B.Tech.

Third Semester Examination, 2010-2011

Electrical Machine-I (EE-207-F)

Note : Q. 1 is compulsory. Attempt any four questions from remaining four parts by selecting one questions from each part.

Q. 1. (a) Explain how the Eddy currents are produced in transformer core.

Ans. Ferromagnetic materials are good conductors, and a core made from ferromagnetic materials, also constitute a single short-circuited turn throughout its entire length. Eddy currents therefore circulate within the core in a plane normal to the flux and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and inverse square of the material thickness. Eddy current losses can be reduced by making the core of a stack of plates electrically insulated from each other, rather than a solid block; all transformers operating at low frequencies use limited or similar cores.

Q. 1. (b) Write down the conditions of parallel operation of single phase transformers.

Ans. The essential conditions for successful parallel operation of transformers are :

(a) Transformation on turn-ratios and voltage ratings are same.

(b) Polarities of transformers are same.

(c) Percent impedances of transformers are same.

(d) Ratios of resistance and reactances are same.

(e) Phase displacement between primary and secondary winding is same.

(f) Phase sequence of transformers are same.

Q. 1. (c) Explain the zig-zag connection of transformers.

Ans. Zig-Zag Transformers :

Star (Wye) Winding *Zig-Zag Winding*

(i) A zig-zag transformer is a special purpose transformer with a zig-zag arrangement. It has primary winding but no secondary winding.

(ii) One application is to drive an earth reference point for an ungrounded electrical system. Another is to control harmonic currents.

(iii) Three phase transformers, the zig-zag transformer contains six coils on three cores. The first coil on each core is connected contraries to second coil on the next core. The second coils are then all tied together to form the neutral and phases are connected to the primary coils. Each phase, therefore, couples with each other phase and the voltages cancel out.

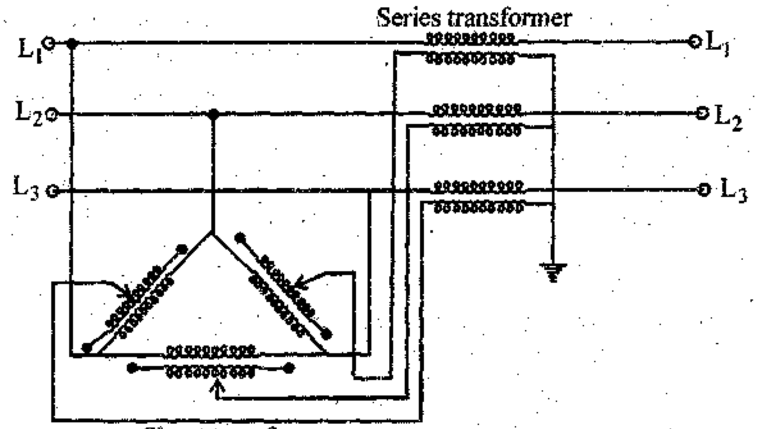
(i) The purpose of a zig-zag transformer is to provide a return path for earth faults on delta connected systems.

(ii) **An Application Examples :** Occasionally engineers use a combination of Y (Wye or star), delta and zig-zag windings to achieve a vector phase shift.

Q. 1. (d) What do you mean by phase shifting transformers.

Ans. Phase Shifting Transformers : A phase-shifting transformers, also called quadrature booster, is a specialised form of transformer used to control the flow of real power on three-phase electricity transmission network.

Phase shifting transformers provide a means of relieving overloads on heavily laden circuits and re-routing power via more favourable paths.



By means of voltage derived from the supply that is first phase shift by 90° and then re-applied to it, a phase angle is developed across the quadrature booster or phase shift transformer.

Q. 1. (e) What is the use of compensating winding in D.C. machines?

Ans. Compensating windings are most effectively means of eliminating the problems of armature reaction and flashover by balancing the armature mmf. Compensating windings are placed in slots provided in pole faces parallel to the rotor (armature) conductors. These windings are connected in series with the armature windings. The direction of currents in the compensating windings must be opposite to that in the armature winding just below the pole faces.

Thus, compensating winding produces an mmf that is equal and opposite to that of the armature mmf. Therefore compensating winding demagnetizes the armature flux.

Q. 1. (f) Explain the effect of distortion on the operation of D.C. generator.

Ans. The Effect of Distortion are :

(i) Magnetic flux density is increased over one half of the pole and decreased over the other half. But the total flux produced by each pole is slightly reduced and therefore, the terminal voltage is slightly reduced.

(ii) The flux wave is distorted and there is shift in the position of the Magnetic Natural Axis (MNA) in the direction of rotation for the generator and against the direction of rotation for the motor.

Q. 1. (g) When the armature of d.c. motor gets over heated?

Ans. The armature current of a d.c. motor is given by

$$\boxed{I_a = \frac{V - E}{R_a}}$$

Therefore, if the load torque T_2 is increased then, the motor will draw more current from the supply in order to run on increased torque but at some lower speed.

As the speed of the d.c. motor reduces the back emf E reduces keeping V as constant. Therefore, armature current I_a is increased due to which winding may get overheated $\left(H = I_a^2 R_t\right)$. If the load torque is increased beyond the safe value than the armature current I_a may flow above its rated value and hence the armature winding may get overheated.

Q. 1. (h) What causes the over heating of commutator in D.C. motor?

Ans. The overheating of commutation in DC motors can be take place when there is heavily flow of armature current, especially at the time of starting or heavy loaded conditions. Due to large load a heavy current starts flowing through armature which heats up the armature coils of the motor. Due to this fast commutating action (conversion of ac to dc or dc to ac is required) is required than in the normal condition or at rated armature current.

Due to fast commutating action a heavy sparking at the commutator and even flash-overs takes place, this causes overheating of the commutator of DC motors.

Part-A

Q. 2. (a) Derive the e.m.f. equation for 1−φ transformer.

Ans. Let the flux at any instant is given by :

$$\phi = \phi_{max} \sin wt$$

The instantaneous e.m.f. induced in a coil of T turns linked by this flux is given by Faraday's law :

$$e = -\frac{d}{dt}(\phi T) = -T.\frac{d}{dt}(\phi_m \sin wt) = -Tw\phi_m \cos wt$$

$$\boxed{e = Tw\phi_m \sin(wt - \pi/2)} \quad ...(1)$$

Equation (1) can be written as

$$e = E_m \sin(wt - \pi/2)$$

$$E_m = Tw\phi_m = \text{maximum value of e.}$$

For sine wave rms value is given by

$$E_{rms} = E = E_m / \sqrt{2}$$

$$E = \frac{Tw\phi_m}{\sqrt{2}} = \frac{T(2\pi f)\phi_m}{\sqrt{2}}$$

$$\boxed{E = 4.44\phi_m fT} \quad ...(2)$$

For primary, $\boxed{E_1 = 4.44f\phi_m T_1}$ ...(3)

For secondary, $\boxed{E_2 = 4.44 f\phi_m T_2}$ ...(4)

Equations (3) and (4) are called the EMF equation is transformer.

Q. 2. (b) The no load current of a transformer is 5A at 0.3 lagging power factor when supplied at 230V, 50 Hz. The number of turns of primary winding is 200. Calculate :

(i) Maximum value of flux in the core

(ii) Core loss

(iii) Magnetising current.

Ans. (i) Maximum Value of Flux in the Core :

We know that

$$E_1 = V_1 = 4.44 f\phi_m T_1$$

$$\phi_m = \frac{V_1}{4.44f \times T_1} = \frac{230}{4.44 \times 50 \times 200} = 0.00518\,\text{wb}$$

Or $\boxed{\phi_m = 5.18\,\text{m Wb}}$ **Ans.**

(ii) Core Loss : $= VI_0 \cos\phi_0$

$$= 230 \times 5 \times 0.3$$

$$= 345 \text{ watts} \quad \textbf{Ans.}$$

(iii) Magnetising Current : I_m

$$I_m = I_o \sin\phi_o$$

$$I_m = 5 \times 0.9539$$

$$\boxed{I_m = 4.7697 \text{ Ampere}} \quad \textbf{Ans.}$$

Q. 3. The primary of a certain transformer takes 1A at a power factor of 0.4 when it is connected across a 200V, 50 Hz supply and the secondary is on open circuit. The number of turns of the primary is twice that on the secondary. A load taking 50A at a lagging power factor of 0.8 is now connected across the secondary. What is now the value of primary current.

Ans. Given : $I_o = 1A$ at $\cos\phi = 0.4$

$$I_o = 1\angle{-66.42^\circ}$$

$$f = 50 \text{ Hz}$$

$$K = \frac{N_2}{N_1} = \frac{1}{2}$$

$I_2 = 50A$ at $\cos\phi = 0.8$

$I_2 = 50\underline{|-36.86°}$

$I_1 = I_0 + I_1'$

$I_1 = I_0 + KI_2 = 1\underline{|-66.42°} + \frac{1}{2}[50\underline{|-36.86}]$

$I_1 = 0.400 - 0.916j + 20.00 - 15j$

$I_1 = 20.400 - 15.916j$

$I_1 = 25.90\underline{|-38.03}$

$\therefore$ $I_1 = 25.90$ Amp. at $\cos\phi = 0.79$ lagging **Ans.**

Part-B

Q. 4. A 1500 KVA, 6000/400 V, 3 phase, transformer is star connected on low voltage side and is delta connected on high voltage side. Determine its % resistance and % reactance drops, % efficiency and % regulation on full load 0.85 leading power factor given the following data

S.C. test : H. V data : 400V, 175A, 17kW

O. C. test : L.V. data : 400V, 150A, 15 kW

Ans. Full load current on h.v. side $= \frac{1500 \times 1000}{\sqrt{3} \times 6000} = 144.34$ Amp.

$\therefore$ The short circuit current is not exactly equal to the full load current. The ratio of full load current and short circuit current will be,

$$= \frac{I_2}{I_{2sc}} = \frac{144.34}{175} = 0.825$$

% Positive drop, V_r = Percentage copper loss

$$= \frac{17 \times 1000}{1500 \times 1000} \times 100 \times 0.825 = 0.9348\%$$

% Impedance drop, $V_z = \frac{V_s}{V_1} \times 100 = \frac{400}{6000} \times 100 = 0.825$

$$= 5.45\%$$

% reactance drop $V_x = \sqrt{(5.45)^2 - (0.9348)^2}$

$$= \sqrt{29.975 - 0.8738} = 5.4\%$$

Regulation of full load and 0.85 p.f. leading

$$= V_r \cos\phi - V_x \cos\phi$$

$$= 0.9348 \times 0.85 - 5.4 \times 0.527$$

$$= -2.05\%$$

$$\text{Total losses} = \text{Full load copper losses} + \text{Iron losses}$$

$$= 17 \times 0.825 + 15$$

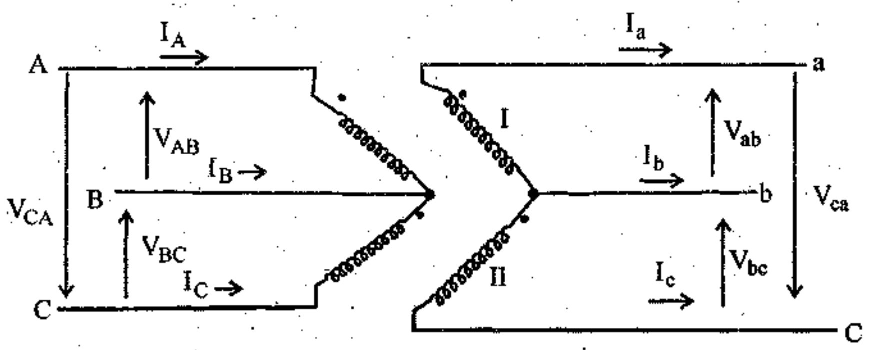
$$= 29 \text{ kW}$$

$$\text{Full load Output} = 1500 \times 0.85 = 1275 \text{ kW}$$

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{1275}{1275 + 29} \times 100 = 97.77\% \qquad \textbf{Ans.}$$

Q. 5. (a) Explain the V-V connections for 3 phase transformers. Prove that in V-V connections each transformer will supply 57.7% of load.

Ans. Open-Delta or V-V Connection : If one transformer of a $\Delta - \Delta$ connected system is damaged or accidently opened, the system will continue to supply $3-\phi$ power. If this defective transformers is disconnected and removed as shown in figure, the remaining two transformers continue to function as a 3-phase bank with rating reduced to about 58% of that of the original $\Delta - \Delta$ bank. This known as open delta or V-V connection.



$$V_{ab} + V_{bc} + V_{ca} = 0$$

$$V_{ca} = -V_{ab} - V_{bc}$$

Let,
$$V_{AB} = V_P \angle 0$$

$$V_{BC} = V_P \angle -120°$$

$$V_{CA} = V_P \angle +120°$$

Where,

V_P = Magnitude of the line voltage on the primary side.

For closed Δ load, V_A.

$$S_{\Delta-\Delta} = \sqrt{3} \times \text{line voltage} \times \text{line current}$$

$$S_{\Delta-\Delta} = \sqrt{3}V_{2B}.\left(\sqrt{3}\,I_{2B}\right) = 3V_{2B}.I_{2B}$$

For open delta, load VA.

$$S_{V-V} = \sqrt{3}\,V_{2B}.I_{2B}$$

$$\therefore \qquad \frac{S_{V-V}}{S_{\Delta-\Delta}} = \frac{\sqrt{3}V_{2B}.I_{2B}}{3V_{2B}.I_{2B}} = \frac{1}{\sqrt{3}} = 0.577$$

Thus, it is seen that the load that can be carried by the open-delta bank without exceeding the ratings of the transformers is 57.7% of the original load carried by the $\Delta-\Delta$ connection.

$$\therefore \qquad \boxed{S_{V-V} = 57.7\% S_{\Delta-\Delta}} \qquad \textbf{Ans.}$$

Q. 5. (b) Two transformers connected in open delta supply a 400 KVA balanced load operating at 0.866 p.f. (lag). The load voltage is 440V. What is the

(i) KVA supplied by each transformer

(ii) KW supplied by each transformer.

Ans. Given,

$$\text{Load KVA} = 400\text{ kVA}$$

$$\cos\phi = 0.866$$

$$\therefore \qquad \boxed{\phi = 30^\circ}$$

Voltage, $\qquad V = 440$ volt

(i) KVA supplied by each transformer will be equal to 400 KVA.

(ii) KW supplied by each transformer are P_1 and P_2.

$$\therefore \qquad P_1 = V_L I_L \cos(30+\phi)$$

$$= 400\times 1000\cos 60^\circ = 400\times 1000\times 0.5$$

$$\boxed{P_1 = 200\,\text{kW}}$$

$$P_2 = V_L I_L \cos(30-\phi)$$

$$= 400\times 1000\times \cos 0$$

$$\boxed{P_2 = 400\,\text{KW}} \qquad \textbf{Ans.}$$

Part-C

Q. 6. What do you mean by armature reaction in D.C generators? Explain the effects of armature reaction and how the effects of armature reaction can be neutralized.

Ans. Armature Reaction in D.C. Generators :

(i) Armature reaction is the effect of magnetic flux set up by armature current upon the distribution of flux under the main poles.

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

Effects of Armature Reaction :

(i) Magnetic flux density is increased over one half of the pole and decreased over the other half. But the total flux produced by each pole is slightly reduced. The effect of total flux reduction by armature reaction is known as demagnetizing effect.

(ii) The flux wave is distorted and there is shift in the position of the magnetic neutral axis (MNA) in the direction of rotation for generator and against the direction of the rotation for the motor.

(iii) Armature reaction establishes a flux in the neutral zero (or commutating zone). Armature reaction flux in the neutral zone will induce conductor voltage that aggravates the commutation problem.

Neutralizing the Effect of Armature Reaction :

(i) Compensating windings are the most effective means for eliminating the problems of armature reaction and flashover by balancing the armature mmf.

(ii) Compensating windings are placed in slots provided in pole faces parallel to the armature conductors.

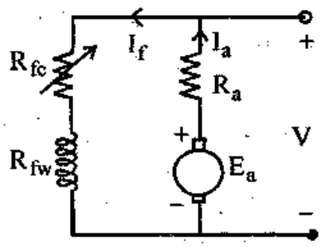
Q. 7. (a) What do you mean by Critical Resistance for shunt generator? How the critical resistance is found for shunt generators?

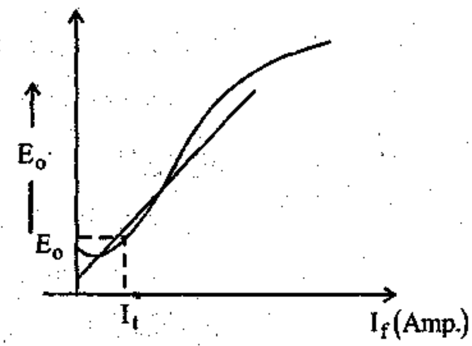
Ans. Critical Resistance for Shunt Generator : The value of resistance of shunt field winding beyond which the shunt generator fails to build up its voltage is known as "critical resistance" at a given speed, it is the maximum field resistance with which the shunt generator excite.

The shunt generator will build up voltage only if field circuit resistance is less than critical field resistance.

Determination of Critical Resistance for Shunt Generators :

Critical resistance can be found out by find open circuit characteristics of dc shunt generators.





Open Circuit Charateristics

Critical resistance,

$$\boxed{R_c = \frac{E_o}{I_f}}$$

Q. 7. (b) The magnetization curve of a d.c. shunt generator at 1500 rpm is

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

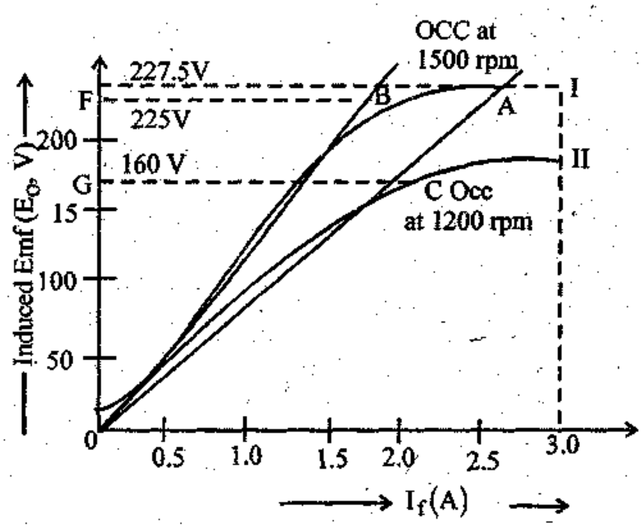
For this generator find :

(i) **No load e.m.f. for a total shunt field resistance of 1000 ohms.**

(ii) **Critical resistance at 1500 rpm**

(iii) **Magnetization curve at 1200 rpm and therefrom open circuit voltage for a field resistance of 100Ω.**

Ans. (i) Draw O.C.C. from the given data as shown in figure.



Draw 100Ω (shunt field resistance) line by joining origin (0, 0) and point (1A, 100V). The voltage corresponding to point A, the intersecting point of OCC drawn and shunt field resistance line is 227.5V.

Hence no-load emf, E_0 = 2275.5 volt.

(ii) Draw a line OB tangent to OCC at origin. The critical field resistance = slope of line OB.

$$= \frac{\text{Ordinate of B in volts}}{\text{Abscissa of B in amperes}} = \frac{225}{1.5} = 150\Omega$$

(iii) For 1200 rpm, the induced emfs for different field currents would be $\left(\frac{1200}{1500}\right)$ i.e., 0.8 times of those for 1500 rpm.

The magnetisation curve at 1200 rpm is given below :

I_f(A):	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.0
E_0(V):	4.8	48	96	138	162	176.8	184.8	189.6	192

The voltage corresponding to point C, the intersecting point of OCC drawn at 1200 rpm and 100Ω resistance line is 160V. So, no load induced e.m.f. is 160V.

Part-D

Q. 8. Derive and explain the Torque equation for D.C. motors. A 220 V dc shunt motors runs at 500 rpm when armature current is 52A. Calculate the speed if torque is doubled if $R_a = 0.25\Omega$.

Ans. Derivation of Torque Equation for D.C. Motors : The voltage equation of a d.c. motor is,

$$V = E + I_a R_a$$

Multiplying both sides by I_a we obtain,

$$VI_a = EI_a + I_a^2 R_a$$

VI_a = Electrical power input to the armature.

$I_a^2 R_a$ = Copper loss in armature

Input = Output + Losses

EI_a = Electrical equivalent of gross mechanical power developed by the armature.

Let, τ_{av} = Average electromagnetic torque developed by the armature in Newton metres.

Mechanical power developed by the armature,

$$P_w = w\tau_{av.} = 2\pi n\tau_{av.}$$

Therefore, $$P_m = EI_a = w\tau_{av.} = 2\pi n\tau_{av.}$$

But, $$E = \frac{nP\phi Z}{A}$$

Therefore, $$\frac{nP\phi Z}{A} I_a = 2\pi n\tau_{av.}$$

$$\boxed{\tau_{av.} = \frac{PZ}{2\pi A} \times \phi I_A}$$

This equation is known as torque equation of d.c. motor.

For given d.c. machine, P, Z, A are constant, therefore $\left(\frac{PZ}{2\pi A}\right)$ is also constant.

Let, $$\frac{PZ}{2\pi A} = K$$

$$\tau_{av.} = K\phi I_a$$

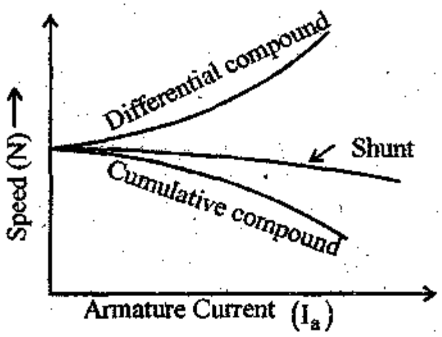
$$\boxed{\tau_{av.} \propto \phi I_a}$$

Hence, the torque developed by a d.c. motor is directly proportional to the flux per poles and armature current.

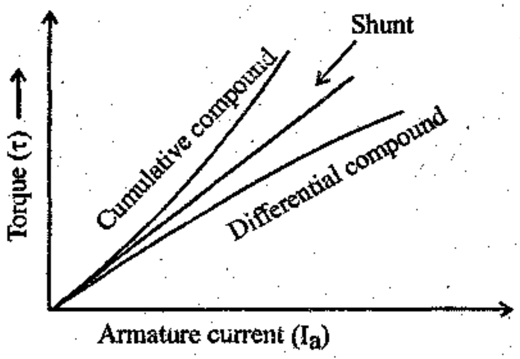
Q. 9. (a) Explain and Draw the characteristics curve of D.C. commutative compound motor and differential compound motor.

(i) T and Ia **(ii) N and Ia**

Ans. Characteristic of Compound Motor :



Speed-Armature Current
(N and I_a) Characteristics



Torque/Armature Current
(τ and I_a) Characteristic

A compound motor has both shunt and series field windings, so its characteristics are intermediate between the shunt and series motors. The cumulative compound motor is generally used in practice. The speed-armature current and torque-armature current characteristics are shown in fig.

Given, $V = 220$ volt

$N_1 = 500 \text{ rpm} \quad R_a = 0.25\Omega$

$I_{a1} - 52A$

$E_1 = V - I_{a_1} R_a$

$= 220 - 52 \times 0.25$

$\boxed{E_1 = 207 \text{ volts}}$

$$\frac{\tau_2}{\tau_1} = \frac{I_{a_2}}{I_{a_1}}$$

$$\frac{2\tau_1}{\tau_1} = \frac{I_{a2}}{(52)} \quad \Rightarrow \quad I_{a_2} = 2 \times (52)$$

$I_{a_2} = 104 \text{ Amp.}$

$E_2 = V - I_{a_2} R_a$

$= 220 - 104 \times 0.25$

$E_2 = 194 \text{ volts}$

$$\frac{N_2}{N_1} = \frac{E_2}{E_1}$$

$$N_2 = \frac{E_2}{E_1} \times N_1 = \frac{194.600}{207} \times 500 = 488.00 \text{rpm}$$

$$\boxed{N_2 = 468 \text{rpm}}$$

When torque is doubled.

Q. 9. (b) Give a comparison between series and shunt D.C. motor depending upon characteristics and applications.

Ans.

(i) A shunt motor have field windings connected in parallel while a series motor has field windings connected in series with the armature.

(ii) Starting torque is high in case of series motors, but it has few turns while shunt motors has almost constant torque motor.

(iii) Series motors are variable speed motors while shunt motors are constant speed motors.

(iv) Series motors are applicable where high starting torques required such as lift elevators, trains etc.

(v) Shunt motors are used where constant speeds are required.

(vi) Large variation of speeds can be obtained in shunt motors as torque varies while in series motor speed remains almost constant as torque increases.