University of Moratuwa, Sri Lanka

B. Sc. Engineering Degree Course

Final Part III Examination 1994/95

UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs May 1997

Answer **F I V E** Questions Only. All Questions carry equal marks

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1 (a) Describe briefly with the aid of suitable diagrams the streamer mechanism of breakdown of gaseous dielectrics. [30 marks]

(b) In a certain Townsend type discharge, the following measurements were made.

d (mm)	1	2	3	4	5	6	8	10	12	14	16
I (pA)	18	20	25	30	38	42	75	100	145	243	410

Deriving any equations used, from first principles, determine the Townsend's first and second ionization coefficients. [70 marks]

2 An overhead line AB (length = 60 km, surge impedance = 500 Ω, attenuation factor for a single transit = 0.95) is fed from a source of negligible internal impedance. A cable BC (length = 20 km, surge impedance = 50 Ω, attenuation factor for a single transit = 0.9) connects the line to a 950 Ω resistive load. Determine using the Bewley lattice diagram the voltage waveforms appearing at B and C for the first 701 μs after a triangular voltage surge (vertical front, 200 kV peak decaying to zero in 400 μs) originates at the source. [100 marks]

[velocity of propagation: overhead line 3×10^8 m/s, cable 2×10^8 m/s]

3 (a) Show from first principles that a surge on transmission lines can be represented by a forward traveling wave and a reverse traveling wave. Show how this result is made use of in the Bergeron's method of graphical solution. [20 marks]

(b) A step voltage source with an effective source resistance of 50 Ω feeds a line AB (surge impedance = 400 Ω, travel time = 0.5 ms). It is terminated at end B in a load and a surge divertor in parallel, which combination may be represented by

$$v = 1.0\, i \quad \text{kV} \quad \text{for} \quad v \leq 105.26 \text{ kV}$$

$$v = 100 + 0.05\, i \quad \text{kV} \quad \text{for} \quad v \leq 105.26 \text{ kV}$$

Using Bergeron's method, determine and sketch the voltage variation at ends A and B for the first 4 ms after the source is connected at the end A. [60 marks]

(c) If the surge divertor was absent, and the load had an effective resistance of 1000 Ω, determine and sketch the resulting voltage waveform at B. [20 marks]

4 (a) Describe briefly with the aid of suitable diagrams one form of electrostatic generator used to obtain high direct voltages. [20 marks]

(b) Outline the significance of type tests, sample tests and routine tests performed on high voltage equipment. [20 marks]

(c) Give the basic circuit and explain briefly a resonance method used to control the output of a high voltage test transformer. [20 marks]

(d) With the aid of suitable diagrams briefly describe the operation of the Kydonograph for the measurement of lightning. [20 marks]

(e) With the aid of suitable diagrams briefly describe the measurement of dielectric constant and loss tangent of an insulating liquid. [20 marks]

5 Show from first principles that the thermal resistance of a buried cable is given by

$$S = \frac{k}{3\pi} \ln \frac{2h}{r}$$

where the symbols have their usual meanings. [30 marks]

A single phase, composite cable operating at 127 kV, 50 Hz is buried in the ground at a depth of 1.5 m below the surface. If the ambient temperature is 28^{o}C and the maximum permissible temperature of the insulation is 65 ^{o}C, determine the current rating of the cable for the following data. [70 marks]

Diameter of core	=	35 mm
Diameter over inner layer of insulation	=	55 mm
Diameter over outer layer of insulation	=	72 mm
Thickness of lead sheath	=	2 mm
Resistivity of conductor at 65 ^{o}C	=	0.015 Ω/km
Relative permittivity of inner layer of insulation	=	4.4
Relative permittivity of outer layer of insulation	=	3.2
Overall dielectric loss factor of cable insulation	=	0.003
Thermal resistivity of cable insulation	=	5 ^{o}C-m/W
Thermal resistivity of ground	=	1.2 ^{o}C-m/W

6 Describe the process of impulse initiation and the breakdown of successive gaps in multi-stage impulse generators. [20 marks]

A certain impulse generator circuit produces the voltage $v(t) = 250\,(e^{-0.014t} - e^{-5t})$ kV with t in μs. If the wavefront time is defined based on 30% to 90% of peak, determine (a) the wavefront time, (b) the wavetail time, and (c) the peak value of voltage. [80 marks]

7 (a) In a high voltage laboratory, a capacitive potential divider is to be used with a delay cable to observe the surge waveform on an oscilloscope. Explain how the cable may be matched to minimise possible waveform distortion. [30 marks]

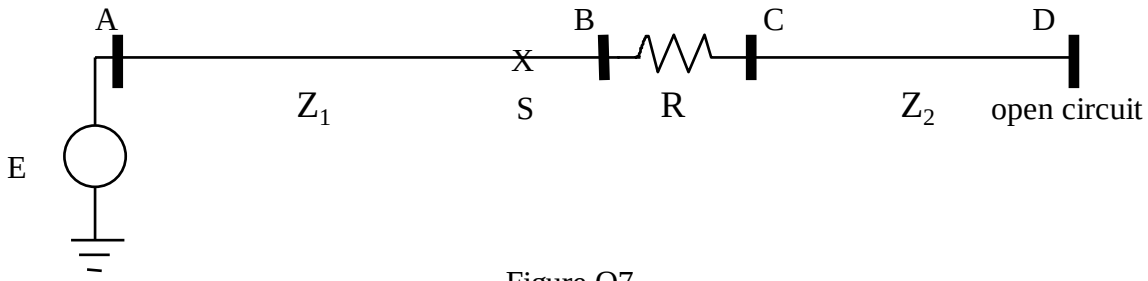

Figure Q7

(b) In the circuit shown in figure Q7, the circuit breaker S energizes the line CD (surge impedance Z_2) through an already energized line AD (surge impedance Z_1). Determine (i) the magnitude of the first surges entering AB and CD and (ii) the magnitude of the surge entering BA due to the first reflection at D. [70 marks]

8 (a) Show from first principles that the distortion in a surge waveform due to corona can be expressed of the form

$$\frac{\Delta t}{x} = k\left[1 - \frac{eo}{e}\right]$$

where Δt is the delay of the voltage element of magnitude e, x is the distance traversed, e_o is the critical voltage, and k is a constant. [40 marks]

(b) For a double star connected bridge convertor, sketch the typical waveforms of (i) the voltage across a thyristor, (ii) current through a thyristor, (iii) input line current on the a.c. side, and (iv) the output d.c. voltage. [30 marks]

Obtain an expression for the mean value of the output voltage when the secondary line voltage of the transformer is E. [30 marks]