THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
BACHELOR OF TECHNOLOGY
ECX5238-HIGH VOLTAGE ENGINEERING AND ELECTRICAL MACHINES
FINAL EXAMINATION - 2014/2015 **CLOSED BOOK**

Date: 14th September 2015 Time: 0930-1230

Instructions to candidates: Answer any ***five (05)*** questions. Select at least ***one*** question from section **B**. Graph papers will be available on your request.

Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m Permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

Section A: High Voltage Engineering

Q1.

a) Define Townsend's first and second ionization coefficients. [4 marks]

b) Explain the Streamer theory of breakdown in air at atmospheric pressure. [4 marks]

c) Describe the various factors that influence breakdown in a gas. [4 marks]

d) Describe very briefly with the aid of suitable diagrams the mechanism of the lightning stroke generation. [4 marks]

e) Describe, the effect of connecting an overhead transmission line to a terminal equipment via a short length of a cable with respect to surges originating in the overhead lines. [4 marks]

Q2.

a) Derive an expression for spark breakdown in the Townsend breakdown process, stating any assumptions made. [4 marks]

b) In an experiment in a certain gas it was found that the steady state current is $5.5 \times 10^{-8} A$ at 8 kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 cm results a current of $5.5 \times 10^{-9} A$. Calculate Townsend's primary ionization coefficient α. [8 marks]

c) In an experiment for determining the breakdown strength of transformer oil, the following observations were made. Determine the relationship between the breakdown voltage and gap in the form of $V = kd^n$.

Gap Spacing (mm)	4	6	10	12
Voltage at breakdown (kV)	90	140	210	255

[8 marks]

Q3.

a) Explain and compare the performance of half wave rectifier and voltage doubler circuits for generation of high **dc** voltages.

b) Why is a Cockcroft-Walton circuit preferred for voltage multiplier circuits? Explain its working with a schematic diagram.

c) Explain clearly the basic principle of operation of an electrostatic generator. Describe with neat diagram the principle of operation, application and limitations of Van de Graf generator.

d) Explain the different schemes for cascade connection of transformers for producing very high **ac** voltages.

e) Why is it preferable to use isolating transformers for excitation with cascade transformer units, if the power requirement is large?

f) Describe the use of sphere gaps in high voltage measurements.

g) Derive an expression for the deflecting torque of an electrostatic voltmeter used to measure high voltages.

h) Derive an expression for spark breakdown in the Townsend breakdown process, stating any assumptions made. [8*2.5= 20 marks]

Q4.

a) A 12-stage impulse generator has 0.126 pF condensers. The wave front and the wave tail resistances connected are 800 Ω and 5000 Ω respectively. If the load condenser is 1000 pF, find the front and tail times of the impulse wave produced. [4 marks]

b) An impulse generator has eight stages with each condenser rated for 0.16 μF and 125 kV. The load capacitor available is 1000 pF. Find the series resistance and the damping resistance needed to produce 1.2/50 μs impulse wave. What is the maximum output voltage of the generator, if the charging voltage is 120 kV? [8 marks]

c) A single phase cable for a 3-phase 66 kV system, is to be designed using 3 insulating materials A, B, and C with peak critical breakdown stresses of 180 kV/cm, 200 kV/cm and 250 kV/cm and corresponding relative permittivities of 4.4, 3.2 and 2.8 respectively. If the conductor radius is 10 mm, determine the order and thickness of the insulation for optimum dimensions of the cable. Take a safety factor as 2 in the design. [8 marks]

Q5.

a) A ten-stage impulse generator has 0.250 μF condensers. The wave front and wave tail resistances are 75 Ohm and 2600 Ohm respectively. If the load capacitance is 2.5 nF, determine the wave front and wave tail times of the impulse wave. [8 marks]

b) 33 kV, 50 Hz high voltage Schering bridge is used to test a sample of insulation. The various arms have the following parameters on balance. The standard capacitance 500 pF, the resistive branch 800 Ohm and branch with parallel combination of resistance and capacitance has values 180 Ohms and 0.15 μF. Determine the value of the capacitance of this sample its parallel equivalent loss resistance, the p.f. and the power loss under these test conditions. [8 marks]

c) A surge of 100 kV travelling in a line of natural impedance 600 Ohms arrives at a junction with two lines of impedances 800 Ohms and 200 Ohms respectively. Find the surge voltages and currents transmitted into each branch line. [4 marks]

Section B: Electrical Machines

Q6.

a) Calculate the basic step angle for the following stepper motors?

1. 8/6 , 4 phase VR steppers
2. 12/8, 3 phase VR steppers
3. 8/72, 4 phase multi-stack motor
4. 4/9 pole , 2 phase, PM hybrid motor

[2*4 = 8 marks]

b) A certain generator subjected to a sudden 3 phase short circuit at its terminal while on no-load with 11 kV between lines produces short circuit fault current given by the following expression:

$$i = (6 + 50e^{-2t} + 15e^{-50t})\sin(\omega t + \theta_o) - 40e^{-20t}\sin\theta_o \; kA$$

1. What is θ_o in this expression?
2. What are the values of sub-transient time constant, transient time constant and armature time constant, under short circuit condition?
3. Determine the values of reactance x_d, x'_d, x''_d and x''_q for the generator
4. Calculate approximate initial rms fault current

[12 marks]

Q7.

a) A 11 kV star connected 3 phase synchronous motor works at constant voltage and constant excitation. Its synchronous impedance is $1.5 + j12\Omega$ per phase. When the input power is 1000 kW, the observed power factor is at 0.8 leading. Find the operating power factor when the input is increased to 1500 kW. [10 marks]

b) A salient-pole synchronous generator has the following per-unit parameters:

$$x_d = 1.2\,pu,\; x_q = 0.8\,pu,\; Armature\,resistance\,(r_a) = 0.025\,pu$$

Compute the excitation voltage on a per unit basis, when the generator is delivering rated kVA at rated voltage and at power factor of 0.8 lagging. [10 marks]

Q8.

a) A three phase synchronous generator is delivering a power of 0.9 p.u to an infinite bus at rated voltage and at 0.8 power factor lagging. The generator has $x_d = 1.0$ p.u and $x_q = 0.6$ p.u . Calculate the internal EMF and the load angle. [8 marks]

b) What will be the revised nameplate data for a 3-phase, 60Hz, 480V, 30A, 20kW, 1435 rpm totally enclosed fan ventilated induction motor in the following circumstances?

1. For the use on 3-phase 50Hz supply without modification
2. After rewinding the motor with coils having half as many turns using wires having twice the cross sectional area
3. For a modified construction of the motor with 10% increase of the active length

[12 Marks]