UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: December 2018

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

[Three Hours]

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

Q1. a) Explain why cables with smaller conductor diameters need to have greater thickness and dielectric strength of insulation than those of the cables with larger conductor diameters.

[2.5 Marks]

b) Describe a technique used in Schering Bridge to reduce the earth capacitance effect.

[3.5 Marks]

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

[3.0 Marks]

d) Discuss the problems of ground return in monopolar HVDC systems.

[3.0 Marks]

Q2. a) Derive the expression that relates Townsend's first ionization coefficient to distance between electrodes, number of electrons at the anode and initial number of electrons available at the cathode when the breakdown voltage is applied between anode and cathode. Ignore the secondary effects.

[2.5 Marks]

b) In an experiment where secondary effects are very low, it was found that current at anode is 1.6×10^{-7} A when the electrodes are 0.01 m apart. When the distance between electrodes is reduced to 0.005 m, current at the anode reduced to 1.6×10^{-8} A. Calculate the Townsend's first ionization coefficient and the initial number of electrons available at the cathode. State the assumptions you make.

[3.0 Marks]

c) Write down the expression that relates Townsend's first and second ionization coefficients to the distance between electrodes, number of electrons at the anode and initial number of electrons available at the cathode when the breakdown voltage is applied between anode and cathode. State the assumptions you make.

[2.0 Marks]

d) Table Q2 shows observed currents at the anode for different electrode separations in an experiment where secondary effects are significant. Calculate Townsend's first and second coefficients of ionization based on these results.

Table Q2: Observed currents at various electrode separations

Electrode separation (mm)	Current (A)
1	3.68×10^{-13}
2	2.46×10^{-12}
3	1.64×10^{-11}
4	1.10×10^{-10}
5	7.35×10^{-10}
6	4.91×10^{-09}
7	3.28×10^{-08}
8	2.20×10^{-07}
9	1.47×10^{-06}
10	9.81×10^{-04}

[4.5 Marks]

Q3. a) Explain the Ferranti effect. Under what conditions the Ferranti effect becomes more prominent?

[2.0 Marks]

b) Derive the following expression for a long high voltage transmission line having series distributed reactance of z and shunt distributed admittance of y per unit length. Other terms have their usual meanings.

$$\frac{d^2V(x)}{dx^2} - V(x).yz = 0$$

[2.5 Marks]

c) Prove that, when there is no load, the receiving end voltage of the transmission line mentioned in part (b) is given by

$$V_s = \frac{1}{2}V_r e^{\gamma l} + \frac{1}{2}V_r e^{-\gamma l}$$

where V_r is the receiving end voltage, V_s is the sending end voltage, l is the line length and $\gamma = \sqrt{yz}$.

[4.5 Marks]

d) Deduce that $Vr > Vs$. State any assumption you make.

[3.0 Marks]

Q4. a) Discuss the similarities between the heat flow out of a cable and the current flow in a circuit.

[2.5 Marks]

b) Define thermal capacitance and express the relationship among thermal capacitance, temperature and heat flow using electrical analogy.

[2.5 Marks]

c) Show that the insulation resistance S of a single core cable is given by

$$S = \frac{k}{2\pi}\ln\frac{r_2}{r_1}$$

where k is thermal resistivity, r_1 is the conductor radius and r_2 is the overall diameter of the cable.

[3.0 Marks]

d) Single core cable with single homogeneous insulation without screens, sheaths and armors is hung in air so that its surface temperature is always at θ_a. The thermal capacitances of the conductor and the insulation are Q_c and Q_d respectively. The conductor has negligibly small thermal resistance but the insulation has insulation resistance of $2T$. This cable was energized after long period of de-energisation and produces heat at a rate W_c. Also cable dielectric losses amount to W_d. Neglect any other heat generating phenomena. If the temperature of the surface of the conductor after time t is θ_1, show that

$$\theta_1 + (2Q_c + Q_d)T\frac{d\theta_1}{dt} + T^2Q_cQ_d\frac{d^2\theta_1}{dt^2} = TW_d + 2TW_c + \theta_a$$

Assume that thermal capacitance occurs at the thermal resistance midpoint when it is represented as a lump parameter.

[4.0 Marks]

Q5. A high voltage impulse that was applied to a test object has been transferred to a measuring circuit (CRO) with capacitive type potential divider that is matched at potential divider end (sending end).

a) Draw the circuit diagram used for this measurement showing important components.

[2.5 Marks]

b) Show that before co-axial cable capacitance getting charged, the voltage entering in to measuring circuit E can be expressed as

$$E = \frac{C_1}{C_1 + C_2} E_1$$

where E_1 is the impulse voltage entering in to divider circuit, C_1 and C_2 are two capacitances which divides that voltage (C_1 being at the high voltage end of the divider).

[3.0 Marks]

c) Briefly explain how the voltage mentioned in part (b) distorts when the cable capacitance gets charged.

[1.5 Marks]

d) What is the remedy you can recommend in order to minimize the distortion due to charging up of cable capacitance? Explain with a suitable circuit diagram.

[3.0 Marks]

e) Derive the condition for minimum distortion for the circuit mentioned in part (d).

[2.0 Marks]