THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY
ECX5238 – Electrical Machines and High Voltage Engineering
Final Examination 2006/2007

061

Duration Three Hours

Date:23rd March 2007 Time: 1400-1700

This paper contains two sections: **Part A** and **Part B**.
Part B is **compulsory**. And answer any **four (4)** questions from **Part A**.

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

Part A *(answer any four)*

01.

(a) Describe briefly with the aid of suitable diagrams (where necessary) the following:
(1) Streamer theory of breakdown in gasses, [3 marks]
(2) Thermal breakdown of a solid dielectric, [3 marks]
(3) Breakdown due to internal discharges, [3 marks]
(4) Mechanism of lightning. [3 marks]

(b) In a certain high voltage equipment, oil ($\varepsilon_{r1} = 2.2$, $\xi_{max1} = 25$ kV/mm) is present between two electrodes 5 mm apart. Determine the maximum permissible voltage across the electrodes. A solid dielectric material ($\varepsilon_{r2} = 4.4$, $\xi_{max2} = 100$ kV/mm) of thickness 1 mm is introduced into the oil between the electrodes in an attempt to increase the maximum permissible voltage. Calculate the new maximum voltage and comment on the decision. [8 marks]

02.

(a) Outline, with the use of an example, the significance of type tests, sample tests and routine tests on high voltage equipment. [3 mark]

(b) Describe with the aid of suitable diagrams and appropriate calculations, the use of the Schering Bridge in high voltage testing. [5 mark]

(c) Three insulating materials A, B and C are available (with properties given in the table) for use in a high voltage a.c. cable. If the conductor radius is 12 mm, and the radius of the sheath is 25 mm, determine the order and thickness of the various layers of insulation for an optimum working voltage. [9 mark]

Material	A	B	C
Breakdown voltage (kV/cm)	150	130	110
Relative Permittivity	3.5	2.5	4.4

Determine also the maximum operating voltage of the cable, if a safety factor of 1.5 is used in the design. [3 mark]

03.

(a) A simplified power system consists of three lines AB (Z_o= 600 Ω), BC (Z_o= 400 Ω, 120 km overhead line) and BD (Z_o= 50 Ω, 20 km, cable). The lines BC and BD are on open circuit at the ends C and D respectively. If a step surge of magnitude 100 kV originates on line AB at A and travels towards B, sketch the voltage waveforms at B, C and D for the first 0.35 ms from the inception of the surge. The lines may be assumed to be lossless and that A is too far from junction B to consider reflections at A coming back to B. [10 marks]

[Velocities of propagation in overhead line and cable are 3 x 10^5 km/s and 2 x 10^5 km/s]

(b) Two overhead lines AB (Z_o= 500 Ω, length = 300 km, attenuation factor = 0.8) and BC (Z_o= 300 Ω, length = 120 km, attenuation factor = 0.9) feed a load of value 1700 Ω. A triangular wave of peak height 100 kV and duration 400 μs originates in the overhead line AB at A and travels towards the junction B. Using Bewley Lattice Diagram, determine and sketch the voltages at A, B and C for the first 1.9 ms. [10 marks]

04.

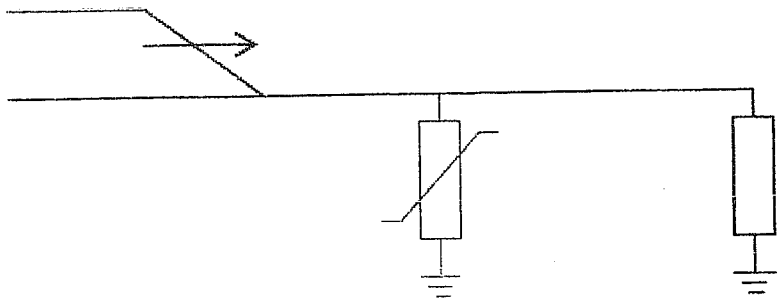

Figure Q4

(a) A 100 kV surge has a linear rate of rise of 500 kV/μs to peak and constant value thereafter (Figure Q4). It originates in an overhead transmission line with a surge impedance of 400 Ω and travels towards a terminal device (Z_0 = 1600 Ω). It is protected by a lightning arrestor (operating voltage is 145 kV) at a distance of 9 m from the device. Sketch the voltage waveform at the arrestor location. [10 marks]

(b) Sketch the voltage at the terminal device [4 marks]

(c) Determine the maximum voltage to which the terminal equipment will rise. [3 marks]

(d) Determine the time at which the arrestor operates. [3 marks]

05.

(a) Sketch the circuit diagram of a double-star connected bridge converter. [3 marks]

(b) The secondary line voltage of the transformer is 220 kV. Calculate the direct voltage output if the delay angle and the commutation angle are absent. [4 marks]

(c) Calculate the rms value of the ripple voltage in the absence of smoothing. [3 marks]

(d) Calculate also the rms value of the harmonic current on the ac side, when transferring 30 MW of power, at a delay angle of 28° and negligible commutation angle, for a ripple free output current. [6 marks]

(e) Determine also the operating power factor. [4 marks]

06.

(a) Figure Q6 shows the equivalent circuit of an impulse generator where the capacitor C_1 (= 0.02 μF) is initially charged to a voltage of 100 kV. Determine the values of R_1, R_2 and C_2 if the impulse generator is to have an efficiency of 90% and a voltage waveform of **1.2/50** μs across the capacitor C_2. [15 marks]

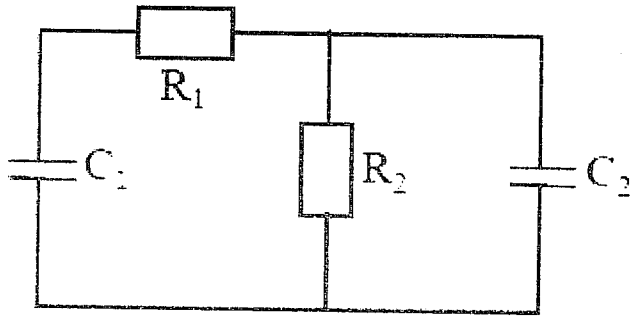

Figure Q6

(b) It is found that the resistor R_2 has an effective series inductance of 60 mH. Using an intuitive approach, sketch what changes you would expect to the voltage waveform across the capacitor C_2. [5 marks]

Part B *(compulsory)*

01.

(a) Explain the following operations of DC motor driver with relevant diagrams and switching sequence of thyristors.

1. First Quadrant Operation
2. Second Quadrant Operation
3. Fourth Quadrant Operation

[15 marks]

(b) What kind of DC Driver shall be used for the operation of a hoisting/ lowering crane? Explain your answer. [5 marks]