
Total (Marks)=123	**28**	**33**	**34**	**28**	

Cognitive level wise question analysis

Question No	Cognitive level			No of questions
	Remember	**Understand**	**Apply**	
Part A (1 Mark)	6	3	0	9
Part B (3 Marks)	4	5	1	10
Part C (7 Marks)	1	8	3	12
Total questions	**11**	**16**	**4**	**31**
Total (Marks)=123	**25**	**74**	**24**	

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Model Question Paper II

DC MACHINES AND TRACTION MOTORS

Time: 3 Hour *Max.Marks: 75*

PART A

I. Answer **all** questions in one word or one sentence. Each question carries 1 mark.

1	State the function of commutator in dc generator	M 1.01	U
2	The type of armature winding suitable for high voltage low current dc machines is ……….	M 1.04	R
3	Write the generated emf equation in dc generator	M 1.03	R
4	Name any one method used to improve commutation in dc machines	M 2.02	R
5	State the function of compensating winding	M 2.01	U
6	Name any two starters used for dc motors	M 3.02	R
7	List the losses in a dc motor	M 3.04	R
8	List any two electric features of traction motor	M 4.02	R
9	Name the speed control of dc motor in which above base speed is obtained	M 4.01	R

PART B

II. Answer any **eight** questions from the following, each question carries 3 marks.

1	Show the power stages of dc generator in a flow diagram	M 1.03	R
2	Derive the condition for maximum efficiency in dc generator	M 1.03	U
3	A long-shunt compound generator delivers a load current of 50 A at 500 V and has armature, series field and shunt field resistances of 0.05 Ω, 0.03 Ω and 250 Ω respectively. Calculate the generated voltage and the armature current. Allow 1 V per brush for contact drop.	M 1.03	A
4	Explain cross magnetising effect of armature reaction	M 2.01	U
5	List the uses of different types of dc generators	M 2.04	R
6	Explain the procedure to draw OCC at different speeds	M 2.03	U
7	Summarize the advantages of parallel operation of dc generators	M 2.04	U
8	Derive the condition for maximum power in dc motor	M 3.01	U
9	List advantages and disadvantages of Swinburne’s test	M 3.03	R
10	Explain regenerative braking in traction motors	M 4.04	U

PART C

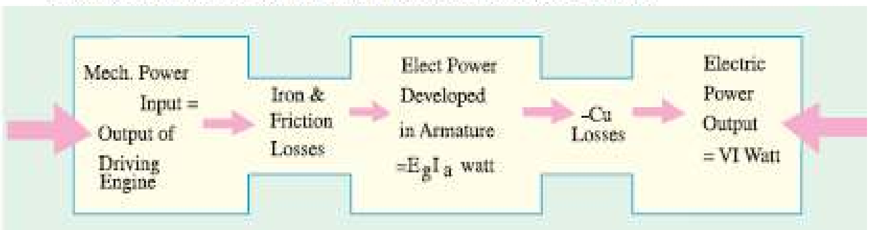
Answer ALL questions. Each question carries 7 marks.

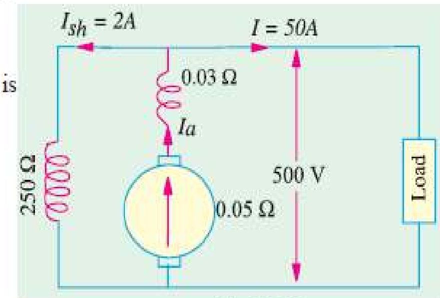
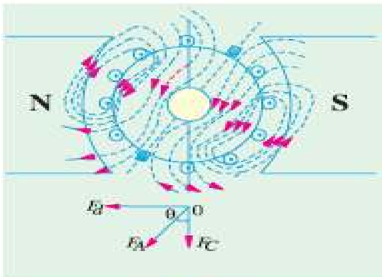
III	Explain the working principle of dc generator	M 1.02	U
	OR		
IV	Summarize the classification of dc generators	M 1.02	U
V	Illustrate the function of interpoles in dc generators	M 2.02	U
	OR		
VI	Draw and explain external characteristics of dc shunt generator	M 2.03	U
VII	Explain Four point starter with the help of a figure.	M 3.02	U
	OR		
VIII	Illustrate calculation of efficiency of dc motor using load test	M 3.03	U
IX	A 4-pole, 240 V, wave connected shunt motor gives 1119 kW when running at 1000 r.p.m. and drawing armature and field currents of 50 A and 1.0 A respectively. It has 540 conductors. Its resistance is 0.1 Ω. Assuming a drop of 1 volt per brush, find (a) total torque (b) useful torque (c) useful flux / pole	M 3.01	A
	OR		
X	A 4 pole, 32 conductor, lap-wound d.c. shunt generator with terminal voltage of 200 volts delivering 12 amps to the load has ra = 2 and field circuit resistance of 200 ohms. It is driven at 1000 r.p.m. Calculate the flux per pole in the machine. If the machine has to be run as a motor with the same terminal voltage and drawing 5 amps from the mains, maintaining the same magnetic field, find the speed of the machine.	M 3.01	A
XI	Illustrate series parallel control by bridge transition method	M 4.03	U
	OR		
XII	A 250 V, d.c. shunt motor has a shunt field resistance of 250 Ω and an armature resistance of 0.25 Ω. For a given load torque and no additional resistance included in the shunt field circuit, the motor runs at 1500 r.p.m. drawing an armature current of 20 A. If a resistance of 250 Ω is inserted in series with the field, the load torque remaining the same, find out the new speed and armature current. Assume the magnetisation curve to be linear.	M 4.01	A
XIII	Explain speed control of dc series motor by flux control method	M 4.01	U
	OR		
XIV	Summarize the use of dc series motors in electric traction	M 4.02	U

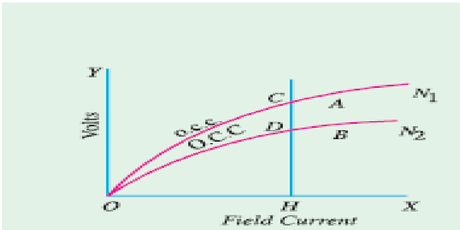
Scoring Indicators

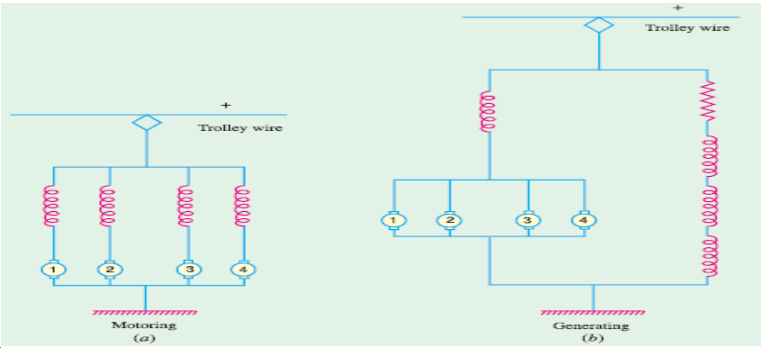
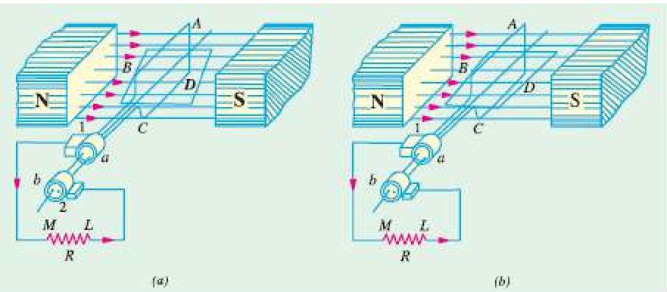
Model Question Paper I

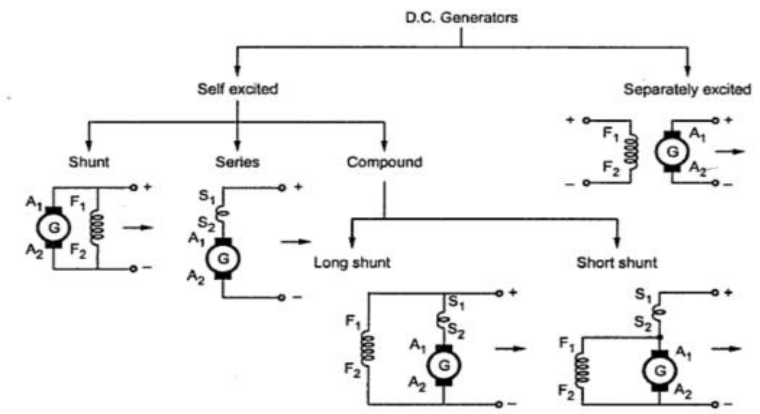
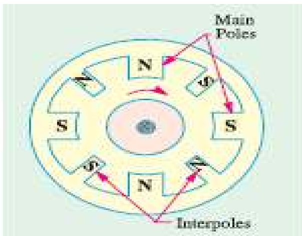
DC MACHINES AND TRACTION MOTORS

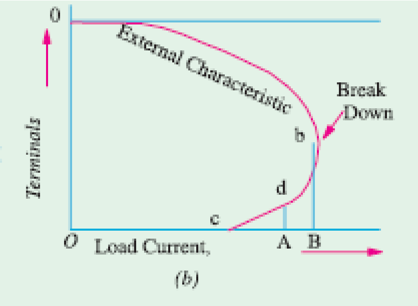
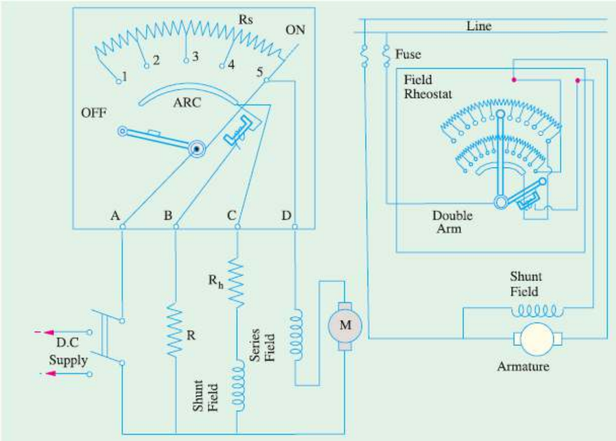
Q No	Scoring Indicators	Split score	Total score
	PART A		
I. 1	The function of the commutator is to convert the alternating current induced in the armature conductors into unidirectional current in the external load circuit.	1	1
I. 2	Wave winding	1	1
I. 3	Generated emf Eg = $\frac{\Phi ZN}{60} \times (\frac{P}{A})$ volt	1	1
I. 4	i. Resistance commutation ii. Emf commutation	Any one	1
I. 5	To neutralize the cross magnetising effect of armature reaction	1	1
I. 6	Three point starter, Four point starter	1	1
I. 7	Copper losses, Magnetic losses and mechanical losses	1	1
I. 8	- High starting torque - Series Speed - Torque characteristic - Simple speed control - Possibility of dynamic/ regenerative braking - Good commutation under rapid fluctuations of supply voltage.	Any two	1
I. 9	Flux control	1	1
	PART B		
II. 1	Power stages of dc generator. Show 3 stages Various power stages in the case of a d.c. generator are shown below : 	1+1+1	3

II. 2	Generator output = VI Generator input = output + losses $= VI + I_a^2R_a + W_c = VI + (I+I_{sh})^2R_a + W_c$ $\quad (\because I_a = I + I_{sh})$ However, if I_{sh} is negligible as compared to load current, then $I_a = I$ (approx.) $\therefore \quad \eta = \frac{\text{output}}{\text{input}} = \frac{VI}{VI + I_a^2R_a + W_c} = \frac{VI}{VI + I^2R_a + W_c}$ $\quad (\because I_a = I)$ $= \frac{1}{1 + \left(\frac{IR_a}{V} + \frac{W_c}{VI}\right)}$ Now, efficiency is maximum when denominator is minimum *i.e.* when $\frac{d}{dI}\left(\frac{IR_a}{V} + \frac{W_c}{VI}\right) = 0$ or $\frac{R_a}{V} - \frac{W_c}{VI^2} =$ or $I^2R_a = W_c$ Hence, generator efficiency is maximum when Variable loss = constant loss.	3	3
II. 3	Generator circuit is shown in Fig. 26.47.  Fig. 26.47 $I_{sh} = 500/250 = 2$ A Current through armature and series winding is $= 50 + 2 = 52$ A Voltage drop on series field winding $= 52 \times 0.03 = 1.56$ V Armature voltage drop $I_aR_a = 52 \times 0.05 = 2.6$ V Drop at brushes = $2 \times 1 = 2$ V Now, $E_g = V + I_aR_a$ + series drop + brush drop $= 500 + 2.6 + 1.56 + 2 = 506.16$ V	3	3
II. 4	**Cross magnetising effect of armature reaction**  Fig. 27.5 Component OFC is at right angles to the vector OFm representing the main m.m.f. It produces distortion in the main field and is hence called the cross-magnetising or distorting component of the armature reaction.	3	3
II. 5	**Uses of D.C. Generators** *list-any three* *3* 1 marks = 3 mark* **1. Shunt generators** with field regulators are used for ordinary lighting and power supply purposes. They are also used for charging batteries **2. Series generators:** Their rising characteristic makes them suitable for being used as boosters in certain types of distribution systems particularly in railway service.	1+1+1	3

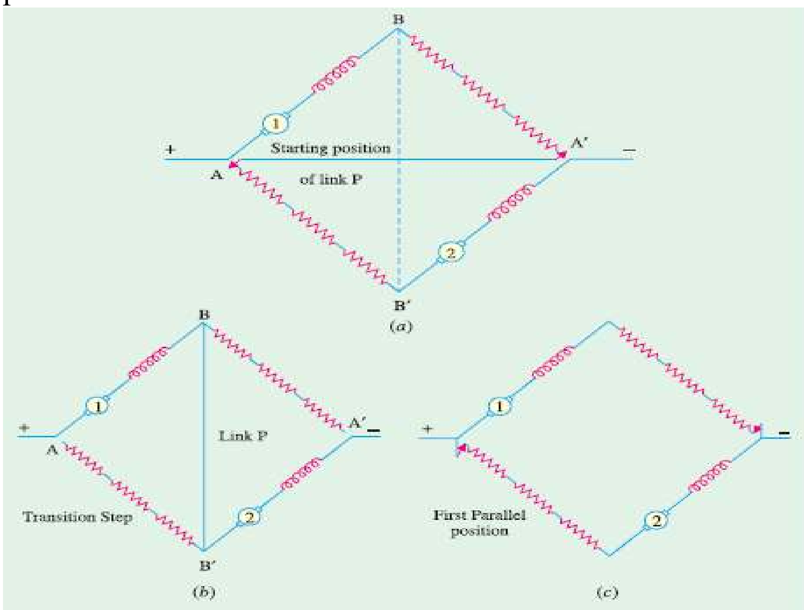
	3. Compound generators The cumulatively-compound generator is the most widely used d.c. generator. Such generators are used for motor driving which require d.c. supply at constant voltage, for lamp loads and for heavy power service such as electric railways.		
II. 6	Suppose we are given the data for O.C.C. of a generator run at a fixed speed, say, N1. It will be shown that O.C.C. at any other constant speed N2 can be deduced from the O.C.C. for N1. In Fig the O.C.C. for speed N1 is shown. Since $E \propto N$ for any fixed excitation, hence $\frac{E_2}{E_1} = \frac{N_2}{N_1}$ or $E_2 = E_1 \times \frac{N_2}{N_1}$ As seen, for $I_f = OH$, $E_1 = HC$. The value of new voltage for the same I_f but at N_2 $E_2 = HC \times \frac{N_2}{N_1} = HD$  In this way, point D is located. In a similar way, other such points can be found and the new O.C.C. at N2 drawn.	Fig 2 Exp 1	3
II. 7	**Advantages of parallel operation of dc generators** *list-any three* *3* 1 marks = 3 mark* (i) Continuity of Service (ii) Efficiency (iii) Maintenance and Repair. (iv) Additions to Plant Explain each	1+1+1	3
II. 8	**Condition for Maximum Power** The gross mechanical power developed by a motor is Pm = V Ia − Ia^2 Ra. Differentiating both sides with respect to Ia and equating the result to zero, we get d Pm/d Ia = V − 2 Ia Ra = 0 ∴ Ia Ra = V/2 As V = Eb + Ia Ra and Ia Ra = V/2 ∴ Eb = V/2 Thus gross mechanical power developed by a motor is maximum when back e.m.f. is equal to half the applied voltage.	3	3
II. 9	**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. **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	3	3

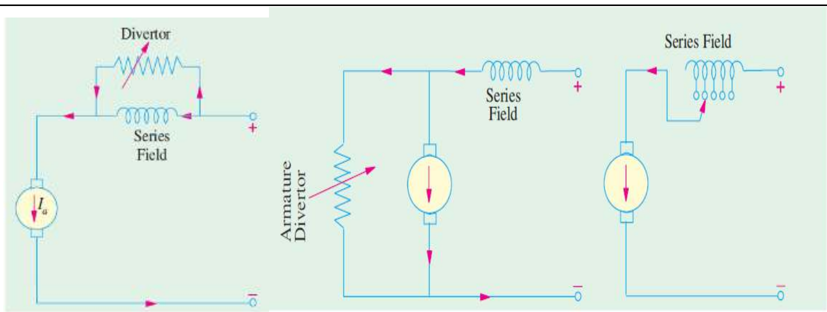
	which increases the iron losses in some cases by as much as 50%. 2. As the test is on no-load, it is impossible to know whether commutation would be satisfactory at full-load and whether the temperature rise would be within the specified limits.		
II.10	**Regenerative braking of traction motor** In order to achieve the regenerative braking, it is essential that (i) the voltage generated by the machine should exceed the supply voltage and (ii) the voltage should be kept at this value, irrespective of machine speed. Fig.(a) shows the case of 4 series motors connected in parallel during normal running i.e. motoring. One method of connection during regenerative braking is to arrange the machines as shunt machines, with series fields of 3 machines connected across the supply in series with suitable resistance. One of the field winding is still kept in series across the 4 parallel armatures as shown in figure (b). D.C. series motor can't be used for regenerative braking without modification for obvious reasons. During regeneration current through armature reverses; and excitation has to be maintained. Hence field connection must be reversed. 	Fig 2 Exp 1	3
	PART C		
III	**Generator Principle** 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 motionally) induced e.m.f. As seen from Fig, 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 generator are (i) a magnetic field and (ii) a conductor or conductors which can so move as to cut the flux. 	Fig 4 Exp 3	7

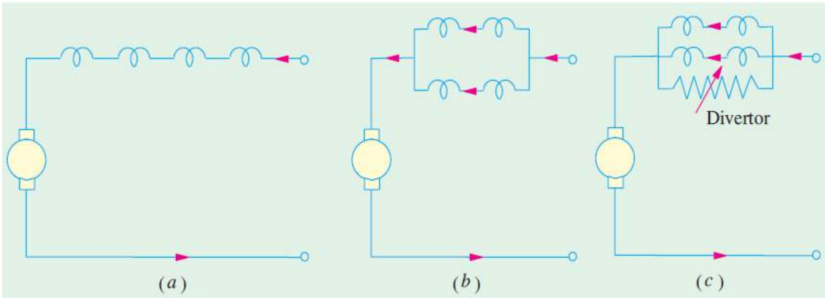
IV	 Explain each	Fig 4 Exp 3	7
V	**The function of interpoles:** (i) As their polarity is the same as that of the main pole ahead, they induce an e.m.f. in the coil (under commutation) which helps the reversal of current. The e.m.f. induced by the compoles is known as commutating or reversing e.m.f. The commutating e.m.f. neutralizes the reactance e.m.f. thereby making commutation sparkless. (ii) Another function of the interpoles is to neutralize the cross-magnetising effect of armature reaction. Hence, brushes are not to be shifted from the original position. This cancellation of cross magnetisation is automatic and for all loads because both are produced by the same armature current. 	7	7

VI	**External characteristics of Shunt generator**  The shunt generator is first excited on no-load so that it gives its full open circuit voltage = Oa. Then, the load is gradually applied and, at suitable intervals, the terminal voltage V and the load current I are noted. The field current is kept constant by a rheostat (because during the test, due to heating, shunt field resistance is increased). By plotting these readings, the external characteristic of is obtained. The portion ab is the working part of this curve. Over this part, if the load resistance is decreased, load current is increased as usual, although this results in a comparatively small additional drop in voltage. These conditions hold good till point b is reached. This point is known as breakdown point. It is found that beyond this point (where load is maximum = OB) any effort to increase load current by further decreasing load resistance results in decreased load current (like OA) due to a very rapid decrease in terminal voltage.	Fig 4 Exp 3	7
VII	 Such a starter with its internal wiring is shown, connected to a long-shunt compound motor in Fig. When compared to the three-point starter, it will be noticed that one important change has been made i.e., the HOLD-ON coil has been taken out of the shunt field circuit and has been connected directly across the line through a protecting resistance as shown. When the arm touches stud No. 1, then the line current divides into three parts (i) one part passes through starting resistance Rs, series field and motor armature (ii) the second part passes through the shunt field and its field rheostat Rh and (iii) the third part passes through the HOLD-ON coil and	Fig 4 Exp 3	7

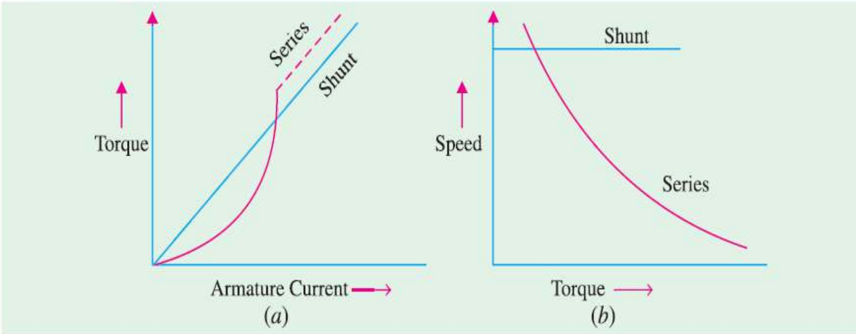
	current-protecting resistance R. It should be particularly noted that with this arrangement any change of current in the shunt field circuit does not at all affect the current passing through the HOLD-ON coil because the two circuits are independent of each other. It means that the electromagnetic pull exerted by the HOLD-ON coil will always be sufficient and will prevent the spring from restoring the starting arm to OFF position no matter how the field rheostat or regulator is adjusted.		
VIII	**Load Test** It is a direct method and consists of applying a brake to a water-cooled pulley mounted on the motor shaft. The motor is running and the load on the motor is adjusted till it carries its full load current. Let W1 = suspended weight in kg W2 = reading on spring balance in kg-wt The net pull on the band due to friction at the pulley is (W1 − W2) kg. wt. or 9.81 (W1 − W2) newton. If R = radius of the pulley in metre and N = motor or pulley speed in r.p.s. Then , shaft torque Tsh developed by the motor = (W1 − W2) R kg-m = 9.81 (W1 − W2) R N-m Motor output power = Tsh × 2π N watt = 2π × 9.81 N (W1 − W2) R watt = 61.68 N (W1 − W2) R watt Let V = supply voltage ; I = full-load current taken by the motor. Then, input power = VI watt ∴ η= Output/Input = (61.68 N(W1-W2)R)/VI	7	7
IX	Eb = V − Ia Ra − brush drop = 240 − (50 × 0.1) − 2 = 233 V Also Ia = 50 A (a) Armature torque Ta = (9.55×EbIa)/N N-m = (9.55 × 233×50)/1000 = 111 N-m (b) Tsh = 9.55×output/N = 9.55×11,190/1000 = 106.9 N-m (c) Eb = (ΦZN) /60 ×(P/A) volt ∴ 233 =(Φ × 540 × 1000)/60 x(4 /2) ∴ Φ = 12.9 mWb	(a) - 2 (b) - 2 (c) - 3	7
X	Current distributions during two actions are indicated in Fig. 29.9 (a) and (b). As a generator, Ia = 13 amp Eg = 200 + 13 × 2 = 226 V $\frac{\square\square}{60} \times \frac{\square}{\square} = 226$ For a Lap-wound armature, P = a ∴ φ= 0.42375 wb As a motor, Ia = 4 amp Eb = 200 − 4 × 2 = 192 V = φ ZN/60 Giving N = 850 r.p.m.	7	7
XI	**Series Parallel Control by Bridge Transition** (a) At starting, motors are in series with Rs i.e. link P in position = AA′		

	(b) Motors in full series with link P in position = BB′ (No Rs in the circuit) The motor and Rs are connected in the form of Wheatstone Bridge. Initially motors are in series with full Rs as shown in Fig. 43.32 (a). A and A′ are moved in direction of arrow heads. In position BB′ motors are in full series, as shown in Fig. 43.32 (b), with no Rs present in the circuit.  		
XII	In this case, the motor speed is changed by changing the flux. Now, $\frac{□2}{□1} = \frac{□□2}{□□1} \times \frac{□1}{□2}$ Since it is given that magnetisation curve is linear, it means that flux is directly proportional to shunt current. Hence $\frac{□2}{□1} = \frac{□□2}{□□1} \times \frac{□□h1}{□□h2}$ where Eb2 = V − Ia2 Ra and Eb1 = V − Ia1 Ra. Since load torque remains the same ∴ Ta ∝ Φ1 Ia1 □ Φ2 Ia2 or Φ1 Ia1 = Φ2 Ia2 ∴ Ia2 = $□□1 \times \frac{□1}{□2} = □□1 \times \frac{□□h1}{□□h2}$ Now, Ish1 = 250/250 = 1 A; Ish2 = 250/(250 + 250) = 1/2 A ∴ Ia2 = 20 ×(1/(1/2)) = 40 A ∴ Eb2 = 250 − (40 × 0.25) = 240 V and Eb1 = 250 − (20 × 0.25) = 245 V ∴ $\frac{□2}{1500} = \frac{240}{245} \times \frac{1}{1/2}$ ∴ N2 = 2, 930 r.p.m.	7	7
XIII	**Speed Control of dc series motor** (a) Field Divertors: The series winding are shunted by a variable resistance known as field divertor	Fig 4 Exp 3	7

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

(b) Armature Divertor: A divertor across the armature can be used for giving speeds lower than the normal speed
(c) Trapped Field Control Field
This method is often used in electric traction


(d) Paralleling Field coils
In this method, used for fan motors, several speeds can be obtained by regrouping the field coils</td><td></td><td></td></tr>
<tr><td>XIV</td><td>General Features of Traction Motor
Electric Features
- High starting torque
- Series Speed - Torque characteristic
- Simple speed control
- Possibility of dynamic/ regenerative braking
- Good commutation under rapid fluctuations of supply voltage.
Mechanical Features
- Robustness and ability to withstand continuous vibrations.
- Minimum weight and overall dimensions
- Protection against dirt and dust
No type of motor completely fulfills all these requirements. Motors, which have been found satisfactory are D.C. series for D.C. systems and A.C. series for A.C. systems.</td><td>7</td><td>7</td></tr>
</table>

	The torque - current and speed - torque curves for D.C. motors are shown in Fig. 43.20 (*a*) and (*b*) respectively.  Fig. 43.20		

Module wise question analysis

Question No	Module				No of questions
	I	**II**	**III**	**IV**	
Part A (1 Mark)	3	2	2	2	9
Part B (3 Marks)	3	4	2	1	10
Part C (7 Marks)	2	2	4	4	12
Total questions	**8**	**8**	**8**	**7**	**31**
Total (Marks)=123	**26**	**28**	**36**	**33**	

Cognitive level wise question analysis

Question No	Cognitive level			No of questions
	Remember	**Understand**	**Apply**	
Part A (1 Mark)	7	2	0	9
Part B (3 Marks)	3	6	1	10
Part C (7 Marks)	0	9	3	12
Total questions	**10**	**17**	**4**	
Total (Marks)=123	**16**	**83**	**24**	

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