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18EE44

Fourth Semester B.E. Degree Examination, July/August 2022

Electric Motors

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. What is back emf? Explain its significance. **(06 Marks)**

b. Derive an expression for the torque of a DC motor. **(06 Marks)**

c. A 250 V DC shunt motor runs at 1000 rpm on no load and takes 5A. The armature and shunt field resistances are 0.2 Ω and 250 Ω respectively. Calculate the speed when loaded and taking a current of 50 A. Due to armature reaction, the field weakened by 3%. **(08 Marks)**

OR

2 a. Explain the different methods of controlling speed of a DC shunt motor. **(06 Marks)**

b. Explain the necessity of a starter for a DC motor and explain the operation of a star delta starter with a neat sketch. **(08 Marks)**

c. Draw and explain the characteristics of DC series motor. **(06 Marks)**

Module-2

3 a. Explain the Swinburne's test to determine no load losses of a DC machine. What are the limitations of this test? **(08 Marks)**

b. When running on no load, a 400 V DC shunt motor takes 5 A, $R_a = 0.5\,\Omega$ and $R_f = 200\ \Omega$. Find the output of the motor and efficiency when running on full load and taking current of 50 A. **(08 Marks)**

c. Briefly explain the various losses occurring in a DC machine. **(04 Marks)**

OR

4 a. Derive Torque equation for a 3ϕ induction motor and derive condition for maximum torque. **(08 Marks)**

b. Discuss the complete Torque-slip characteristics of a 3ϕ induction motor including motoring generating and braking regions. **(08 Marks)**

c. A 4 pole, 3ϕ induction motor is supplied from 50 Hz supply. Determine its synchronous speed. On full load, its speed is observed to be 1410 rpm. Calculate its full load slip. **(04 Marks)**

Module-3

5 a. Starting from the fundamentals develop the equivalent circuit of a polyphase induction motor and explain how mechanical power developed is taken care of in the equivalent circuit. **(10 Marks)**

b. Describe the constructional features of a double cage and deep bar rotors of 3ϕ induction motors and explain its operation. **(10 Marks)**

OR

6 a. A 415 V, 29.84 kW, 50 Hz Delta connected motor gave the following test data :

No load test	415 V	21 A	1250 W
Blocked Rotor test	100 V	45 A	2730 W

Construct the circle diagram and determine
(i) Line current and power factor for rated output.
(ii) The maximum Torque. Assume stator and rotor copper losses are equal at stand still. **(14 Marks)**

b. Explain the phenomenon of cogging and crawling in a 3ϕ Induction motor. **(06 Marks)**

Module-4

7 a. List the different methods of starting a squirrel cage induction motor and explain star-delta starter of 3ϕ induction motor with a suitable circuit diagram. **(10 Marks)**

b. Enumerate the speed control methods of 3ϕ induction motor and explain supply frequency control method. **(10 Marks)**

OR

8 a. Explain the double field revolving theory as applied to a single phase induction motor and prove that it cannot produce any starting torque. **(10 Marks)**

b. With a schematic connection diagram, explain the construction, working and applications of capacitor start 1ϕ induction motor. **(10 Marks)**

Module-5

9 a. List the methods of starting synchronous motor and explain slip ring-induction motor with a neat sketch. **(10 Marks)**

b. A factory has a total load of 1800 kW at a power factor of 0.6 lagging. If it is desired to improve the factory power factor to 0.95 lagging with the installation of synchronous condenser then calculate, (i) The KVA rating of synchronous condenser (ii) Total KVA of the factory. **(10 Marks)**

OR

10 a. Explain the operation of synchronous motor at constant load variable excitation and V and inverted V curves. **(10 Marks)**

b. Explain the working, characteristics and applications of universal motor. **(10 Marks)**

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(1/7)

Scheme & Solutions

Signature of Scrutinizer

Subject Title : Electric motors **Subject Code :** 18EE44

Question Number	Solution	Marks Allocated

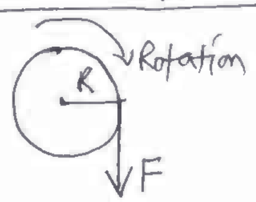
1 (a) Back emf :- When the armature of a DC motor rotates under the influence of the driving Torque, the armature conductors moves through the magnetic field. The induced emf acts in opposite direction to the applied voltage V, is known as back emf ; $E_b = \frac{P\phi NZ}{60A}$ → (4M) — **6M**

Significance of back emf :-

1> It makes the DC motor a self regulating machine i.e. it makes the motor to draw as much armature current as just as sufficient to develop the required by the load.

2> $I_a = \frac{V-E_b}{R_a}$; under no load $V \simeq E_b$ → (2M)

(b) Torque equation of a DC motor :-



Twisting force about an axis is called Torque.

$\omega = \frac{2\pi N}{60}$ rad/sec [ω → angular speed]

W = F x distance travelled in 1 revolution

$W = F \times 2\pi R$

$P = \frac{\text{Workdone}}{\text{Time}} = \frac{F \times 2\pi R}{60/N}$ → (2M)

Question Number	Solution	Marks Allocated
	$P = (F \times R)\ \frac{2\pi N}{60}$ $P = T \times \omega$ watts ; T = Torque in N-m $E_b I_a = T_a \times \frac{2\pi N}{60}$ [but $E_b = \frac{P\phi NZ}{60A}$] → (2M) $\frac{P\phi NZ}{60A} I_a = T_a \times \frac{2\pi N}{60}$ $\frac{1}{2\pi} \phi I_a \frac{PZ}{A} = T_a$ $T_a = 0.159\ \phi I_a \frac{PZ}{A}$ Nm → (2M)	(6M)
1(c)	Given; $V = 250V$, $N_0 = 1000$ rpm, $I_0 = 5A$ $R_a = 0.2\Omega$, $R_{sh} = 250\Omega$ $I_{sh} = \frac{V}{R_{sh}} = \frac{250}{250} = 1A$ → (1M) $I_{a0} = I_0 - I_{sh} = 5 - 1 = 4A$ → (1M) $E_{b0} = V - I_{a0}R_a = 250 - (4 \times 0.2) = 249.2V$ → (1M) $I_L = 50A$ on Load $I_{sh} = \frac{V}{R_{sh}} = 1A$ $I_a = I_L - I_{sh} = 50 - 1 = 49A$ → (1M) $E_{b1} = V - I_a R_a = 250 - (49 \times 0.2) = 240.2$ Volts → (1M) $N \propto \frac{E_b}{\phi}$ ie. $\frac{N_0}{N_1} = \frac{E_{b0}}{E_{b1}} \times \frac{\phi_1}{\phi_0}$ $\phi_1 = \phi_0 - 0.03\phi_0 = 0.97\phi_0$ [field weakened by 3%] → (1M) $\frac{1000}{N_1} = \frac{249.2}{240.2} \times 0.97$ $N_1 = 994$ rpm → (2M)	(8M)

Subject Title : Electric motor   Subject Code : 18EE44   3/7

Question Number	Solution	Marks Allocated

2 (a) Methods of Speed Control :-

1. Flux control method
2. Armature Voltage control method
3. Applied Voltage Control

brief explanation 2×3 → (6M)

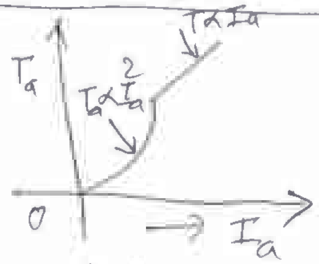
(b) Necessity of starter :- To reduce the inrush drawn by the motor during starting → (2M)

Y-Δ starter —— diagram → (4M)

explanation → (2M)   (8M)

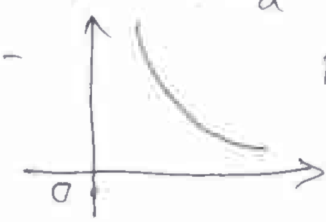
(c) Characteristics of DC series motor

i) T_a v/s I_a :-



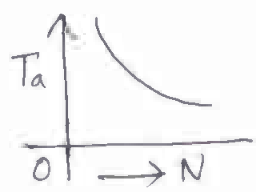
$T_a \propto \phi I_a \propto I_a^2$ → 2M

ii) N v/s I_a :-



$N \propto \frac{E_b}{\phi} \propto \frac{V - I_aR_a - I_aR_{se}}{I_a}$ → 2M

iii) N v/s T_a :-



$T \propto I_a^2$

$N \propto \frac{1}{I_a}$ → 2M

$N \propto \frac{1}{\sqrt{T}}$

(6M)

Module-2

3 (a) Swinburne's Test :- circuit diagram —— 4M

explanation —— 2M

limitations —— 2M   (8M)

(b) $V = 400V$

$I_{sh} = \frac{V}{R_{sh}} = \frac{400}{200} = 2$ Amps

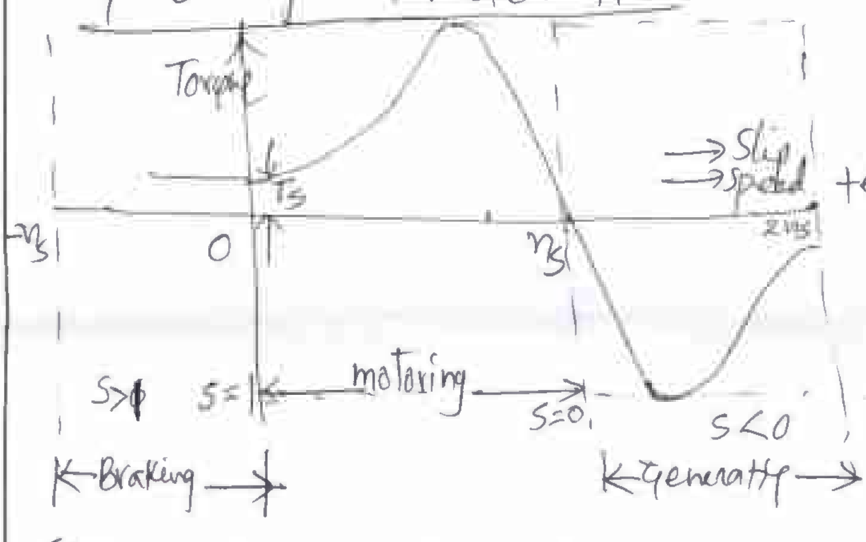
$I_0 = 5A$ [no Load current]

No Load input $= VI_0 = 400 \times 5 = 2000W$

$I_{a0} = I_{L0} - I_{sh} = 5 - 2 = 3$ Amps → (1M)

$I_{a0}^2 R_a = (3)^2 \times 0.5 = 4.5W$ [no load armature cu loss] → (1M)

Subject Title : Subject Code :

Question Number	Solution	Marks Allocated
	Constant loss = P_C = No Load input − $I_a^2 R_a$ = 2000 − 4.5 = 1995.5 watts → 1M	8M
	On Full Load :- $I_L = 50A$; I/p = $V I_L$ = 400×50 I/p = 20,000 watts $I_a = I_L - I_{sh} = 50 - 2 = 48A$ → 1M	
	armature Copper loss = $I_a^2 R_a = (48)^2 \times 0.5 = 1152\ W$ → 1M Total losses = Constant loss + armature Copper loss = 1995.5 + 1152 = 3147.5 W → 1M	
	o/p = I/p − losses = 20,000 − 3147.5 = 16852 W $\%\eta = \frac{O/P}{I/P} \times 100 = \frac{16852.5}{20,000} \times 100 = 84.26\%$ → 2M	
3(c)	explanation of constant loss → 2M variable loss → 2M	4M
4(a)	Derive Torque equation — 6M Condition for maximum Torque — 2M	8M
(b)	Torque-slip characteristics  explanation 4+4 → 8M	8M
(c)	Given: P = 4; f = 50 Hz, N = 1410 rpm N_s = ? S_f → Full load slip = ? $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ rpm → 2M $S_f = \frac{N_s - N}{N_s} = \frac{1500 - 1410}{1500} = 0.06$ → 2M $S_f = 6\%$	4M

Subject Title : Electric motors **Subject Code :** 18EE44

Question Number	Solution	Marks Allocated
5(a)	Developing equivalent circuit ⟶ 7M Explanation of how mechanical power developed is taken care of in eqt ckt ⟶ 3M	10M
(b)	Double Cage Rotor ⟶ Fig + explanation ⟶ 5M Deep bar rotor ⟶ Fig + explanation ⟶ 5M	10M

6(a)

$\cos\phi_0 = \frac{W_0}{\sqrt{3} V_0 I_0} = \frac{1250}{\sqrt{3} \times 415 \times 21} = 0.082$ $\boxed{\phi_0 = 85.25^\circ}$ → 1M

$\cos\phi_{sc} = \frac{W_{sc}}{\sqrt{3} V_{sc} I_{sc}} = \frac{2730}{\sqrt{3} \times 100 \times 45} = 0.3502$ $\boxed{\phi_s = 69.49^\circ}$ → 1M

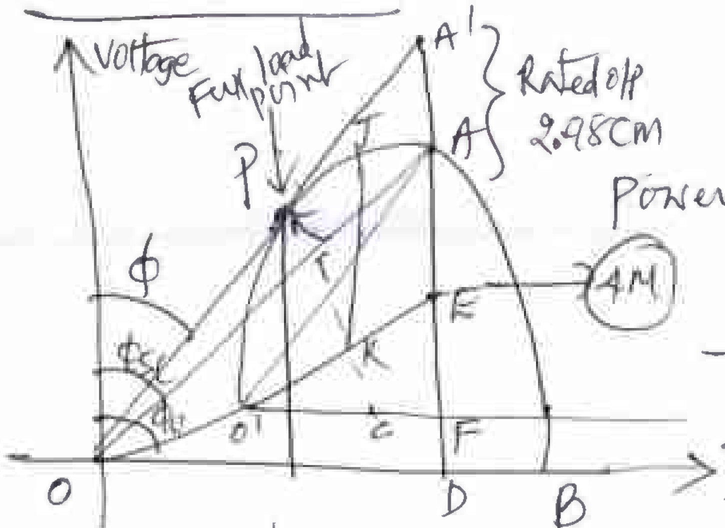
$I_{SN} = I_{SC}\left(\frac{V_L}{V_{SC}}\right) = \frac{45}{\sqrt{3}}\left(\frac{415}{100}\right) = \boxed{107.82\ A}$ → 1M

$I_{ph} = \frac{I_L}{\sqrt{3}}$; $W_{SN} = W_{SC}\left(\frac{I_{SN}}{I_{SC}}\right)^2 = 2730 \times \left(\frac{107.82}{45/\sqrt{3}}\right)^2$

$\boxed{W_{SN} = 47{,}017}$ Watts → 1M

Current scale :- 1 cm = 8A $I_0 = \frac{21}{\sqrt{3}} = \boxed{1.515\ cm}$

$I_{SN} = \frac{107.8}{8} = \boxed{13.4\ cm}$ → 1M



→ 4M

Power scale = $\frac{W_{SN}}{L_{AD}} = \frac{47017}{4.7}$

$\boxed{P_{scale} = 9997\ W/cm}$ → 1M

$AA' = \frac{29.8k}{9997} = 2.985\ cm$ → 1M

i> Line current $L_{OP} \times$ current scale $= 4.29 \times 8 \times \sqrt{3}$ $= 59.4\ A$

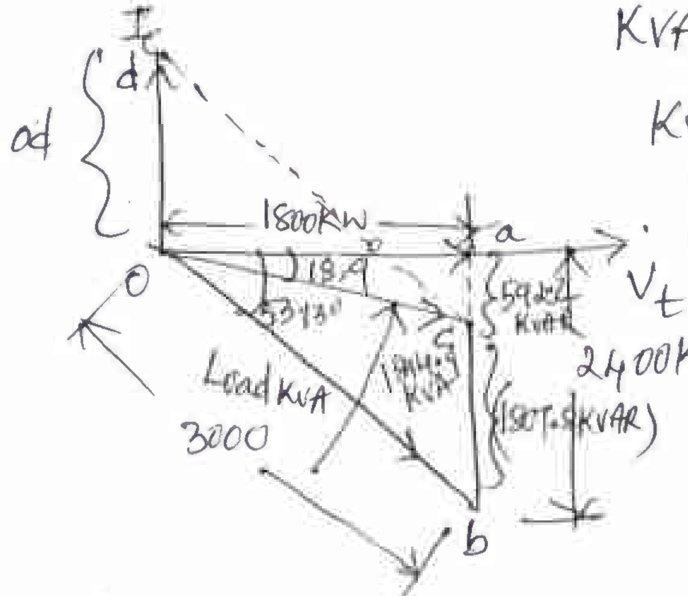
ii> $\cos\phi = \cos 35^\circ = 0.819$ lagging

iii> $L_{JK} \times$ scale $= 5.26 \times 9997 = 52{,}595$ Syn Watt → 3M

14M

6(b) Phenomenon of Cogging ⟶ 3M Crawling ⟶ 3M ⟶ 6M

SN	Question	Marks
	Module-4	
7a	Starting of 3ϕ IM:- 1> stator Resistance. 2> Autotransformer. 3> Y-Δ. 4> Rotor resistance 5> DOL. 6> Electronic method: → (2M) explanation of Y-Δ Starter Fig → 4M explanation - 4M] 8M	10M
b	Speed Control methods of 3ϕ IM:- 1> Supply frequency Control. 2> Supply voltage Control. 3> Controlling no of poles. 4> adding Resistance in Stator circuit. 5> adding Resistance in Rotor circuit. 6> Cascade control → (3M) Speed Control of 3ϕ IM by supply frequency Control method:- Fig + explanation (4+3) → 7M	10M
8a	Double field revolving Theory Fig + explanation → 7M expl of why ~~not self~~ starting Torque is zero → 3M	10M
b	Capacitor Start 1ϕ IM Figure → 5M explanation → 5M	10M
	Module-5	
9a	Methods of starting synchronous Motor 1. Using pony motor. 2> Damper winding 3> Slip ring induction motor. 4> Small DC machine coupled to it → (2M) Explanation of ~~starting synchronous motor by~~ slip ring Induction motor method Figure → 4M explanation → 4M] 8M	10M

S.No	Question	Marks
9(b)		

$KVA = ob = \frac{KW}{\cos\phi_1}$

$KVA = \frac{1800}{0.6} = 3000$

$\angle aob = \cos^{-1}(0.6)$

$\angle aob = 53.13^\circ$

$KVAR = ab$

$= ob \sin(53.13^\circ)$

$= 3000 \times 0.8$

$= 2400 KVAR$

Combined $KVAR = ac = oa \tan(18.95^\circ)$

$= 1800 \times 0.329$

$= 592.2 KVAR$

(a) Synchronous condenser rating

$od = bc = (ab - ac)$

$od = 2400 - 592.2 = 1807.8 KVA$ → 5M

(b) Total resultant KVA of the factory.

$oc = \sqrt{oa^2 + ac^2} = \sqrt{(1800)^2 + (592.2)^2}$

$oc = 1894.9 KVA$ → 5M

(10M)

10(a) Synchronous motor:- Constant load variable excitation

Fig + explanation → 6M

V & Inverted V curve → 4M

(10M)

(b) universal motor

Working — 4M

Characteristics — 4M

applications — 2M

(10M)