00156

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX5538/ECX5238**
	High Voltage Engineering and Electrical Machines
Academic Year	: 2019/2020
Date	: 07th October 2020
Time	: 1330-1630hrs

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of two sections, **Section A** and **Section B** with **Eight (8)** questions in **Six (06)** pages.
3. Answer **Five (5)** questions selecting at least **One (1)** question from **Section B**, All the questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant figures and tables are provided with the question paper
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear hand writing.
8. Do not use red colour pen.

SECTION-A
HIGH VOLTAGE ENGINEERING

Question 1

a) Figure Q1 shows the experimental set-up for studying the Townsend discharge. The experiment is conducted by measuring the current I at the different gap distance, *d*. Table Q1 gives the set of observation obtained when studying the conduction and breakdown in a gas.

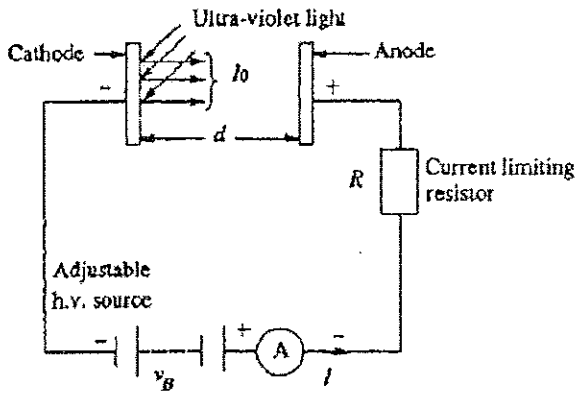

Figure Q1 – Townsend's experimental set-up

d (mm)	1	2	3	4	5	6	8	10	12	14	16
I (pA)	19	21	26	32	40	45	80	106	152	255	430

Table Q1- Townsend's experimental data

I. Determine the initial current (I_0) **[4 Marks]**

II. Calculate the value of the Townsend's primary and secondary ionization coefficients. **[5 Marks]**

b) Define the term intrinsic strength of dielectrics. What are the categories of impurities which lead to the breakdown of commercial liquids below their maximum breakdown strength? **[3 Marks]**

c) State **three** causes which lead to the breakdown of solid dielectrics below their intrinsic strength. Briefly explain **one** of the mentioned causes. **[2 Marks]**

d) Describe very briefly with the aid of suitable diagrams about the

I. Mechanism of lightning stroke discharge through the earth **[3 Marks]**

II. Three possible lighting discharging paths that can cause surges on the transmission line **[3 Marks]**

Question 2

a) Show that the deflecting torque of an electrostatic voltmeter is proportional to the square of applied voltage. **[3 Marks]**

b) A 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 Ω and branch with parallel combination of resistance and capacitance has values 180 Ω and 0.15 μF respectively. Determine the capacitance value of this sample, its parallel equivalent loss resistance and power loss under these test conditions. **[5 Marks]**

c) What is the definition of 'partial discharge'? State the importance of conducting partial discharge tests. **[5 Marks]**

d) Define below terms which are associated with insulation coordination. **[3 Marks]**

I. Maximum System Voltage
II. Factor of Earthing
III. Statistical Impulse Withstand Voltage

e) Explain very briefly the evaluation of the risk factor with regard to the statistical insulation co-ordination. **[4 Marks]**

Question 3

a) Explain the terms **wave front time** and **wave tail time** with the help of suitable diagrams. **[4 Marks]**

b) A long overhead transmission line AB (Surge impedance = 550 Ω) is connected to the terminal equipment (Surge impedance = 2450 Ω) through a cable (Length = 1 km, Surge impedance = 50 Ω, attenuation in single transit = 0.95) as shown in figure Q3.

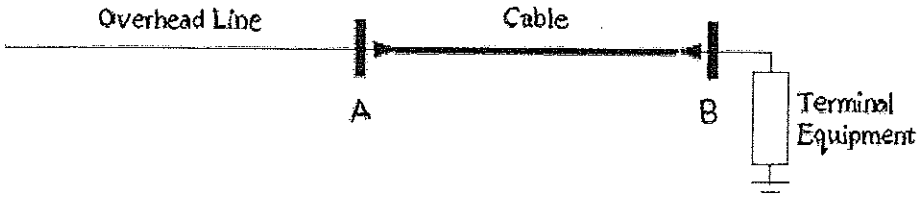

Figure Q3 – Overhead Transmission line Connected to the terminal equipment

A triangular voltage surge (vertical front, 200 kV peak decaying to zero in 40 μs) originates in the overhead line and arrives at A at time t = 0. Draw the Bewley Lattice diagram and sketch the voltage variation at A and B for the first 25μs.

[velocity in overhead line = 3 $X10^8$ m/s, velocity in cable = 2 $X10^8$ m/s]

[12 Marks]

c) State **four** advantages and **four** disadvantages of DC transmission over AC transmission. **[4 Marks]**

Question 4

a) High voltages are primarily used for power transmission purposes and secondly used for equipment testing purposes.

I. What are the different High Alternating Voltage generating methods used for the testing purposes? **[3 Marks]**

II. Why the high voltage generating methods used in high power applications are not applicable for equipment testing purposes? **[3 Marks]**

b) The simplified equivalent circuit of an impulse generator is shown in figure Q4, with the capacitor C1 being initially charged.

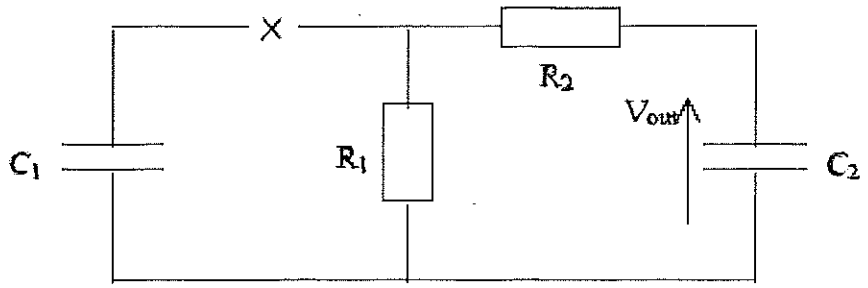

Figure Q4 – Simplified equivalent circuit of an impulse generator

I. Obtain expressions for the wave front time (based on 30% to 90%) and the wave tail time in terms of charging time constant (τ_c), discharging time constant (τ_d) and voltage efficiency (η). **[4 marks]**

II. It is desired to design a 6-stage impulse generator to have an output voltage of 1000 kV of standard IEC waveform (1.2/50 μs with 90% voltage efficiency), and to have an output energy of 50 kJ. Making reasonable judgments, determine the main components of the multistage impulse generator. **[7 marks]**

III. Draw the complete impulse generator circuit indicating values for each component. **[3 marks]**

Question 5

a) State and explain the types of power losses that can incur in a high voltage cable. **[3 Marks]**

b) Briefly explain the term "**Cross-Bonding of Cables**". **[2 Marks]**

c) Show that the most economical conductor diameter (which has minimum possible maximum dielectric stress) in a high voltage cable is given by

$$d = D/2.718$$

Where **D** is the inter sheath diameter **[3 Marks]**

d) Find the most economical conductor diameter and internal sheath diameter of a single-core cable working on a 132 kV, 3-phase system, if a dielectric stress of 60 kV/cm can be allowed. **[3 Marks]**

e) What are the difficulties associated with the grading methods which are used for stress distribution in high voltage underground cables? **[2 marks]**

f) A single core lead sheathed cable has a conductor diameter of 3 cm; the diameter of the cable being 9 cm. The cable is graded by using two dielectrics of relative permittivity 5 and 4 respectively with corresponding safe working stresses of 30 kV/cm and 20 kV/cm. Calculate the radial thickness of each insulation and the safe working voltage of the cable. **[7 Marks]**

SECTION-B
ELCTRICAL MACHINES

Question 6

a) Compare the main three types of stepper motors based on their construction principle. **[3 marks]**

b) What is the difference between full switching sequence and half switching sequence of stepper motors? **[3 marks]**

c) Sketch the pole arrangement of 4/6 pole 2 phase permanent magnet stepper motor including the value of basic step angle. Write down the phase switching sequence for the given motor with respect to the clockwise and counter clockwise rotation. **[6 marks]**

d) Cross section of a three phase multi stack stepper motor is given by the Figure Q6.

I. Identify the type of given stepper motor **[1 marks]**

II. Calculate the basic step angle **[1 marks]**

III. Hence calculate the number of steps per revolution. **[1 marks]**

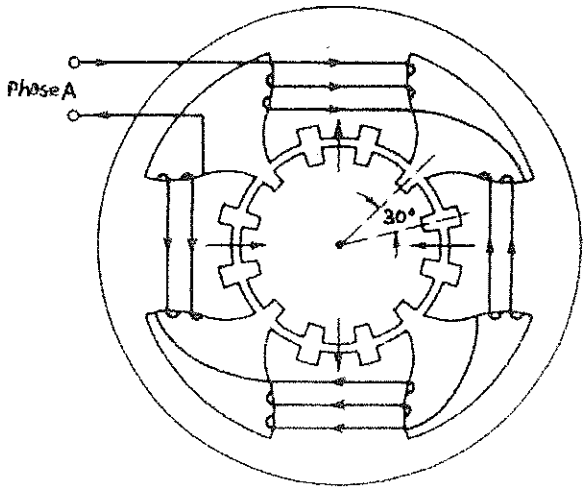

Figure Q6: Cross section of a multi stack stepper motor

e) Sketch the torque speed characteristics of stepper motor including all the necessary terms. **[3 marks]**

Define the terms given below. **[2 marks]**

I. Detent torque

II. Holding Torque

Question 7

a) Sketch the typical line current waveform of a synchronous generator which is following a sudden three-phase short circuit at its terminals (at the time t=0) indicating all the necessary information. Assume the generator was operating at no-load condition prior to the short circuit. **[3 marks]**

b) Considering above mentioned synchronous generator write down an expression for the instantaneous per unit current at phase A while defining the terms in your expression. **[5 marks]**
Explain the significance of all four major components in that short circuit current expression. **[2 marks]**

c) A three phase 12.5kV, 200MVA salient pole rotor synchronous generator has following parameters.

Direct Axis Synchronous Reactance (X_d) =1.5pu
Quadratic Axis Synchronous Reactance (X_q) =1.5pu

If the generator delivers 100MW and 30MVAr at rated voltage to an infinite bus-bur, determine the internal EMF and the load angle. **[10 marks]**

Question 8

a) Brushless Direct Current Motor (BLDCM) is the latest addition to the family of DC motors. What is the major difference of BLDCM when compared with the conventional DC motor? What are the inherent advantages of BLDCM with regard to that difference? **[3 marks]**

b) Sketch the internal structure of the BLDCM and briefly explain how the motor operation takes place with help of that diagram. **[4 marks]**

c) Briefly describe available rotor position sensing techniques used in BLDCM. **[3 marks]**

f) A BLDCM has following data.

Rotor radius = 8cm
Rotor axial length = 25cm
Airgap flux density due to rotor magnets = 0.7T
Number of turns per phase = 36 turns
Stator resistance per phase = 0.4 Ω
Stator Inductance per phase = 1 mH

The DC supply voltage at input terminals is 320V. Determine the motor **speed** and **efficiency** when delivering a load of load-torque 65Nm. State any assumptions you made. **[10 marks]**