UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: December 2025

Module Number: EE8308 **Module Name: High Voltage Engineering (C-18)**

[Three Hours]

[Answer **all questions**, each question carries **10** marks]

Q1 a) i) Describe briefly with the aid of suitable diagrams, equations, and/or examples, the breakdown of liquids below intrinsic strength due to one of the impurities mentioned below.

I. Gaseous inclusions
II. Liquid globules

ii) State three methods used for purification of liquid dielectrics and briefly describe one of them.

iii) Describe briefly with the aid of suitable diagrams, the breakdown of solids having voids due to internal discharges in the presence of the applied voltage.

iv) What is meant by "surface flashover" of a piece of solid insulator?

[5.0 Marks]

b) Figure Q1 shows a transformer which has an impulse insulation level of 550 kV and an insulation margin of 20% under lightning impulse conditions. The transformer has a surge impedance of 1887 Ω and is connected to a transmission line having a surge impedance of 470 Ω. A short length of overhead earth wire is to be used for shielding the line near the transformer from direct strikes. Beyond the shielded length, direct strokes on the phase conductor can give rise to voltage waves of the form $1150e^{-0.05\,t}$ kV (with t expressed in μs). If the corona distortion in the line is represented by the expression, $\frac{\Delta t}{x} = \frac{1}{B}\left[1 - \frac{e_o}{e}\right]$ μs/m, where B = 110 m/μs and e_0 = 200 kV, determine the minimum length of shielding wire necessary in order that the transformer insulation will not fail due to lightning surges.

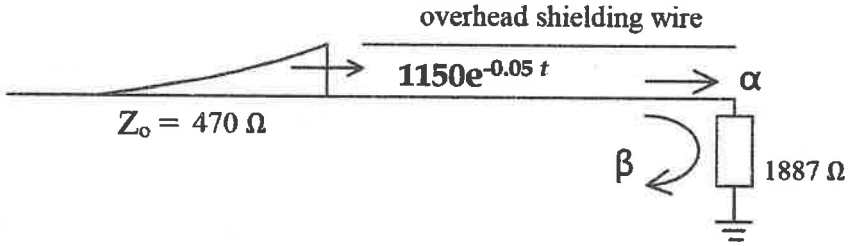

Figure Q1.

[5.0 Marks]

Q2 a) i) What is meant by "stepped leader" and "return stroke" in the process of lightning stroke generation.

ii) With the aid of suitable diagrams, briefly explain one of the below mentioned methods used to design the air termination system of a structure to be protected against lightning.

I. Protective angle method

II. Rolling sphere method

III. Mesh method

iii) State three problems occurred in transmission lines caused by lightning and briefly describe one of them.

iv) Describe the theory of shielding of an overhead transmission line and explain why a taller tower would require a smaller protection angle from an overhead earth wire.

[5.0 Marks]

b) Figure Q2 shows an overhead line AB (length 45 km, Zo = 350 Ω, attenuation factor = 0.9) feeding a terminal equipment (Zo = 1550 Ω) at C through a cable BC (surge impedance = 50 Ω, length 10 km, attenuation factor = 0.95). A step surge of magnitude 100 kV comes to A through a very long overhead line (Zo = 450 Ω). Take the ratio between velocity of propagation of a cable to velocity of propagation of an overhead line as 2:3.

Figure Q2

i) Sketch the Bewley lattice diagram indicating significant values on it for the first 350 μs after the surge is initiated at A. State any assumptions made in your calculations.

ii) Sketch, indicating significant values, the voltage at B for the first 350 μs after the surge is initiated at A.

[5.0 Marks]

Q3 a) Explain the practical existence of chopped surge waveforms and how we can generate them for high voltage testing purposes.

[2.0 Marks]

b) Define the followings for an unchopped surge. Use a diagram to define.

i) Surge front time

ii) Surge tail time

[2.0 Marks]

c) Unchopped surge has 0.1 μs wave front time and 60 μs wave tail time. Establish the equation of the surge. Assume surge magnitude scaling factor is k.

[3.0 Marks]

d) Calculate the time when the peak of this wave form happens.

[3.0 Marks]

Q4 a) Explain the necessity of cable grading.

[2.0 Marks]

b) Single core cable has outer diameter of 4 cm. When the cable core diameter is optimally selected and cable outer diameter is fixed, calculate the value of the maximum voltage that can be applied to the cable, if the maximum stress in insulation to be contained within 12 kV/cm.

[3.0 Marks]

c) Above cable is introduced with an inter-sheath. Calculate the position of the inter-sheath within the cable so that the maximum stress within the cable will be minimised. Calculate the maximum voltage that can be impressed on the cable when the stress within the cable is maintained at the level mentioned in part b.

[5.0 Marks]

Q5 a) Classify the various tests done to ensure the quality of the insulations with brief explanation of each type.

[2.0 Marks]

b) Explain the multilevel test method used for determining insulation breakdown voltage.

[3.0 Marks]

c) Draw a measuring system with potential divider set up for matching the cable at the oscilloscope end.

[2.0 Marks]

d) 500 kV surge is fed into a testing system which consists of resistance type potential divider, coaxial cable and an oscilloscope. The potential divider is provided with high voltage resistor of value 70 kΩ. The characteristic impedance of the cable connecting the divider and measuring instrument is 75 Ω. Calculate the value of the low voltage resistance of the divider that helps to have 74 V at the oscilloscope.

[3.0 Marks]