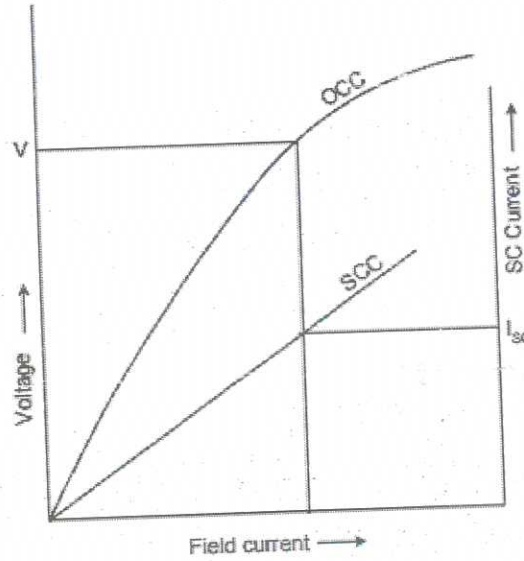


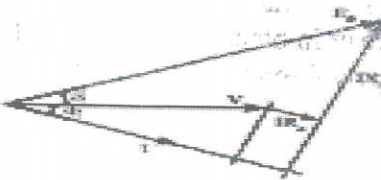
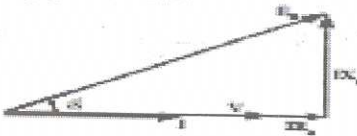
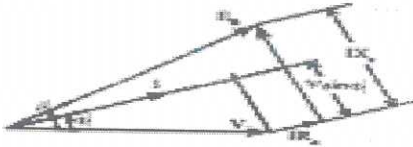
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VERSION 1
D-9

SCHEME OF VALUATION				
(Scoring indicators)				
Revision:2015			Course code:6033	
Course Title: SYNCHRONOUS MACHINES AND F.H.P MOTORS				
Qst. No	Scoring Indicator	split up score	sub Total	Total
PART A				
1	The Coil Span Factor or Pitch Factor K_C is defined as the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil.	1 1	1 1	2
2	<ul style="list-style-type: none"> • Load supply can be increased. • During light loads, more than one alternator can be shut down while the other will operate in nearly full load. • High efficiency. • The operating cost is reduced. 	2x1	2	2
3	Constant speed applications Synchronous condenser.	2x1		2
4	The universal motor is so named because it is a type of electric motor that can operate on AC or DC power	2x1	2	2
5	Metal Cutting & Metal Forming Machines Robotics Conveyor Belts	2x1		2
PART B				
1	<p>In salient pole type of rotor consist of large number of projected poles i.e. salient poles mounted on a magnetic wheel. Construction of a salient pole rotor is as shown in the figure at left. The projected poles are made up from laminations of steel. The rotor winding is provided on these poles and it is supported by pole shoes.</p> <ul style="list-style-type: none"> • Salient pole rotors have large diameter and shorter axial length. • They are generally used in lower speed electrical machines, say 100 RPM to 1500 RPM. • As the rotor speed is lower, more number of poles is required to attain the required frequency. ($N =$ 			6

	<p>120f/P). Typically number of salient poles is between 4 to 60.</p> <ul style="list-style-type: none"> • Flux distribution is relatively poor than non-salient pole rotor, hence the generated emf waveform is not as good as cylindrical rotor. • Salient pole rotors generally need damper windings to prevent rotor oscillations during operation. • Salient pole synchronous generators are mostly used in hydro power plants. <p>Non-salient pole or Cylindrical rotors are cylindrical in shape having parallel slots on it to place rotor windings. It is made up of solid steel. Sometimes, they are also called as drum rotor.</p> <ul style="list-style-type: none"> • They are smaller in diameter but having longer axial length. • Cylindrical rotors are used in high speed electrical machines, usually 1500 RPM to 3000 RPM. • Windage loss as well as noise is less as compared to salient pole rotors. • Their construction is robust as compared to salient pole rotors. • Number of poles is usually 2 or 4. • Damper windings are not needed in non-salient pole rotors. • Flux distribution is sinusoidal and hence gives better emf. • Non-salient pole rotors are used in nuclear, gas and thermal power plants. 			
2	<ol style="list-style-type: none"> 1. It is easier to insulate stationary winding for high voltages for which the alternators are usually designed. It is because they are not subjected to centrifugal forces and also extra space is available due to the stationary arrangement of the armature. 2. The stationary 3-phase armature can be directly connected to load without going through large, unreliable slip rings and brushes. 3. Only two slip rings are required for d.c. supply to the field winding on the rotor. Since the exciting current is small, the slip rings and brush gear required are of light construction. 	4x1.5	6	6

	<p>4. Due to simple and robust construction of the rotor, higher speed of rotating d.c. field is possible. This increases the output obtainable from a machine of given dimensions.</p>			
<p>3</p>	<p>EMF method (Synchronous impedance method)</p> <p>Tests: Conduct tests to find OCC (upto 125% of rated voltage) SCC (for rated current) Armature resistance (per phase)</p>  <p>V = rated phase voltage I_{sc} = short circuit current corresponding to the field current producing the rated voltage</p> <p>$\% \text{Regulation} = \frac{E_o - V}{V} \times 100$</p>	<p>3</p> <p>3</p>	<p>3</p>	<p>6</p>

	<p>Synchronous impedance per phase,</p> $Z_s = \frac{V}{I_a}$ $X_s = \sqrt{Z_s^2 - R_s^2}$ <p>For any load current I and phase angle ϕ, find E_b as the vector sum of V, IR_s and IX_s.</p> <p>For lagging power factor</p>  $E_b = \sqrt{(V \cos\phi + IR_s)^2 + (V \sin\phi + IX_s)^2}$ <p>For unity power factor</p>  $E_b = \sqrt{(V + IR_s)^2 + (IX_s)^2}$ <p>For leading power factor</p>  $E_b = \sqrt{(V \cos\phi + IR_s)^2 + (V \sin\phi - IX_s)^2}$			
4	<ol style="list-style-type: none"> 1.direct loading method 2.emf method 3.mmf method 4.zpf method. 	4+2	6	6
5	<ol style="list-style-type: none"> 1.Pony Motors 2.starting by dc source 3.damper winding 	3+3	6	6
6	<p>Synchronous Motor Working Principle: When a 3 phase electric conductors are placed in a certain geometrical positions (In certain angle from one another) then an electrical field is generated. Now the rotating magnetic field rotates at a certain speed, that speed is called synchronous speed. Now if an electromagnet is present in this rotating magnetic field,</p>			

the electromagnet is magnetically locked with this rotating magnetic field and rotates with same speed of rotating field.

Synchronous motors is called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there or in other words it's in synchronism with the supply frequency.

$$N_s = \frac{120f}{p}$$

Synchronous speed is given by

Where, f = supply frequency and p = no. of poles

7 Repulsion motors are based on the principle of repulsion between two magnetic fields. Consider a 2-pole salient pole motor with a vertical magnetic axis. The armature is connected to a commutator and brushes. The brushes are short circuited using a low-resistance jumper. When alternating current is supplied to the field (stator) winding, it induces an electromotive force(emf) in the armature. The direction of alternating current is such that it creates a north pole at the top and a south pole at the bottom. The direction of induced emf is given by Lenz's law, according to which the direction of induced emf opposes the cause producing it. The induced emf induces current in the armature conductors and the direction of the induced current depends on the position of the brushes.

PART C

III (a)

Let,
 P= No. of poles
 Z= No. of Conductors or Coil sides in series/phase i.e.
 Z= 2T
 f = frequency of induced e.m.f in Hz
 ϕ = Flux per pole (Weber)
 N = rotor speed (RPM)
 K_d = Distribution factor
 K_c or $K_p = \cos \alpha/2$
 If induced e.m.f is assumed sinusoidal then,
 K_f = Form factor = 1.11
 In one revolution of the rotor i.e. in $60/N$ seconds, each conductor is cut by a flux of $P\phi$ Webers.
 $d\phi = \phi P$ and also $dt = \text{seconds} \frac{60}{N}$

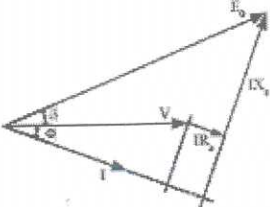
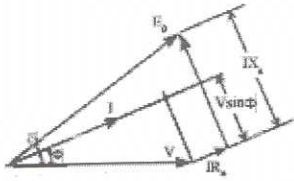
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4

8

4

4

IV(a)	<p>For lagging power factor</p>  $E_0 = \sqrt{(V \cos \Phi + IR_s)^2 + (V \sin \Phi + IX_s)^2}$ <p>For leading power factor</p>  $E_0 = \sqrt{(V \cos \Phi + IR_s)^2 + (V \sin \Phi - IX_s)^2}$	4	4	8
IV(b)	<p>Given Data :</p> <p>No. of slots / pole / phase, $m = 4$ coil span = 10 slots K_d & $K_c = ?$</p> <p>No. of slots / pole, $n = m \times \text{number of phase}$ $= 4 \times 3 = 12$</p> <p>Angular displacement, $\beta = \frac{180^\circ}{n} = \frac{180^\circ}{12} = 15^\circ \text{ elec.}$</p> $K_d = \frac{\sin \frac{m \beta}{2}}{m \sin \frac{\beta}{2}} = \frac{\sin \frac{4 \times 15}{2}}{4 \times \sin \frac{15}{2}} = \frac{\sin 30^\circ}{4 \sin 7.5^\circ} = 0.9576 \text{ Ans.}$ <p>Coil span = $\frac{180^\circ \times \text{coil span in terms of slots}}{n}$</p> $= 180 \times \frac{10}{12} = 150^\circ$ $\alpha = 180 - 150 = 30^\circ$ $\therefore K_c = \cos \frac{\alpha}{2} = \cos \frac{30^\circ}{2} = \cos 15^\circ$ $= 0.966 \text{ Ans.}$	4	4	7
		3	3	

V(a)	<p>Alternator</p> <p>$R_a = 0.2 \Omega$</p> <p>$I_f = 40 \text{ A}$</p> <p>$I_{sc} = 200 \text{ A on S.C.}$</p> <p>$E_{co} = 1040 \text{ V on O.C.}$</p> <p>p.f. = 0.8 lead</p> <p>$Z_s = \frac{E_{oc} / \text{ph}}{I_{sc}} = \frac{1040 / \sqrt{3}}{200} = 3 \Omega$</p> <p>$X_s = \sqrt{Z_s^2 - R_a^2} = \sqrt{3^2 - 0.2^2} = 2.99 \Omega$</p> <p>Voltage / phase = $\frac{3000}{\sqrt{3}} = 1732 \text{ V}$</p> <p>Full-load current = $\frac{100 \times 10^3}{\sqrt{3} \times 3000} = 19.245 \text{ A}$</p> <p>$\cos \phi = 0.8 ; \sin \phi = 0.6$</p> <p>$E_o = \sqrt{(V \cos \phi + IR_a)^2 + (V \sin \phi - IX_s)^2}$</p> <p>$= \sqrt{(1732 \times 0.8 + 19.245 \times 0.2)^2 + (1732 \times 0.6 - 19.245 \times 2.99)^2}$</p> <p>$= 1701.2 \text{ V}$</p> <p>$\therefore \text{Regulation} = \frac{E_o - V}{V} \times 100 = \frac{1701.2 - 1732}{1732} \times 100$</p> <p>$= -1.78\% \text{ Ans.}$</p>	4	4	8
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V(b)	<p>MMF method (Ampere turns method)</p> <p>Tests: Conduct tests to find OCC (upto 125% of rated voltage) SCC (for rated current)</p>	3	3	7
		4	4	
	<p>Steps:</p> <ol style="list-style-type: none"> 1. By suitable tests plot OCC and SCC 2. From the OCC find the field current I_{f1} to produce rated voltage, V. 3. From SCC find the magnitude of field current I_{f2} to produce the required armature current. 4. Draw I_{f2} at angle $(90+\Phi)$ from I_{f1}, where Φ is the phase angle of current from voltage. If current is leading, take the angle of I_{f2} as $(90-\Phi)$. 5. Find the resultant field current, I_f and mark its magnitude on the field current axis. 6. From OCC, find the voltage corresponding to I_f which will be E_0. 			

VI(a)	<p>Given Data : 2000 V 1-phase Alternator</p> <p>$I = 100 \text{ A}$</p> <p>p.f. = 0.8 lead</p> <p>$I_{sc} = 100 \text{ A on S.C.}$</p> <p>$I_f = 2.5 \text{ A}$</p> <p>$E_{oc} = 500 \text{ V on O.C.}$</p> <p>$R_a = 0.8 \Omega$</p> $Z_s = \frac{E_{oc}}{I_{sc}} = \frac{500}{100} = 5 \Omega$ $X_s = \sqrt{Z_s^2 - R_a^2} = \sqrt{5^2 - 0.8^2}$ $= 4.936 \Omega$ $E_g = \sqrt{(2000 \times 0.8 - 100 \times 0.8)^2 + (2000 \times 0.6 - 100 \times 4.936)^2}$ $= 1822.5 \text{ V}$ $\therefore \text{Regulation} = \frac{E_g - V}{V} = \frac{1822.5 - 2000}{2000}$ $= -0.089$ $= -8.9\% \text{ Ans.}$			
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Steps:

1. By suitable tests plot OCC and SCC
2. Draw tangent to OCC (air gap line)
3. Conduct ZPF test at full load for rated voltage and fix the point B.
4. Draw the line BH with length equal to field current required to produce full load current at short circuit.
5. Draw HD parallel to the air gap line so as to touch the OCC.
6. Draw DE parallel to voltage axis. Now, DE represents voltage drop IX_L and BE represents the field current required to overcome the effect of armature reaction.

Triangle BDE is called Potier triangle and X_L is the Potier reactance

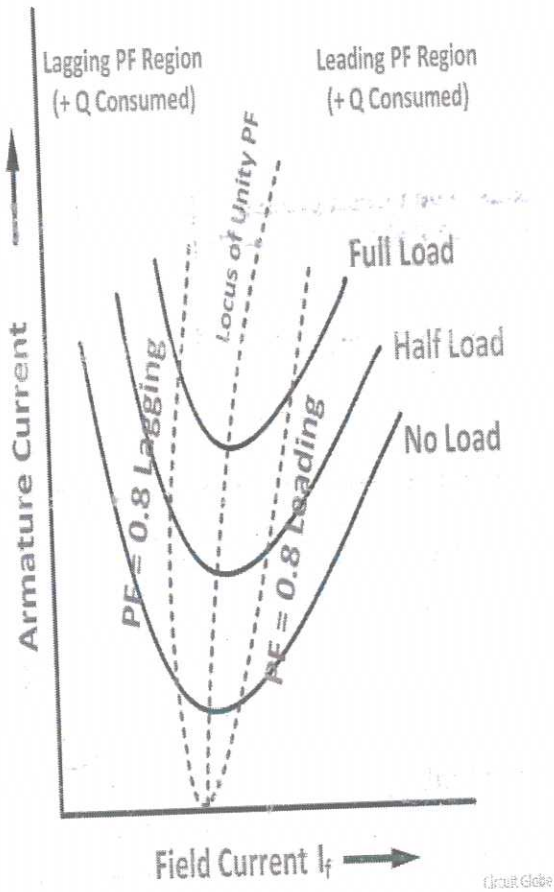
7. Find E from V , IX_L and Φ . Consider R_a also if required. The expression to use is

$$E = \sqrt{(V \cos \Phi + IR_a)^2 + (V \sin \Phi + IX_L)^2}$$

8. Find field current corresponding to E.
9. Draw FG with magnitude equal to BE at angle $(90+\Phi)$ from field current axis, where Φ is the phase angle of current from voltage vector E (internal phase angle).
10. The resultant field current is given by OG. Mark this length on field current axis.
11. From OCC find the corresponding E_b .

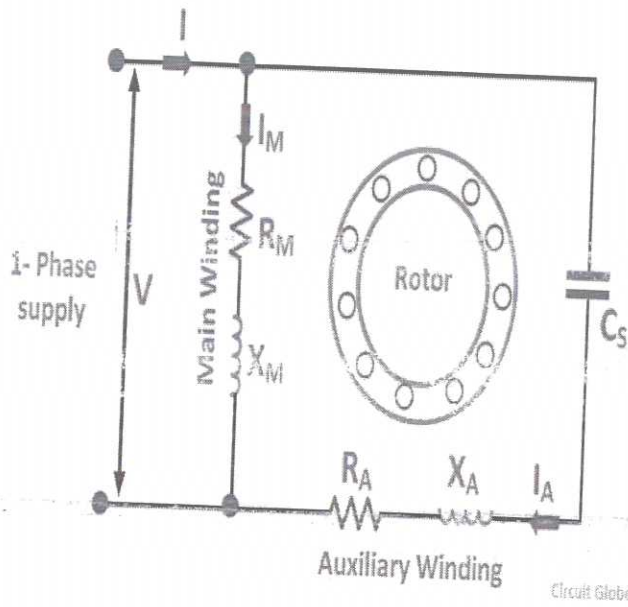
<p>VII(a)</p>		<p>8</p>	<p>8</p>	<p>8</p>
<p>VII(b)</p>		<p>7</p>	<p>7</p>	<p>7</p>
<p>VIII(a)</p>	<p>Single phase induction motor has <i>distributed stator winding</i> and a <i>squirrel-cage rotor</i>. When fed from a single-phase supply, its stator winding produces a flux (or field) which is only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving (or rotating) flux as in the case of a two or a three phase stator winding fed from a 2 of 3 phase supply. Now, an alternating or pulsating</p>			<p>8</p>

	flux acting on a stationary squirrel-cage rotor cannot produce rotation (only a revolving flux can produce rotation). That is why a single phase motor is not self-starting			
VIII(b)	<p>V Curve of a Synchronous Motor</p> <p>V curve is a plot of the stator current versus field current for different constant loads. The Graph plotted between the armature current I_a and field current I_f at no load the curve is obtained known as V Curve. Since the shape of these curves is similar to the letter "V", thus they are called V curve of synchronous motor The power factor of the synchronous motor can be controlled by varying the field current I_f. As we know that the armature current I_a changes with the change in the field current I_f. Let us assume that the motor is running at NO load. If the field current is increased from this small value, the armature current I_a decreases until the armature current becomes minimum. At this minimum point, the motor is operating at unity power factor. The motor operates at lagging power factor until it reaches up to this point of operation.</p> <p>If now, the field current is increased further, the armature current increases and the motor start operating as a leading power factor. The graph drawn between armature current and field current is known as V curve. If this procedure is repeated for various increased loads, a family of curves is obtained.</p> <p>The V curves of a synchronous motor are shown below.</p>	4	4	7



Unit: Gole

IX(a)



3 3 8

The Permanent Split Capacitor motor also has a cage rotor and the two windings named as main and auxiliary windings similar to that of a Capacitor Start and Capacitor Start Capacitor Run Motor. It has only one capacitor connected in series with the starting winding. The capacitor C is permanently connected in the circuit both at the starting and the running,

5 5

IX(b)

the **universal motor** is so named because it is a type of electric motor that can operate on AC or DC power. It is a **commutated series-wound motor** where the stator's field coils are connected in series with the rotor windings through a commutator. It is often referred to as an AC series motor. The universal motor is very similar to a DC series motor in construction, but is modified slightly to allow the motor to operate properly on AC power. This type of electric motor can operate well on AC because the current in both the field coils and the armature (and the resultant magnetic fields) will alternate (reverse polarity) synchronously with the supply. Hence the resulting mechanical force will occur in a consistent direction of rotation, independent of the direction of applied voltage, but determined by the commutator and polarity of the field coils

7

X(a)	<p>Hysteresis motor is defined as a <u>synchronous motor</u> that is having cylindrical rotor and works on <u>hysteresis losses</u> induced in the rotor of hardened steel with high retentivity. It is a single phase motor and its rotor is made of <u>ferromagnetic material</u> with non magnetic support over the shaft.</p> <p>Figure:</p>	4 3	4 3	7
X(b)	<p>The shaded-pole motor is the original type of <u>AC single-phase induction motor</u>. A shaded-pole motor is a small <u>squirrel-cage motor</u> in which the auxiliary <u>winding</u> is composed of a copper ring or bar surrounding a portion of each pole.^[1] This auxiliary single-turn winding is called a shading coil. Currents induced in this coil by the magnetic field create a second electrical phase by delaying the <u>phase of magnetic flux</u> change for that pole (a <i>shaded pole</i>) enough to provide a 2-phase <u>rotating magnetic field</u>. The direction of rotation is from the unshaded side to the shaded (ring) side of the pole.^[1] Since the phase angle between the shaded and unshaded sections is small, shaded pole motors produce only a small starting <u>torque</u> relative to torque at full speed. Shaded-pole motors of the asymmetrical type shown are only reversible via disassembly and flipping over the stator, though some similar-looking motors have small, switch-shortable auxiliary windings of thin wire instead of thick copper bars and can reverse electrically. Another method of electrical reversing involves four coils (two pairs of identical coils).</p> <p>Figure:</p>	4 3	4 3	7

