9210-210
Level 7 Post Graduate Diploma in Engineering
High voltage engineering

Sample Paper

You should have the following for this examination
- one answer book

The following data is attached
- Worksheet WSQ1

General instructions
- This paper consists of **eight** questions.
- Answer **five** questions.

1 a) Explain Townsend's breakdown mechanism in gases. (6 marks)

b) In a Townsend discharge, the current ***I*** as a function of the gap length ***d*** can be mathematically described by the equation.

$$I(d) = \frac{I_0 e^{\alpha d}}{[1-\beta(e^{\alpha d}-1)]} \text{ ---------- (Equation Q1)}$$

i) Define coefficients α and β used in this equation. (2 marks)

ii) In an experiment, the Townsend discharge current I, was measured for different gap lengths at a constant electric field as shown in the Table Q1. Determine coefficients α and β. (8 marks)

I/pA	14	18	24.5	31	52	86	200	500
d/mm	1	2	3	4	6	8	10	12

Table Q1

c) Explain the time lags involved in breakdown due to impulse voltages. (2 marks)

d) List two adverse effects of corona in transmission lines. (2 marks)

2 a) Define shielding angle of an overhead earth wire. (2 marks)

b) Explain three possible ways in which surges are caused in transmission lines during lightning. (6 marks)

d) Explain the effect of a lightning stroke to an overhead phase conductor. (4 marks)

e) The topmost conductors of an overhead line are strung at an average height of 20 m above the earth in an area of isokeraunic level of 50. The lateral spacing between conductors is 7 m. The number of lightning strokes to earth per square km may taken as 20% of the isokeraunic level. A leader stroke may be attached to the conductors at a distance less than twice their heights. The probability of amplitude exceeding current which corresponds to the flashover level of the line is 75%. Estimate the number of flashovers due to direct strokes per 100 km-year. (8 marks)

3 a) Derive an expression for the velocity of wave propagation and characteristic impedance of a lossless transmission line. (6 marks)

b) An underground cable of inductance 0.189 mH/km and of capacitance 0.3 μF/km is connected to an overhead line having an inductance of 1.26 mH/km and capacitance of 0.009 μF/km. A surge (step voltage) of 200 kV travels to the junction, along the cable. Calculate:

i) the characteristic impedance and velocity of surge propagation of the cable. (2 marks)

ii) the characteristic impedance and velocity of surge propagation of the overhead line. (2 marks)

ii) reflection coefficient at the junction. (2 marks)

iii) magnitude of transmitted and reflected voltage waves at the junction. (4 marks)

iv) magnitude of transmitted and reflected current waves at the junction. (2 marks)

c) What is the voltage magnitude of the reflected wave, if the surge travels to the junction along the overhead line? (2 marks)

4 a) A single stage impulse generator has the charging resistor $R_1 = 30\ \Omega$; the discharging resistor $R_2 = 1\ k\Omega$; charging capacitor $C_1 = 100$ nF; and load capacitor $C_2 = 20$ nF.

i) What is the efficiency of the impulse generator? (2 marks)

ii) Find the front time T_1 and Time to half value T_2 of the generated impulse. (4 marks)

iii) Are these times in part ii), within the acceptable limits? (4 marks)

b) A resonance transformer of Q factor of 50 consists of a feeding transformer, inductor and a capacitor. The output voltage of the feeding transformer is 5 kV. The inductor is a reactor of 10 μH connected through a transformer with a transformer ratio of 1:100. The total capacitance is 100 μF.

i) What is the expected maximum output of the resonance transformer? (2 marks)
ii) Find the resonance frequency. (2 marks)
iii) Calculate the internal resistance of the resonance transformer. (3 marks)
iv) What is the short circuit current? (3 marks)

5 a) A resistive voltage divider has 100 Nos of 1 kΩ resistors connected in series as the high voltage arm (R1). Its low voltage arm resistor (R2) is 50 Ω. A coaxial cable with characteristic impedance of 75 Ω is connected between the divider and the oscilloscope.
i) What is the ratio of the divider if the effect of the characteristic impedance is not considered? (2 marks)
ii) What are the suitable matching impedances required at the divider end and the oscilloscope end? (4 marks)
iii) Draw a diagram showing the divider, coaxial cable, oscilloscope and the matching impedances. (4 marks)
iv) If 100 kV is applied to the high voltage end of the divider, what is the voltage at the oscilloscope for part iii)? (2 marks)
b) With the help of a suitable circuit diagram explain how a corona detector can be used to detect internal discharges. (8 marks)

6 a) List three mechanisms that cause breakdown of liquid dielectrics. (3 marks)
b) List three mechanisms that cause breakdown of solid dielectrics. (3 marks)
c) Explain the process of solid insulation breakdown due to internal discharges. (6 marks)
d) Describe the breakdown process in lightning. (8 marks)

7 a) A cable having a surge impedance of 50 Ω and length of 150 m is used to connect two overhead lines having characteristic impedances of 500 Ω and 600 Ω. Surge propagation velocity of the cable is 1.5×10^8 m/s. A step voltage surge of 1 kV propagating along the 500 Ω overhead line is entering the cable at t = 0.
i) Construct a Brawley lattice diagram for the duration of 5 μs after the surge enters the cable. (6 marks)
ii) Draw a waveform of the voltage entering the 600 Ω overhead line. (4 marks)
b) i) Draw a circuit diagram for a three stage Marx type impulse generator. (4 marks)
ii) Label wave front and wave tail resistors in the circuit diagram. (2 marks)
iii) Indicate the current path during charging and discharging of capacitors. (4 marks)

8 a) Draw a three stage cascade transformer arrangement to obtain high ac voltage. (4 marks)
b) Explain generation of high dc voltages using an electrostatic generator. (6 marks)
c) A sphere gap set up with 12.5 cm diameters is used to calibrate an electrostatic voltmeter. According to IEC 60052, for a given gap distance of 3 cm, the breakdown voltage (peak value) of the sphere gaps is 85 kV. The measured rms value of the voltage of the electrostatic voltmeter is 60 kV. The atmospheric conditions are temperature 25°C, pressure 720 mmHg and the relative humidity 77%.
i) Draw a diagram to show the laboratory set up to calibrate the electrostatic voltmeter. (4 marks)
ii) What is the correction factor? Assume that relative air density and air density correction factor are the same. (3 marks)
iii) What is the error between the measured and the actual rms readings? (3 marks)