Student Name: [illegible] **Student ID#:** 0132806 **Serial #:** 28

Grade: 63 /90 21 /30

Question # 1 (10 marks) **ABET outcome "*h*" Assessment**

1.1 Name four methods of induction motor starting.

a. ~~Squirrel cage deep bar~~ Squirell cage deep bar method

b. ~~Rh~~ changing the freq

c. putting a Rheostat at the rotor

d. Changing the applied voltage ✓

5/10 — 1.5 — .75

1.2 Name four methods of speed control of induction motor. Show how the speed-torque C/C are changed.

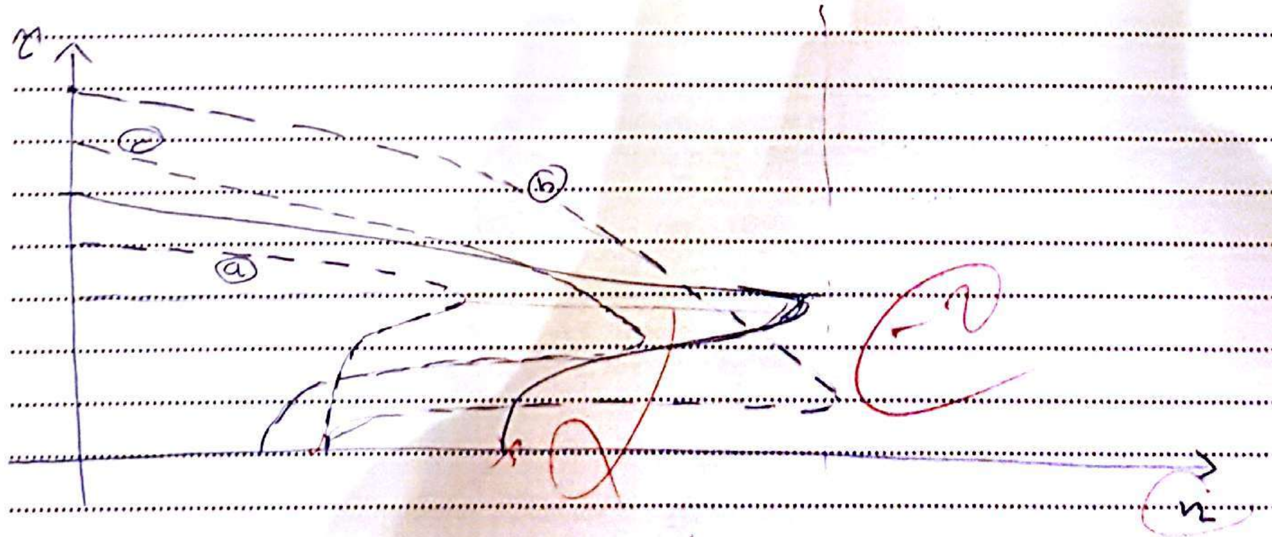
a. Reducing the voltage

b. Increasing ~~changing~~ the rotor resistance

c. changing the Freq. ✓

d. changing the # of Poles ✓

3.5 — 0.5



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Question # 2 (20 marks)

Select the correct answer for each of the following statements and fill the corresponding letter in the provided answer sheet.

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Question No.	Answer	Question No.	Answer
2.1	d ✓	2.11	a ✓
2.2	b ✓	2.12	d ✓
2.3	c ✓	2.13	b ✓
2.4	d ✓	2.14	d ✓
2.5	a ✓	2.15	d ✗
2.6	a ✓	2.16	b ✓
2.7	c ✓	2.17	d ✓
2.8	d ✗	2.18	c ✗
2.9	b ✓	2.19	a ✓
2.10	d ✗	2.20	b ✓

(1 hp = 746 W)

720 = (1-s) n_s

2.1 The number of poles of a 50 Hz, 3-ph I.M. with a full-load speed of 720 r.p.m. is ... 720 = 120·50/P

a. 4 b. 6 c. 12 (d.) 8

2.2 When the applied rated voltage per phase is doubled, the starting torque of a SCIM becomes .... of the starting torque with rated voltage. V = 2V

a. 2 (b.) 4 c. 1/2 d. 1/4

2.3 A 3 phase 50 Hz, induction motor, has a full-load slip S = 5%. The frequency of the rotor current at full load speed is .... Hz.

a. 50 b. 45 (c.) 2.5 d. 47.5

60 Hz

2.4 The synchronous speed for a 3 phase 6-pole induction motor is 1200 rpm. If the number of poles is now reduced to 4 with the frequency remaining constant, the rotor speed with a slip of 5% will be .... rpm. n_s = 1800

a. 1690 b. 1500 c. 1750 (d.) 1710

120·50/6 = 1000 rpm 1000

2.5 A 500 kW, 3-phase, 440 volts, 50 Hz, A.C. induction motor has a speed of 960 r.p.m. on full load. The machine has 6 poles. The slip of the machine will be ...

(a.) 0.04 b. 0.03 c. 0.02 d. 0.01

2.6 The power factor of an induction motor under no-load conditions will be closer to ...

(a.) 0.2 lagging b. 0.2 leading c. 0.5 leading d. 1.0

2.7 The speed of a squirrel-cage induction motor can be controlled by all of the following except ....

a. changing supply frequency b. changing number of poles (c.) changing winding resistance d. reducing supply voltage

[illegible] [illegible] of the slip ring induction motor can be increased by adding ...
a. [illegible] to the rotor
b. [illegible] to the rotor
c. external capacitance to the rotor
d. both resistance and inductance to rotor

[illegible] induction motor the maximum torque ...
a. [illegible] to rotor resistance R_2
b. [illegible] R_2
c. is proportional to $\sqrt{R_2}$
d. is proportional to $(R_2)^2$

[illegible] direct line-starting of induction motor and use starter because ...
a. [illegible] full load current
b. [illegible] direction
c. it will pick-up very high speed and may go out of step
d. starting torque is very high

[illegible] phases [illegible] induction motor are interchanged
a. [illegible]
b. [illegible]
c. the motor will not run
d. the motor will burn

[illegible] induction motors is used to find out ...
a. [illegible]
b. [illegible]
c. short-circuit current under rated voltage
d. all of the above

[illegible] induction motor is ...
a. [illegible] full load torque
b. [illegible] full load torque
c. equal to full load torque
d. equal to maximum torque

[illegible] induction motors, the torque is ....
a. [illegible]
b. [illegible]
c. inversely proportional to slip *s*.
d. directly proportional to slip *s*.

[illegible] induction motor can be increased by adding ...
a. [illegible] to the rotor
b. [illegible] to the rotor
c. external capacitance to the rotor
d. both resistance and inductance to rotor

[illegible] method of speed control is used for ....
a. [illegible] induction motors only
b. [illegible] induction motors only
c. both (a) and (b).
d. none of the above.

[illegible] which gives maximum torque at starting torque is ...
a. [illegible]
b. class B
c. class C
d. class D

[illegible] is recommended where ...
a. [illegible]
b. [illegible] starting, stopping and reversing is required
c. high starting torque is needed
d. all above features are required

[illegible] is preferred over squirrel cage induction motor where ....
a. [illegible] torque is required
b. [illegible] torque is required
c. load torque is heavy
d. all of the above

[illegible] induction motor running at slip δ, the mechanical power developed, P_d, [illegible] of air gap power P_g is ....
a. [illegible] P_g
b. $(1-\delta)P_g$
c. $P_g/(1-\delta)$
d. δP_g

Question # 3 (10 marks) **SHOW YOUR CALCULATIONS**

Provide the final answer for the following question.

The torque speed characteristic of a 3-phase, 440-V, induction motor is shown below. The full-load slip of the motor is 2.778%, and the rotational loss P_{rot} is negligible.

$n_{sync} = 1800$, $n_m = 1750$ rpm

3.1 The expected source frequency is ....
$f =$ 30 Hz

3.2 The speed of the stator rotating field in rad/s is ....
$\omega_s =$ 188.5 rad/s

$n_m = 1750$
$n_{sync} = 1800$ rpm
$n_{sync} = 1800$

3.3 The expected number of poles of the IM is ....
P = 2

3.4 The starting developed torque is ...
$T_{st} =$ 300 Nm

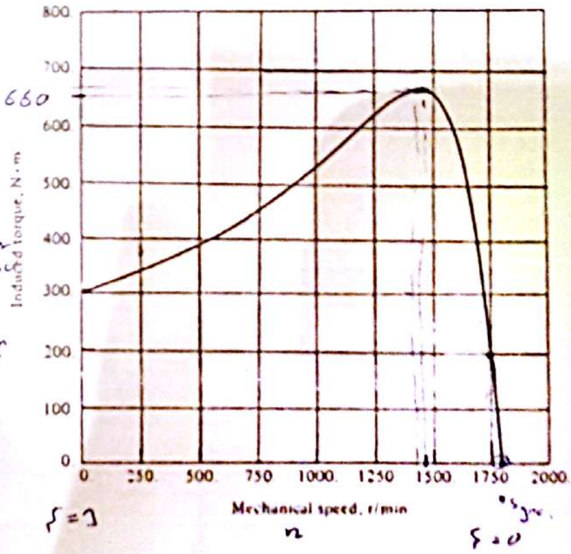
3.5 The maximum developed torque is ....
$T_{max} =$ 660 Nm

3.6 The slip at maximum torque is ....
$S_{max} =$ .1944

Assume n_m @ T_{max} = 1450

3.7 The full-load developed torque is ....
$T_{FL} =$ 200 Nm

3.8 The full-load output horse power is
$P_o =$ 49.13 hp



IM Speed-Torque C/C.

3.9 If the rotor resistance is doubled, the maximum torque becomes ....
$T_{max} =$ 660 Nm

3.10 If the number of poles is doubled, the starting torque becomes .....
$T_{st} =$ doubled Nm

(600)

Question # 4 (20 marks) **SHOW YOUR CALCULATIONS** 8/20

A 208-V, 60 Hz, six-pole Y-connected 25-hp design class B induction motor is tested in the laboratory, with the following results:

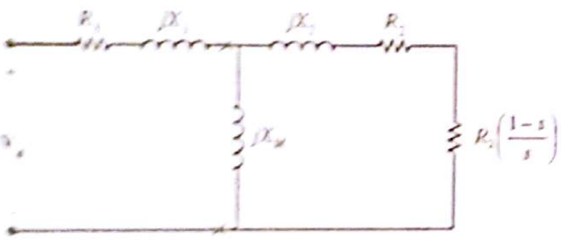
Test	Voltage (V)	Current (A)	Power (W)	Frequency (Hz)
No Load	208	22.0	1200	60
Blocked Rotor	24.6	64.5	2200	15
DC Resistance	13.5	64		

Find the equivalent circuit parameters of this motor.

$R_1 =$	.1	Ω
$R'_2 =$	.0762	Ω
$X_1 =$	.1353	Ω
$X'_2 =$	.2029	Ω
$X_M =$	9.45	Ω
$P_{rot} =$	1200	W

Division of blocked-rotor reactance for NEMA-design motors

	A, D	B	C	Wound Rotor
X_1	$0.5X_{BR}$	$0.4X_{BR}$	$0.3X_{BR}$	$0.5X_{BR}$
X_2	$0.5X_{BR}$	$0.6X_{BR}$	$0.7X_{BR}$	$0.5X_{BR}$



$n_{sync} = 1200$ rpm

-12

D.C. test

$2R_{dc} = \frac{V_{dc}}{I_{dc}} \Rightarrow R_{dc} \Rightarrow R_1 = .105$

No-load test

22

208 I

P/c $Z = X_m = \frac{V}{I}$

$= \frac{208}{22} = 9.45$

Blocked Rotor test

$P_\phi = \frac{2200}{3}$ $R_{eq} = R_1 + R_2 = \frac{.276613}{I^2}$

$R_2 = .0762$

$Z_{BR} = \frac{24.6}{64.5} = .3814$ $.3814 = \sqrt{.1762^2 + X_{eq}^2}$

$X_{eq} = .33826$

$\tau_{max} = \frac{3V^2}{2\omega_s(R_1^2 + \sqrt{R_1^2 + X_{eq}^2})}$ $\qquad \tau_{start} = \frac{3V^2 R_2'}{\omega_s((R_1+R_2')^2 + X_{eq}^2)}$

Question # 5 (30 marks) **SHOW YOUR CALCULATIONS**

A 208-V, two-pole, 60-Hz Y-connected wound-rotor induction motor is rated at 15 hp. Its equivalent circuit components are shown in Fig. Q5.

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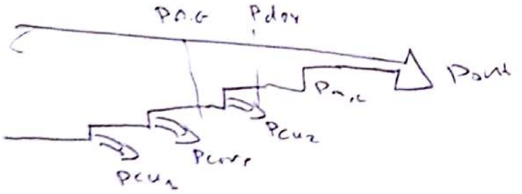
$R_1 = 0.20\ \Omega$, $X_1 = 0.41\ \Omega$, $R'_2 = 0.12\ \Omega$, $X'_2 = 0.41\ \Omega$, $X_M = 15.0\ \Omega$, $P_{mech} = 250$ W, $P_{core} = 180$ W



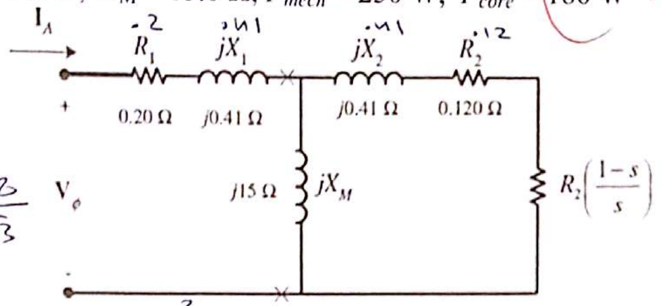


Fig. Q5

$V_\phi = \frac{208}{\sqrt{3}}$

$S_{max} = \frac{R_2'}{\sqrt{R_1^2 + X_{eq}^2}}$

$\tau_{st.} = \frac{3 \cdot V_\phi^2 \cdot R_2}{\omega_s((R_1+R_2')^2 + X_{eq}^2)}$

For a slip $S = 0.05$, find

5.1	The motor speed in revolutions per minute, n_m $\quad (1-s)n_s$	$n_m =$ 3420 rpm
5.2	The motor speed in radians per second, ω_m $\quad \frac{2\pi}{60} \cdot n_m$	$\omega_m =$ 114π = 358.14 rad/s
5.3	The equivalent impedance seen by the source phase voltage, Z_{eq}	$Z_{eq} =$ 2.6815 ∠25.51 Ω
5.4	The line current, I_L $\quad (V_\phi = 208/\sqrt{3})$	$I_L =$ 44.78 ∠−25.51 A
5.5	The stator copper losses, P_{cu1} $\quad 3 \cdot I_L^2 \cdot R_1$	$P_{cu1} =$ 1203.15 W
5.6	The air-gap power, P_g $\quad P_{in} - P_{core} - P_{SCL(cu1)}$	$P_g =$ ~~13356.8~~ 13.17675 kW
5.7	The power converted from electrical to mechanical form, P_d $\quad (1-s)P_g$	$P_d =$ ~~12689~~ 12.518 kW
5.8	The torque induced, T_d $\quad = \frac{P_{AG}}{\omega_s}$	$T_d =$ ~~35.43~~ 33.2 N.m 34.95
5.9	The output power torque, P_{out} $\quad P_{out} = P_d + P_{mech}$	$P_{out} =$ ~~12.268~~ 12.268 kW
5.10	The load torque, T_o $\quad \frac{P_{out}}{\omega_m}$	$T_o =$ 35.051 N.m
5.11	The overall machine efficiency, η $\quad \frac{P_{out}}{P_{in}} \cdot 100\%$	$\eta =$ 87.692 %
4.12	The starting developed torque, T_{dst} $\quad = \frac{3V^2 R_2'}{\omega_s((R_1+R_2')^2 + X_{eq}^2)}$	$T_{dst} =$ 17.77 Nm
5.13	The maximum developed torque, T_{dmax} $\quad \frac{3V^2}{2\omega_s(R_1^2 + \sqrt{R_1^2 + X_{eq}^2})}$	$T_{dmax} =$ 64.9 N.m
5.14	The slip at maximum torque, S_{max} $\quad \frac{R_2'}{\sqrt{R_1^2 + X_{eq}^2}}$	$S_{max} =$ .142
5.15	The speed at maximum torque, n_{Tmax} $\quad (1-S_{max})n_s$	$n_{Tmax} =$ 3088.17 rpm

$n_{sync.} = \frac{60 \cdot 120}{2} = 3600$ $\quad 120\pi = \omega_s$

$n_m = (1-s)n_s = 358.14$ 3420

$Z_{eq} = \left[\left(\frac{R_2}{s} + jX_2\right) \| jX_m\right] + [R_1 + jX_1]$

$\left[\left(\frac{.12}{.05} + .41j\right) \| 15j\right] + (.2 + j.41)$

$P_{cu1} = 3 I_1^2 R_1 = 1203.15$

$P_{in} = 14559.9$ 14560

$P_{AG} = P_{in} - P_{cu1} - P_{core} = 13356.2$ 13176.8

$P_{out} = 11190$

$P_{dev} = (1-s)P_{AG}$

$P_{out} = P_{d} - P_{mech}$

6

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