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

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| Study Programme | : Bachelor of Technology Honours in Engineering |
| Name of the Examination | : Final Examination |
| Course Code and Title | : **EEX5338** |
| | **High Voltage Engineering** |
| Academic Year | : 2021/2022 |
| Date | : 23rd February 2023 |
| Time | : 1330-1630hrs |

## General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions in **Four (04)** pages.
3. Answer **all questions**, 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.

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## Technical Information

1. Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ **H/m**
2. Permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12}$ **F/m**
3. Velocity of light in free space = $3 \times 10^8$ **m/s**

## Question 1

**a)** 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? **[4 Marks]**

**b)** Figure Q1 shows an experimental set-up for studying the Townsend discharge. The experiment is conducted by measuring the current I at the different gap distance, d.

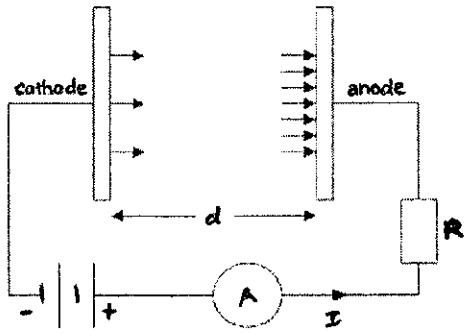



Figure Q1 – Townsend's experimental set-up

**I.** Prove that the Townsend's current growth equation is given by the following equation. **[5 Marks]**

$$I = \frac{I_0\, e^{\alpha d}}{1-\gamma(e^{\alpha d}-1)}$$

Where, $\alpha$ = Townsend's first ionization coefficient
$\gamma$ = Townsend's second ionization coefficient
d = Distance between anode and cathode
$I_o$ = Initial photo-electric current at the cathode

**II.** Hence deduce the Townsend's breakdown criteria. **[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. **[3 Marks]**

**d)** Describe very briefly with the aid of suitable diagrams (including relevant technical terms) about the mechanism of lightning stroke discharge through the earth **[5 Marks]**

## Question 2

**a)** What is the definition of 'partial discharge'? State the importance of conducting partial discharge tests. **[6 Marks]**

**b)** Figure Q2 shows a circuit diagram of a high voltage Schering Bridge, with the values at the balance condition. If the dielectric has a cross-section area of 0.01 $m^2$ and the spacing of 2 cm, determine the relative permittivity and the resistivity of the material. **[7 Marks]**

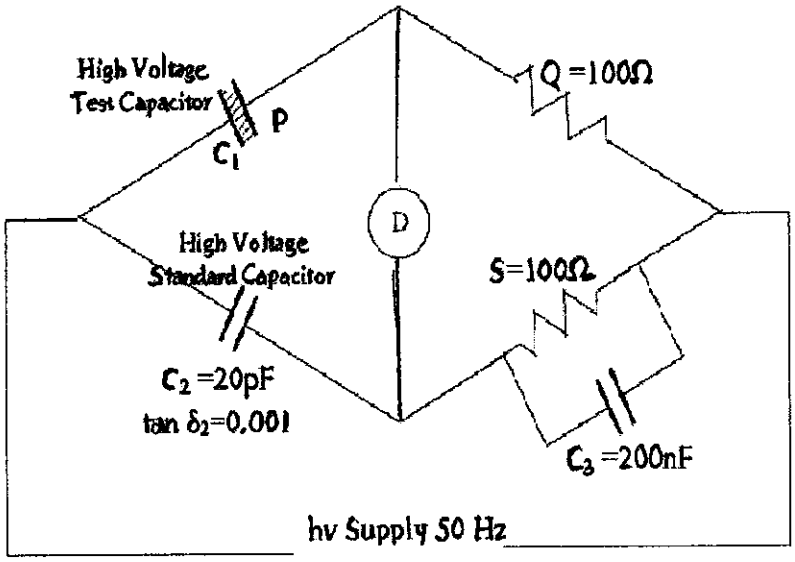



Figure Q2

**c)** Define below terms which are associated with insulation coordination. **[2 Marks]**

I. Maximum System Voltage
II. Factor of Earthing

**d)** Briefly explain the following terms with the aid of suitable diagrams. **[5 Marks]**

I. Statistical Impulse Withstand Voltage
II. Statistical Impulse Voltage

## 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.

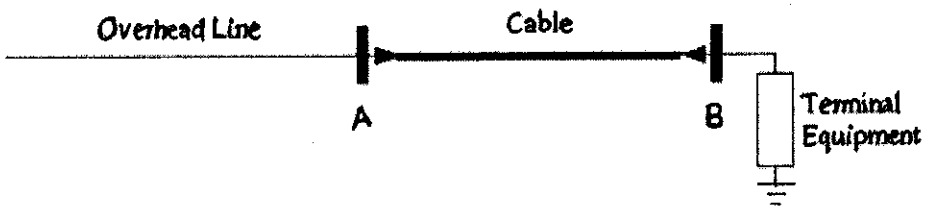



Figure Q3 – Overhead Transmission line Connected to the terminal equipment

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 X$10^8$ m/s, velocity in cable = 2 X$10^8$ m/s] **[11 Marks]**

**c)** State three advantages of DC transmission over AC transmission. **[2 Marks]**

**d)** Briefly explain why the proposed HVDC line from Tamil Nadu to Sri Lanka is not financially viable with respect to the Sri Lankan context. **[3 Marks]**

## Question 4

**a)** High voltages are primarily used for power transmission purposes and secondly used for equipment testing purposes. Why the high voltage generating methods used in high power applications are not applicable for equipment testing purposes? **[3 Marks]**

**b)** Outline the significance of type tests, sample tests and routine tests performed on high voltage equipment. **[4 Marks]**

**c)** An impulse generator is to be designed to generate 600 kV standard impulse voltage waveform (1.2/50 μs) to the test equipment. The nominal energy desired for the impulse generator is 10 kJ. A 65 kV single phase transformer is available.

I. Obtain the values of the coefficients α and β for the standard waveform. **[4 Marks]**

II. If the desired voltage efficiency is 95%, determine the required number of stages for the impulse generator. **[3 Marks]**

III. Sketch the basic impulse generator circuit and determine the values of the associated elements in the circuit to produce the required waveform. **[6 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) Briefly describe two methods that are used to distribute the stress more equally in the high voltage underground cables. **[4 Marks]**

d) A single core cable of conductor diameter 2 cm and lead sheath of diameter 5.3 cm is to be used on a 66kV, 3-phase system. Two inter-sheaths of diameter 3.1 cm and 4.2 cm are introduced between the core and lead sheath. If the maximum stresses in these layers are same, find the voltages on the inter-sheaths. **[11 Marks]**