UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: February 2020

Module Number: EE8301 **Module Name: High Voltage Engineering**

[Three Hours]

[Answer **all questions**, each question carries 12 marks]

Q1. a) Table Q1.a) shows the measurements which were made in a certain Townsend type discharge. Deriving any equations used, determine the Townsend's first and second ionization coefficients.

[6.0 Marks]

b) A cubical dielectric is tested for insulation resistance by the loss of charge method. An electrostatic voltmeter of infinite resistance is connected between two opposite faces of the dielectric. In parallel with the dielectric, a capacitor is connected with capacitance of 600 pF. It is observed that after charging the capacitor to 300 V and disconnecting it from the supply, the voltage across the dielectric falls as indicated in table Q1.b).

i) Draw the equivalent circuit diagram for above circuit.

[1.0 Mark]

ii) Derive an expression for the voltage across the insulation resistance (R) at time t. How this relationship can be used to determine the value of R experimentally?

[2.0 Marks]

iii) Determine the insulation resistance of the dielectric.

[2.0 Marks]

iv) Discuss the errors in the above test and the measures that can be taken to correct these errors.

[1.0 Mark]

Q2. a) Draw a diagram clearly showing the region in which the lightning stroke is most likely to terminate on the phase conductor, when the tower has shielding wire at the top.

[1.5 Marks]

b) Briefly state what is protective zone of a lightning conductor.

[1.0 Mark]

c) Show that radius of protection (i.e. protection from lightning) for a tower with height h, for a striking distance r_s is given by,

$$h\sqrt{\frac{2r_s}{h}-1}$$

[2.0 Marks]

d) Draw the area of attraction in preference to the earth for a lightning conductor running on a tower with height 175 m for a leader core having a striking distance of 91 m.

[1.5 Marks]

e) A long transmission line AB (Z_o = 450 Ω) is connected to a terminal device at C (Z_o = 1950 Ω) through a short length of cable BC (Z_o = 50 Ω, 400 m, attenuation factor in single transit = 0.9). A rectangular wave of peak height 100 kV originates in the overhead line AB and travels towards the cable. Sketch the Bewley Lattice Diagram, with values for the first 11 μs from the arrival of the surge at junction B. Point A may be assumed to be too far from junction B to consider reflections at point A coming back to junction B. [Velocity of propagation in cable is 2×10^5 km/s]

[6.0 Marks]

Q3. a) Describe the important parameters in defining an impulse voltage (surge).

[2.0 Marks]

b) What are the common impulse voltage types and explain the difference of them with application of each type.

[2.0 Marks]

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

[2.0 Marks]

d) Show that the circuit shown in figure Q3 can be utilized to generate impulse wave form

$$e(t) = \frac{V}{R_1 C_2} \cdot \frac{1}{\beta - \alpha}(e^{-\alpha t} - e^{-\beta t})$$

[6.0 Marks]

Q4. a) In High Voltage DC (HVDC) transmission systems, earth is used as return current path. Discuss the disadvantages of this practice.

[3.0 Marks]

b) Briefly describe bipolar HVDC transmission system.

[3.0 Marks]

c) Define Flexible AC transmission systems (FACTS).

[1.0 Mark]

d) A series compensated transmission line is shown in figure Q4. The compensator Vss' which is generating voltage phasor $Vss'e^{j\beta}$ (β is measured with respect to sending end voltage), is located very close to end A. Assume that line impedance can be lumped to a series inductor X. Active power P, reactive power Q, and voltage V at various points of the system are shown in figure Q4.

i) Plot Q_s against P_s. Derive all formulae you use.

[4.0 Marks]

ii) Identify voltage regulator line, phase angle regulator line, point at which $\beta = 0$ and $\beta = 90^0$ in the plot you have drawn for part i).

[1.0 Mark]

Q5. a) i) Ungraded cable has outer diameter R and conductor diameter r. Assuming that the cable has only single insulation across its diameter, in order to minimize the maximum electrical stress on the insulation, show that the cable diameter and the conductor diameter shall be selected according to

$$\frac{R}{r} = e$$

Also show that the minimum of the maximum stress is given by

$$(E_{max})_{min} = \frac{V}{r}$$

[1.0 Mark]

ii) The cable designed according to part i) has been introduced an inter-sheath at the radius r_1. Leaving R and r fixed and varying only r_1, prove that the minimum of the maximum electrical stress occurs when r_1 is satisfying

$$\ln\frac{r}{r_1} = -\frac{r}{r_1}$$

[2.0 Marks]

iii) For cable in part ii), prove that

$$(E_{max})_{min} = \frac{0.7517V}{r}$$

[2.0 Marks]

iv) Describe the principle behind the skin effect and its impact on distribution of current in cable conductor.

[1.0 Mark]

b) i) What is insulation coordination used in power systems?

[1.5 Marks]

ii) Explain the mechanism of Backflash (due to lightning).

[1.5 Marks]

iii) Explain the reason for having gaps in SiC surge arresters and the ability to build gapless surge arresters using ZnO.

[1.5 Marks]

iv) A certain insulator was selected according to the statistical method of analysis. Curves considered during the selection are shown in figure Q5.b)

1. If $f(V_1) = 2\%$, find $P(V_1)$.
2. Write an expression for the Risk of failure curve (R) in terms of $f(U)$ and $P(U)$.

[1.5 Marks]

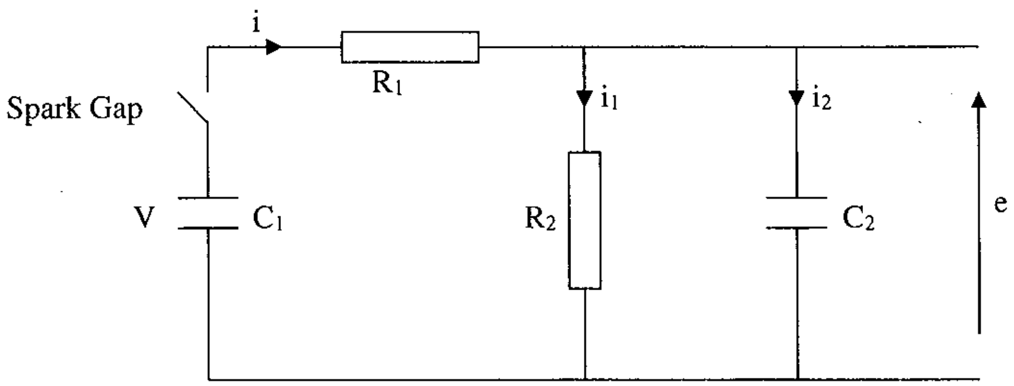

Figure Q3

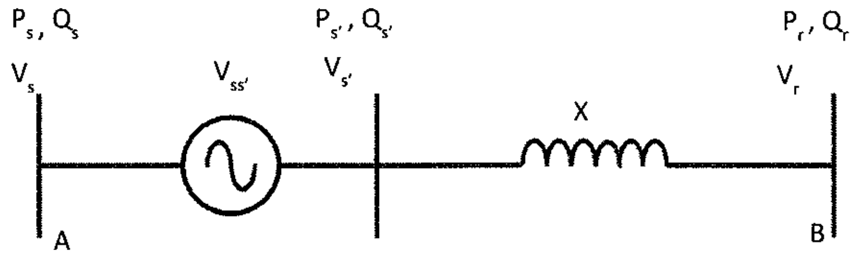

Figure Q4

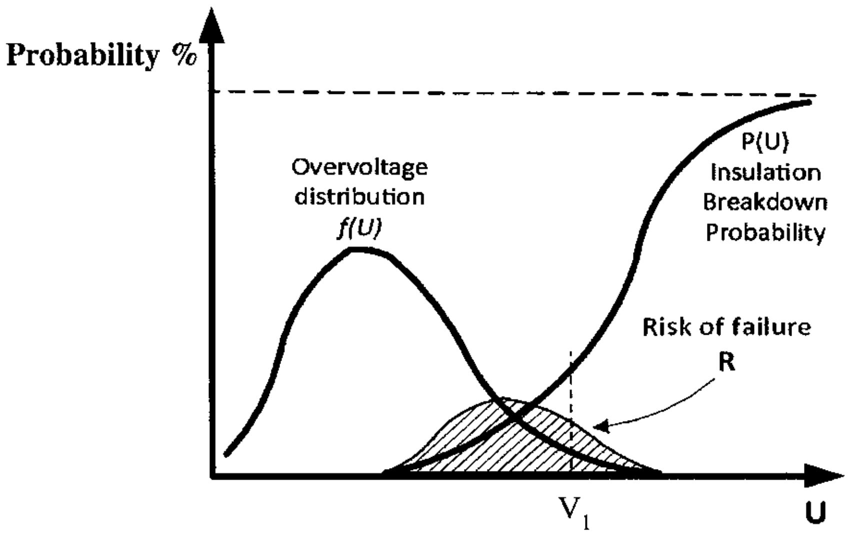

Figure Q5.b)

Table Q1.a)

Distance between anode and cathode - d (mm)	4	6	8	10	12	14	16	18	20	22
Circuit current - I (pA)	20	28	35	50	65	96	145	240	480	1600

Table Q1.b)

Time [min]	0	20	35	60	85
Voltage [V]	300	220	175	119	81