Philadelphia University
Faculty of Engineering

Student Name:
Student Number:

Dept. of Electrical Engineering
Final Exam, First Semester: 2017/2018

Course Title: Electrical Machines I	**Date: 25/1/2018**
Course No: (610314)	**Time Allowed: 2 Hours**
Lecturer: Dr. M. Abu-Naser, Dr. F. Obeidat	**No. of Pages: 7**

Question 1: ***(8Mark)***

Objectives: This question is related to multiple choices

1) Which of the following is **not** a necessary condition for parallel operation of synchronous generators:
   a) RMS voltage of all machines must be the same
   b) All machines must have the same phase sequence
   c) All machines must operate at the same frequency
   d) All machines must have the same number of poles

2) We can obtain zero voltage regulation with
   a) Lagging power factor loads
   b) Leading power factor loads
   c) Unity power factor loads
   d) All of the above

3) When the frequency is doubled, what are the change in eddy current and hysteresis losses:
   a) Hysteresis loss doubles, Eddy current loss doubles
   b) Hysteresis loss doubles, Eddy current loss quadrapples
   c) No change in hysteresis and Eddy current losses
   d) Hysteresis remaining same, Eddy current loss reduced to half

4) V curve of a three phase synchronous motor is the relation between:
   a) Voltage and current
   b) Voltage and number of poles
   c) Speed and number of poles
   d) Field current and armature current

5) A 6 pole 5 KW, 50 Hz, 3Φ induction motor having a full load slip of 3%, what will be the speed at full load:
   a) 1200 rpm
   b) 1164 rpm
   c) 970 rpm
   d) 1000 rpm

6) A DC machine is distinguished by the presence of
   a) Commutator
   b) Two slip rings
   c) Three slip rings
   d) None of the above

7) In DC motor the speed is
   a) Proportional to flux
   b) Proportional to square of flux
   c) Inversely proportional to flux
   d) Does not depend on flux

8) Which of the following statements is true
   a) The armature is the rotor in DC machines and the stator in AC machines
   b) The armature is the stator in DC machines and the rotor in AC machines
   c) The armature is the rotor in both DC and AC machines
   d) The armature is the stator in both DC and AC machines

Question 2: ***(6Mark)***

Objectives: This question is related to transformers

A 20-kVA, 20000/480-V, 60-Hz distribution transformer is tested with the following results:

Open- Circuit Test (measured from secondary side)	Short-Circuit Test (measured from primary side)
Vo.c = 480	Vs.c = 1130 V
Io.c = 1.6 A	Is.c = 1.0 A
Po.c = 305 W	Ps.c = 260 W

Find the resistance and reactance of this transformer (Rc, Xm, Req, Xeq).
What is the efficiency of this transformer at full load 0.85 power factor.

OCT

$$(R_c)_{LV} = \frac{V_{oc}^2}{P_{oc}} = \frac{480^2}{305} = 755.4\,\Omega$$

$$S = V_{oc} I_{oc} = 480 \times 1.6 = 768$$

$$Q_{oc} = \sqrt{768^2 - 305^2} = 704.8$$

$$(X_m)_{LV} = \frac{V_{oc}^2}{Q_{oc}} = \frac{480^2}{704.8} = 326.9\,\Omega$$

SCT

$$(R_{eq})_{HV} = \frac{P_{sc}}{I_{sc}^2} = \frac{260}{1^2} = 260\,\Omega$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{1130}{1} = 1130$$

$$(X_{eq})_{HV} = \sqrt{1130^2 - 260^2} = 1099.7\,\Omega$$

$$\eta = \frac{S \times PF}{S \times PF + P_{core} + P_{cu}}$$

$P_{core} = P_{oc} = 305W$

$P_{cu} = P_{sc} = 260W$

$$= \frac{20000 \times .85}{20000 \times .85 + 305 + 260} = 96.8\%$$

Question 3: ***(6Mark)***

Objectives: This question is related to AC machines

a) Compare between induction and synchronous machines in terms of

	Induction	Synchronous
Speed of rotation	slightly less than synchronous speed	constant at synchronous speed
Power factor	Lagging	laggining, unity, or leading
Starting requirement	self-starting	not self starting
Excitation to rotor	not required	required - permenant magnet or electromagnet
Cost	cheap	expensive
Maintenance	easy	difficult

b) Fill in the blanks with (increases) or (decreases) or (remains constant)

When load is placed on a 3-phase induction motor, its

1) speed decreases
2) slip increases
3) rotor induced emf increases
4) motor current increases
5) motor torque increases
6) speed of rotating magnetic field remains constant

Question 4: *(9Mark)*

Objectives: This question is related to synchronous machines

A 480-V, 60-Hz, Δ-connected, four-pole synchronous generator. This generator has an armature resistance of 0.015Ω and a synchronous reactance of 0.1Ω. Armature rms induced voltage (Eg) equal to 532 V and the torque angle is 5.3° at a terminal voltage of 480 V. Ignore any field circuit losses. Find:

1) Speed of rotation.
2) Magnitude of load current (line).
3) Load power factor and determine whether it is lagging or leading.
4) Output power of the generator.
5) Air gap power of the generator.
6) Find the air gap torque.
7) If the generator's efficiency is 89.7%, find friction and iron losses?
8) Find the input torque.
9) Suppose a new load drawing a line current of 1200 A at unity PF is connected to the generator. Find the required excitation voltage (Eg) to keep terminal voltage at 480 V? What is the voltage regulation?
10) Suppose a new load drawing a line current of 1200 A at 0.8 PF leading is connected to the generator. Find the required excitation voltage (Eg) to keep terminal voltage at 480 V? What is the voltage regulation?

1) $n_s = \frac{120f}{P} = \frac{120 \times 60}{4} = 1800$ rpm

2) $E_g = V_t + I_a Z$

$532\angle 5.3^\circ = 480\angle 0^\circ + I_a(.015 + j.1)$

$\Rightarrow I_a = \frac{532\angle 5.3 - 480}{.015 + j.1} = 692.8\angle -36.9^\circ$ A

$I_L = \sqrt{3} \times I_a = 1200$ A

3) $PF = \cos -36.9^\circ = .8$ lagging

4) $P_{out} = \sqrt{3} V_t I_L \times PF = \sqrt{3} \times 480 \times 1200 \times .8 = 799$ KW

5) $P_{cu} = 3 I_a^2 R_a = 3 \times 692.8^2 \times .015 = 21.6$ KW

$P_g = P_{out} + P_{cu} = 799 + 21.6 = 820.6$ KW

6) $T_g = \frac{P_g}{\omega_s} = \frac{820600}{1800 \times \frac{2\pi}{60}} = 4353.4$ N.m

7) $P_{in} = \frac{P_{out}}{\eta} = \frac{799}{.897} = 890.6$ KW

$P_{core+f} = P_{in} - P_g = 890.6 - 820.6 = 70$ KW

8) $T_{in} = \frac{P_{in}}{\omega_s} = \frac{890600}{1800 \times \frac{2\pi}{60}} = 4724.8$ N.m

9) $I_a = \frac{1200}{\sqrt{3}} = 692.8$ A

$E_g = V_t + I_a Z$

$= 480 + 692.8\angle 0° (.015 + j.1)$

$= 495.26 \angle 8.04°$ V

$VR = \frac{495.26 - 480}{480} = 3.18\%$

10) $I_a = \frac{1200}{\sqrt{3}} = 692.8 \angle \cos^{-1}.8 = 692.8 \angle 36.9°$

$E_g = V_t + I_a Z$

$= 480 + 692.8 \angle 36.9° (.015 + j.1)$

$= 451 \angle 7.86°$ V

$VR = \frac{451 - 480}{480} = -6.04\%$

Question 5: ***(5Mark)***

Objectives: This question is related to DC machines

A six pole DC generator has a flux per pole of 30 mWb. The armature has 536 conductors connected as a lap. The DC generator runs at 1050 rpm, and delivers a rated armature current of 225 A to a load connected to its terminals. The field and armature windings are connected in series ($R_f = R_a = 0.05\Omega$). Combined friction, windage, and core losses are 2kW. Calculate:

1) Generated voltage, E_g
2) The power developed by armature, P_{dev}
3) The developed torque, T_{dev}
4) Terminal voltage, V_t
5) Efficiency

1) $E_g = \frac{n \phi Z}{60}$

$= \frac{1050 \times .03 \times 536}{60} = 281.4\ V$

2) $P_{dev} = E_g I_a = 281.4 \times 225 = 63.3\ KW$

3) $T_{dev} = \frac{P_{dev}}{\omega} = \frac{63315}{1050 \times \frac{2\pi}{60}} = 575.8\ N.m$

4) $V_t = E_g - I_a(R_a + R_f)$

$= 281.4 - 225(.05 + .05)$

$= 258.9\ V$

5) $P_{Cu} = I_a^2(R_a + R_f) = 225^2 \times .1 = 5.06\ KW$

$P_{core+fw} = 2\ KW$

$P_{out} = V_t I_a = 258.9 \times 225 = 58.25\ KW$

$\eta = \frac{P_{out}}{P_{in}} = \frac{58.25}{58.25 + 5.06 + 2} = 89.2\%$

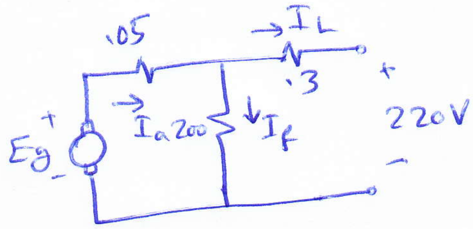
Question 6: **(6Mark)**

Objectives: This question is related to DC machines

A 6.6kW, 220V short shunt compound DC machine has an armature, series field and shunt field resistances of 0.05Ω, 0.3Ω and 200Ω respectively. Determine the total armature power developed when working as:

a) Generator delivering 6.6kW output

b) Motor taking 6.6kW input.



a) $I_L = \frac{P_{out}}{V_t} = \frac{6600}{220} = 30A$

$I_f R_{sh} = I_L R_{se} + V_t$

$I_f \times 200 = 30 \times .3 + 220 \Rightarrow I_f = 1.145A$

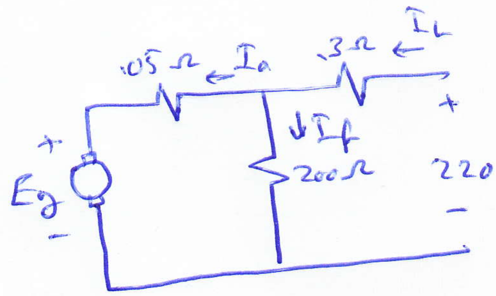
$I_a = I_f + I_L = 1.145 + 30 = 31.145A$

$E_g = I_a R_a + I_L R_{se} + V_t$

$= 31.145 \times .05 + 30 \times .3 + 220$

$= 230.55\ V$

$P_{dev} = E_g I_a = 230.55 \times 31.145 = 7180.7\ W$



b) $I_L = 30A$

$I_f R_{sh} = V_t - I_L R_{se}$

$I_f \times 200 = 220 - 30 \times .3 \Rightarrow I_f = 1.055A$

$I_a = I_L - I_f = 30 - 1.055 = 28.945A$

$E_g = V_t - I_L R_{se} - I_a R_a$

$= 220 - 30 \times .3 - 28.945 \times .05$

$= 209.55\ V$

$P_{dev} = E_g I_a = 209.55 \times 28.945 = 6065.5\ W$