Scoring Indicators

Question Paper I

DC MACHINES AND TRACTION MOTORS 3032

Q No	Scoring Indicators	Split score	Sub Total	Total Score
	PART A			9
I.1.	Mechanical Energy to Electrical Energy		1	
I. 2.	No. of Poles		1	
I. 3.	Magnetic Characteristic		1	
I. 4.	Compound Generators		1	
I. 5.	V=Eb+IaRa		1	
I. 6.	DC Series Motor		1	
I. 7.	DC Series Motor		1	
I. 8.	Regenerative Braking		1	
I. 9.	Flux Control Method		1	
	PART B			24
II. 1.	Whenever a change takes place in the magnetic flux whose linking is with a circuit, an emf current is induced in the circuit. The magnitude of the induced emf happens to be directly proportional to the rate of the change of magnetic flux whose linking is with the circuit.		3	

II.2.	The lap winding has many paths and hence it is used for the larger current applications. The only disadvantage of the lap winding is that it requires many conductors which increase the cost of the winding. In Wave winding, the conductors are connected to two parallel paths irrespective of the number of poles of the machine. The wave winding is mainly used in high voltage, low current machines.		3	
II.3.	Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor according to Faraday's law of induction.If the core is made up of solid iron of larger cross-sectional area, the magnitude of I will be very large and hence losses will be high. The eddy current loss can be reduced by reducing the magnitude of the eddy current. The magnitude of the current can be reduced by splitting the solid core into thin sheets called laminations, in the plane parallel to the magnetic field. Each lamination is insulated from the other by a thin layer of coating of varnish or oxide film. By laminating the core, the area of each section is reduced and hence the induced emf also reduces. As the area through which the current is passed is smaller, the resistance of eddy current path increases.		3	
IY.4.	The main purpose of compensating winding is to nullify the effect of armature reaction on the main field flux under the pole faces in DC machine. Due to the effect of armature reaction mmf, the flux distribution under the pole faces is distorted which leads to poor commutation and flashover. Compensating winding is embedded in the slots in pole faces. It is connected in series with the armature winding so that their mmfs are proportional to the same current. To compensate the effect of armature reaction, the direction of current in compensating winding must be opposite to that in the armature winding just below the pole face		3	
II.5.	***Any three----3 marks***		3	
	Conditions for Parallel Operation of Dc Generator : To connects the generators in parallel to common bus-bars, the generators should satisfy the following			

	conditions. 1. The incoming generator's voltage should be the same as the bus-bar voltage. 2.The +ve and -ve terminals (i.e. polarity) of generators must be connected to +ve and -ve of bus-bars (otherwise a serious short-circuit will occur). 3.Equalizer bar should be used for compound and series generators. 4.Induced e.m.fs of generators should be preferably the same (otherwise circulating currents result).			
II.6.	Back emf is very significant in the working of a dc motor. The presence of back emf makes the d.c. motor a *self-regulating machine* i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load. $I_a = \frac{V - E_b}{R_a}$ When the motor is running on no load, small torque is required to overcome the friction and windage losses. Therefore, the armature current Ia is small and the back emf is nearly equal to the applied voltage. If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore, the speed at which the armature conductors move through the field is reduced and hence the back emf Eb falls. The decreased back emf allows a larger current to flow through the armature and larger current means increased driving torque. Thus, the driving torque increases as the motor slows down. The motor will stop slowing down when the armature current is just sufficient to produce the increased torque required by the load.		**3**	

II.7.

Since,

$$V = E_b + I_aR_a \quad \dots\dots(1)$$

Multiplying the equation (1) by I_a we get

$$VI_a = E_bI_a + I_a^2R_a \quad \dots\dots(2)$$

Where,

VI_a is the electrical power input to the armature.

$I^2_aR_a$ is the copper loss in the armature.

Total electrical power supplied to the armature = Mechanical power developed by the armature + losses due to armature resistance

Now, the mechanical power developed by the armature is Pm,

3

$$P_m = F_bI_a \quad \dots\dots(3)$$

Also, the mechanical power that rotates the armature can be given regarding torque T and speed n.

$$P_m = \omega T = 2\pi\, nT \quad \dots\dots(4)$$

Where n is in revolution per seconds (rps) and T is in Newton-Meter.

Hence,

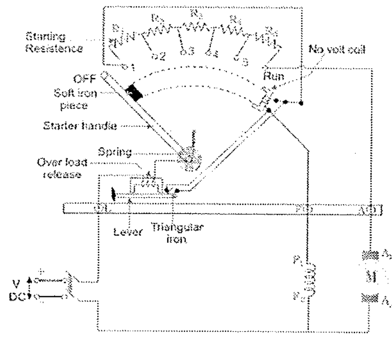
$$2\pi\, nT = E_bI_a \quad \text{or}$$

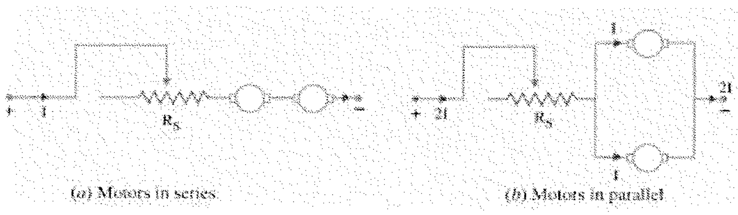
$$T = \frac{E_bI_a}{2\pi n}$$

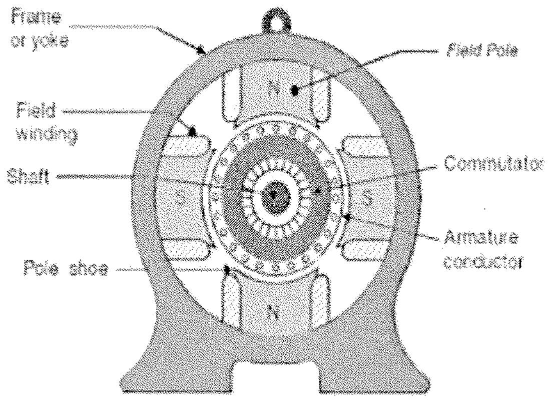
But,

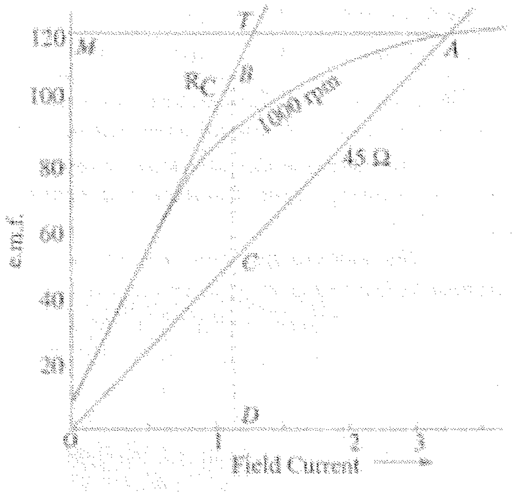
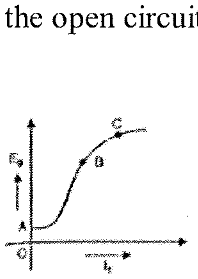
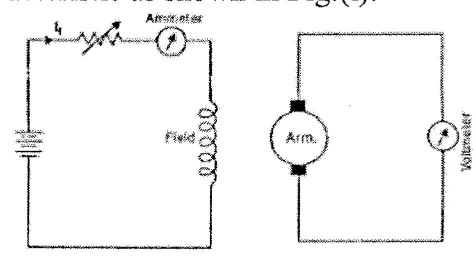
$$E_b = \frac{\varphi ZNP}{60\ A}$$

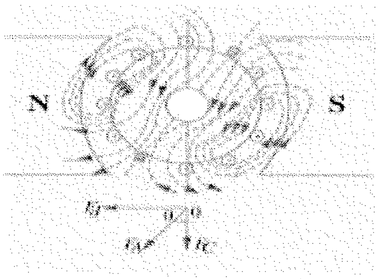
Where N is the speed in revolution per minute (rpm) and

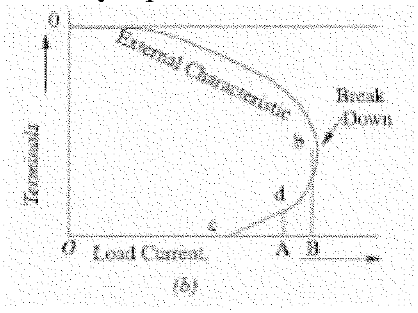
	$n = \frac{N}{60}$ Where n is the speed in (rps). Therefore, $E_b = \frac{\varphi ZnP}{A}$ So, the torque equation is given as: $T = \frac{\varphi ZP}{2\pi A} \cdot I_a$			
II.8	 		**3**	
II.9.	(a) Series operation. The two motors are started in series with the help of Rs. The current during starting 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 two motors + IR drops of two motor		**3**	

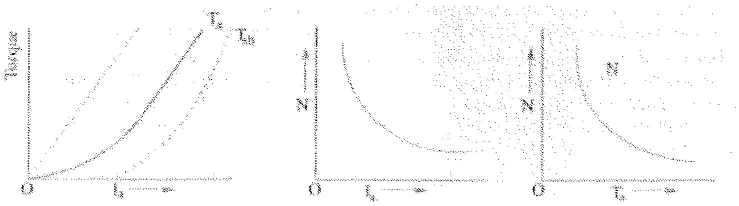
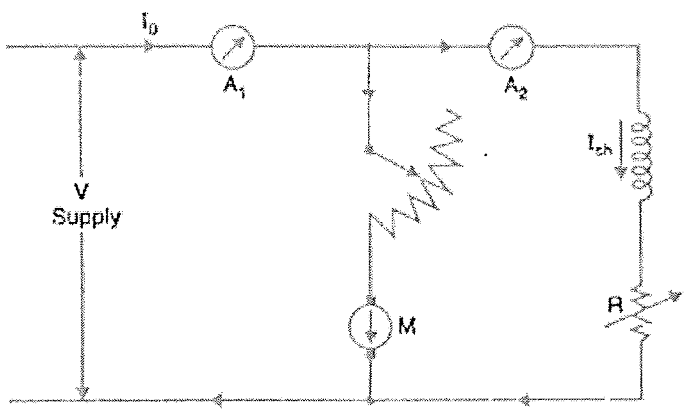
	 (b) Parallel operation. The motors are switched on in parallel at the instant 'E', with Rs reinserted as shown in Fig. Current drawn is 2I from supply. When the motors are in full parallel, (Rs = 0 and both the motors are running at rated speed) Supply voltage = V = Normal Back e.m.f. of each motor + IR drop in each motor.			
II.10.	In this type of braking, the DC motor is disconnected from the supply and a braking resistor R_b is immediately connected across the armature. The motor will now work as a generator and produces the braking torque. During electric braking when the motor works as a generator, the kinetic energy stored in the rotating parts of the motor and a connected load is converted into electrical energy. It is dissipated as heat in the braking resistance R_b and armature circuit resistance R_a.		**3**	
	PART C			**42**
III	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		**7**	

	Hence, according to Faraday's Laws of Electromagnetic Induction, EMF generated/conductor = $d\Phi\ dt$ = ϕPN 60 volt No. of conductors (in series) in one path = Z/A In general generated emf Eg = (ΦZN /60)× ($P/\ A$) volt Where A = 2- for simplex wave winding = P for simplex lap winding			
IV	 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 crosssection, 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.	**Fig 3 Exp 4**	**7**	

V	In Figure, OA represents the 45 ohm line which is drawn as usual. (i)The voltage to which machine will build up=OM=118 V (ii) OT is the tangent to the initial part of the O.C.C. It represents the Critical Resistance.Take Point B lying on this line.Voltage and exciting current corresponding to this point are 110V and 1.1 A respectively.  Critical Resistance= 110/1.1 = 100 ohms.			
VI	***Diagram- 3 Marks*** ***Explanation – 4 Marks***	**4+3**	**7**	
	Open Circuit Characteristic of a D.C. Generator The field winding of the d.c. generator (series or shunt) is 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).  (i)  (ii) 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			
VII	Armature Reaction – 1 Mark Cross Magnetisation– 3 Marks De magnetisation– 3 Marks	1+3+3	**7**	
	The armature, in carrying the current, sets up a magnetic field of its own. This field combines with the main field, producing a resultant field, and the process is called armature reaction. Cross magnetising effect of armature reaction  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 De Magnetising Effect The term demagnetizing field reflects its tendency to act on the magnetization so as to reduce the total magnetic moment. The demagnetizing component acts in the opposite direction, reducing flux/pole in a machine, which will ultimately reduce generator emf.		**7**	

<table>
<tr><td>VIII</td><td>Figure -3
Explanation -4</td><td>3+4</td><td>7</td><td></td></tr>
<tr><td></td><td>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.

</td><td></td><td></td><td></td></tr>
<tr><td>IX</td><td>Equation – 4 Marks
Calculation – 3 Marks</td><td>4+3</td><td>7</td><td></td></tr>
<tr><td></td><td>$\frac{N}{N_0} = \frac{E_b}{E_{b0}} \times \frac{\Phi_0}{\Phi}$; Since $\Phi_0 = \Phi$ (given); $\frac{N}{N_0} = \frac{E_b}{E_{b0}}$
$I_{sh} = 250/250 = 1$ A
$E_{b0} = V - I_{a0} R_a = 250 - (7 \times 0.2) = 248.6$ V; $E_b = V - I_a R_a = 250 - (49 \times 0.2) = 240.2$ V
$\frac{N}{1000} = \frac{240.2}{248.6}$; $N = 966.1$ r.p.m.</td><td></td><td></td><td></td></tr>
</table>

X	Diagram – 3Mark Explanation – 4 Marks	3+4	7	
	 Electrical Characteristics Before Magnetic Saturation Ta is proportional to square of Ia. Hence Ta- Ia Curve is a parabola for smaller values of Ia. After Magnetic saturation of field poles,flux is independent of Armature Current. Hence flux varies proportional to Ia only. Mechanical Characteristics As Torque increases, Ia increases which increases flux and hence speed decreases with torque.			
XI	Diagram- 1 Mark Explanation – 6 Marks	1+6	7	
	Swinburne's test is the simplest indirect method of testing dc machines. In this method, the dc machine (generator or motor) is run as a motor at no-load and 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.  Let V = Supply voltage			

I_o = No-load current read by ammeter A_1
I_{sh} = Shunt-field current read by ammeter A_2.

∴ No-load armature current, $I_{a0} = I_o - I_{sh}$

No-load input power to motor = $V I_o$

No-load power input to armature = $V I_{ao} = V(I_o - I_{sh})$

Since the output of the motor is zero, the no-load input power to the armature supplies

i. iron losses in the core
ii. friction loss
iii. windage loss

armature Cu loss [$I_{ao}^2R_a$ or $(I_o - I_{sh})^2R_a$.

Constant losses, W_c = Input to motor – Armature Cu loss

$$W_c = V I_o - (I_o - I_{sh})^2R_a$$

Since constant losses are known, the efficiency of the machine at any other load can be determined. Suppose it is desired to determine the efficiency of the machine at load current I. Then,

Armature current, $I_a = I - I_{sh}$ … if the machine is motoring

$= I + I_{sh}$ … if the machine is generating

Efficiency when running as a motor

Input power to motor = VI

Armature Cu loss = $I_a^2R_a = (I - I_{sh})^2R_a$

Constant losses = W_c found above

Total losses = $(I - I_{sh})^2R_a + W_c$

∴ Motor efficiency, η_m = (Input – Losses)/Input = $[VI - (I - I_{sh})^2R_a + W_c]/VI$

Efficiency when running as a generator

The output of generator= VI

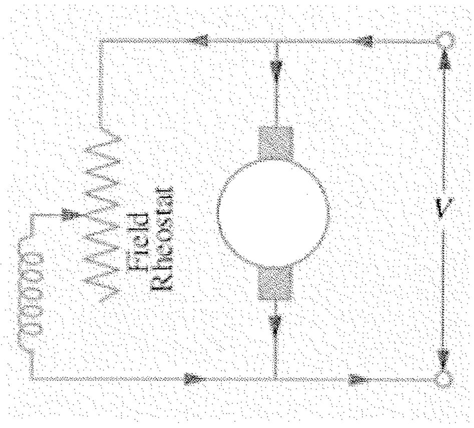
Armature Cu loss = $I_a^2R_a = (I + I_{sh})^2R_a$

Constant losses = W_c found above

Total losses = $(I + I_{sh})^2R_a + W_c$

∴ Motor efficiency, η_m = (Input – Losses)/Input = $VI/[VI + (I + I_{sh})^2R_a + W_c]$

XII	***Applications of DC Series motor .....3 Marks*** ***Applications of DC Shunt Motor ..... 3 Marks*** ***Applications of DC Compound Motor ..... 1 Mark***	3+3+1	7	
	Application of DC series motor ⇒ DC series motors are used where high starting torque required. These motors are only used where the variation of speed is possible. series motors are not suitable for constant speed applications. ⇒ DC series motor is used in a vacuum cleaner, traction systems, sewing machines, cranes, air compressors etc. ***Application of DC shunt motor*** ⇒ DC shunt motors are used where constant speed is needed. So these motors are commonly used in fixed speed applications. ⇒ This type of motor is used in Lathe Machines, Centrifugal Pumps, Fans, Blowers, Conveyors, Lifts, Weaving Machine, Spinning machines, etc. ***Application of DC Compound motor*** ⇒ By compound motor, we get high starting torque and nearly constant speed. Because of that Compound motors are used where we require high starting torque and constant speed. ⇒ A compound motor is used in Presses, Shears, Conveyors, Elevators, Rolling Mills, Heavy Planners, etc.			
XIII	***Figure ---- 2marks*** ***Explanation----- 5marks***	**2+5**	**7**	
	Variation of Flux or Flux Control Method 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 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 I2R 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.  			
XIV	***List Factors affecting speed Control – 3 marks*** ***Explanation– 4 marks***	**3+4**	**7**	
	The speed of a motor is given by the relation $N = (V - IaRa)/Z\phi * (A/P) = K * (V - IaRa)/\phi\ r.p.s$ 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).			