CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 2, 2016

FINAL EXAMINATION	**DURATION**
ENG224 – Electrical Machines and Power Systems	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a CLOSED BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	**EXAMINATION MATERIALS TO BE SUPPLIED**
No additional printed material is permitted	1 x 20 Page Book 1 x Scrap Paper

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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<u>QUESTION 1 (10 marks)</u>

Define the following terms in plain English without using any equations or formulas.

(2 marks each)

Q1.1 Ferromagnetic materials
Q1.2 Relative permeability
Q1.3 Permeability
Q1.4 Inductance
Q1.5 Magnetic field intensity

<u>QUESTION 2 (10 marks)</u>

A 240 kW, 240 volt, 6 pole, 600 rpm, separately excited generator is delivering the rated load at the rated voltage. The generator has an armature resistance of 0.01 ohm, field winding resistance of 30 ohms. The field winding is powered by a 120 volt battery. Rotational losses are estimated to be 10 kW. Determine

Q2.1 The electromotive force induced at full load
Q2.2 The electrical power developed in the machine
Q2.3 The mechanical torque applied to the generator.

<u>QUESTION 3 (10 marks)</u>

A 9 kVA, 208 volt, 3 phase, star connected, synchronous generator has a winding resistance of 0.1 ohm per phase and a synchronous reactance of 5.6 ohm per phase. Determine the voltage regulation when the power factor of the supplied load is

Q3.1 80% lagging (3 marks)
Q3.2 Unity (3 marks)
Q3.3 80% leading. (4 marks)

<u>QUESTION 4 (10 marks)</u>

A 230 volt, 60 Hz, 4 pole star connected, three phase induction motor operates at a full load speed of 1710 rpm. The power developed at this speed is 2 horse power. If the supply voltage fluctuates ±10%, determine the torque range of the motor.

<u>QUESTION 5 (10 marks)</u>

Q5.1 Write short notes on (1) step motors, (2) hysteresis motors, (3) linear induction motors, (4) brushless dc motors and (5) permanent magnet motors.
(1 mark each)

Q5.2 A 100 MW 11 kV three phase alternator has synchronous reactance of 0.5 ohms per phase and negligible armature resistance. Calculate the synchronous reactance in per unit based on machine ratings. (2 marks)

Q5.3 The machine referred to in the above question is required to be used in a 10.5 kV network. The base quantities are 500 MVA and 10.5 kV at the generator terminals. Calculate the generator synchronous reactance in per unit under the new circumstance. (3 marks)

<u>End of questions.</u>

FORMULAS

(Symbols have their usual meanings in the context of the particular formula)

MAGNETIC CIRCUITS: $L = \lambda/i = N^2/\Re = \mu N^2 A/d$; $Ni = \sum H\ell = \varphi \Re$;

$B = \mu H = \mu Ni/\ell$; $\mu = \mu_r \mu_0$; $\Re = \ell/\mu A$

TRANSFORMERS: $\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$; $Z_1 = \left(\frac{N_1}{N_2}\right)^2 Z_2$; $R_c^{'} = \frac{V_{oc}}{I_{oc}\cos\theta}$; $X_m = \frac{V_{oc}}{I_{oc}\sin\theta}$;

$\cos\theta = \frac{P_{oc}}{V_{oc} I_{oc}}$; $\eta = \frac{V_2^{'} I_2^{'} \cos\theta}{V_2^{'} I_2^{'} \cos\theta + P_c + R_{eq}^{'} (I_2^{'})^2} \times 100\%$

$$\eta_{AD} = \frac{\text{Energy output over 24 hours}}{\text{Energy input over 24 hours}} \times 100\%$$

$$\text{Regulation} = \frac{\text{No load voltage} - \text{Full load voltage}}{\text{Full load voltage}} \times 100$$

INDUCTION MACHINES: (Torque and power are given on a per phase basis)

$n = 120\frac{f}{p}$; $s = \frac{(n_s - n)}{n_s}$; $f_2 = sf_1$; $E_{rms} = 4.44 f N_{ph} \varphi_p K_w$

$V_{th} = \frac{X_m}{\sqrt{R_1^2 + (X_1 + X_m)^2}} V_1$; $R_{th} \cong \left(\frac{X_m}{X_1 + X_m}\right)^2 R_1$ $X_{th} \cong X_1$

$P_{mech} = T_{mech}\,\omega_{mech} = (1-s)P_{air\_gap}$; Ideal Efficiency = 1-s;

$T_{mech} = \frac{1}{\omega_s} I_2'^2 \frac{R_2'}{s} = \frac{1}{\omega_s} \frac{V_{th}^2}{(R_{th} + R_2'/s)^2 + (X_{th} + X_2')^2} \frac{R_2'}{s}$; $P_{air\_gap} = I_2'^2 \frac{R_2'}{s}$

$s_{Tmax} = \frac{R_2'}{\sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$; $T_{max} = \frac{1}{2\omega_s} \frac{V_{th}^2}{R_{th} + \sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$

DC MACHINES: $K_a = \frac{Zp}{2\pi a}$; $E_a = K_a \varphi\omega$; $T = K_a \varphi I_a$; $P_{out} = E_a I_a = T\omega$; La=p wound.

ALTERNATORS: $E_f \propto I_f$ $E_f = V_t + jI_a X_s$ $E_f = V_t + I_a R_a + jI_d X_d + jI_q X_q$

$P = \frac{|V_t||E_f|}{|Z_s|}\cos(\theta_s - \delta) - \frac{|V_t|^2}{|Z_s|}\cos\theta_s$ $Q = \frac{|V_t||E_f|}{|Z_s|}\sin(\theta_s - \delta) - \frac{|V_t|^2}{|Z_s|}\cos\theta_s$

$E_f = V_t\cos\delta \pm I_d X_d$, $I_a = |I_q| - j|I_d|$ and $V_t = |V_t|\angle{-\delta}$

$P = \frac{|V_t||E_f|}{|X_d|}\sin\delta + \frac{|V_t|^2 (X_d - X_q)}{2X_d X_q}\sin 2\delta$ $Q = \frac{|V_t||E_f|}{|X_d|}\cos\delta + |V_t|^2 \left|\frac{\sin^2\delta}{X_q} + \frac{\cos^2\delta}{X_d}\right|$

PER UNIT SYSTEM: $Z_{pu} = \frac{Z_{ohm}}{Z_{base}}$; $Z_{base} = \frac{(kV_{base})^2}{MVA_{base}}$;

$S_{pu} = kV_{pu}\, kA_{pu}$ (no √**3**); $kA_{pu} = \frac{MVA_b}{\sqrt{3}\ kVA_b}$; $Z_{pu2} = Z_{pu1} \times \frac{S_{base2}}{S_{base1}} \times \frac{kV_{base1}^2}{kV_{base2}^2}$

OTHERS: $S = \sqrt{3} V_L I_L$; 1 horse power = 746 watts.