Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	HIGH VOLTAGE ENGINEERING
COURSE CODE	:	BEV40403
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 As a lead engineer in an engineering consultant, you are required to give presentations on the following topics:

(a) Analyze the process of electrical breakdown in gaseous dielectrics by comparing the Townsend and Streamer theories. Include diagrams and equations pertinent to each theory to support your analysis.

(10 marks)

(b) Examine the factors that affect the breakdown strength in transformer oils as liquid dielectrics. Analyze how moisture content, temperature, and the presence of suspended particles influence the dielectric strength. Include a diagram to illustrate the impact of suspended particles on breakdown.

(7 marks)

(c) Analyze the different mechanisms that cause breakdown in solid dielectrics, specifically focusing on intrinsic breakdown, electromechanical breakdown, and thermal breakdown. Include diagrams to demonstrate the process of thermal breakdown and discuss the factors that influence it.

(8 marks)

Q2 High voltages AC and DC are generated and measured in many ways. Depending on the types of voltages, there are specific methods to safely generate and measure them. Give answers to the following questions:

(a) High Voltage AC Generation and Measurement:

(i) Describe the operating principle of a single-phase transformer used for generating high voltage AC.

(4 marks)

(ii) Describe the method of measuring high voltage AC using a capacitive voltage divider. Include a schematic diagram of the setup.

(4 marks)

(iii) Analyse the expected output voltage if a transformer with a turns ratio of 1:100 is connected to a 230 V supply. What would be the implications if the secondary voltage is used to test insulation materials?

(4 marks)

(b) High Voltage DC Generation and Measurement:

(i) Evaluate the construction and operation of a Cockcroft-Walton multiplier used for generating high voltage DC. Compare it with a basic rectifier setup and discuss the differences. Include a schematic diagram to support your evaluation.

(4 marks)

(ii) Describe how a resistor-capacitor (RC) divider can be used for measuring high voltage DC and discuss its advantages and limitations compared to direct measurement methods.

(4 marks)

(c) Describe the generation of impulse voltages using a Marx generator. Explain the role of each component in the setup. Provide a drawn and labeled circuit diagram of a Marx generator with three stages.

(5 marks)

Q3 (a) Explain **two (2)** important reasons for engineer to conduct HV measurement.

(4 marks)

(b) Salt fog test can be categorised as destructive test which usually being used to verify the durability of the insulation material in withstanding severe electrical stresses.

(i) Explain **three (3)** key differences of destructive test as compared to non-destructive test.

(6 marks)

(ii) Propose an experimental setup of salt fog test to conduct acceleration aging test on outdoor insulator. Include appropriate schematic diagram and explanations.

(7 marks)

(c) A Schering bridge as in **Figure Q3(c)** is used to measure the capacitance and dissipation factor of insulation system in power transformer. The bridge achieved balance at the following condition:

Arm 1 Standard condenser of 1000 pF

Arm II Resistance of 200 Ω

Arm IV A capacitance of 70 nF in a parallel with a resistance of 1000 Ω

Determine the capacitance and dissipation factor of the transformer's insulation.

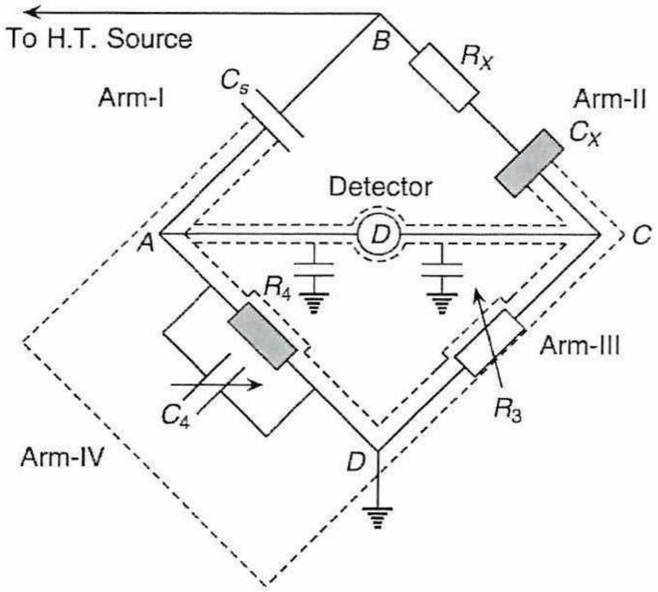

Figure Q3(c)

(4 marks)

(d) A solid insulating medium with a thickness of 1.5 cm having a dielectric constant of 4.5 is subjected to a power frequency. The specimen contains an air void of thickness 1 mm. Determine the maximum voltage that can be applied across the specimen without any internal discharge. Assume the breakdown strength of air is 30 kV/cm.

(4 marks)

Q4 (a) Discuss the important of insulation coordination based on **two (2)** appropriate examples of high voltage applications.

(4 marks)

(b) An overhead line suspended on transmission tower needs to have 50% ability to withstand 1425 kV_{peak} lightning, 1050 kV_{peak} switching and 480 kV_{peak} power frequency overvoltages.

(i) Classify the required electrical clearance distances for the conductor to tower structure. Consider the gap factor, K_g = 1.55 and the altitude correction factor, K_A = 1.15.

(6 marks)

(ii) Determine the value of gap factor, K_g if the electrical clearance distance for temporary overvoltages, *TOV* is to be at 0.55 m. Use K_A = 1.15.

(3 marks)

(c) The lightning flashes may be created based on the interaction of charge separation took place in the thunderhead cloud. The creation of the flash can be divided into two groups; the first stroke and the second stroke phenomenon. **Figure Q4(c)** shows the cloud to ground conditions associated with the creation of first stroke phenomenon.

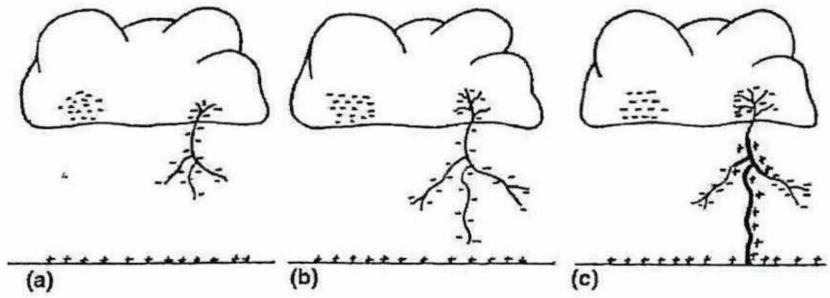

Figure Q4(c)

(i) Illustrate the cloud to ground conditions associated with the creation of second stroke phenomenon.

(3 marks)

(ii) Based on the illustration in **Q4(c)(i)** and in **Figure Q4(c)**, briefly explain both the first stroke and second stroke phenomenon

(6 marks)

(iii) Sketch a waveform of 600 kV_{peak} standard lightning impulse waveform characterise by rise time, T1 and decay time, T2.

(3 marks)

- END OF QUESTIONS -

APPENDIX A

The Townsend's Ion Pairs Criterion Equation

$$\alpha d = \ln\left(1+\frac{1}{\gamma}\right) = ion\_pairs$$

The Electric Field of Charged Sphere Surface Equation

$$E_{r\_V/m} = \varepsilon \frac{e^{\alpha d}}{4\pi K_0 r_d^{\;2}}$$

The Paschen's Law Equation

$$V_{b\_kV} = 24.22\frac{293p}{760T}d + 6.08\sqrt{\frac{293p}{760T}d}$$

The Stark and Garton's Equation

$$V_s = d\sqrt{\frac{2Y}{\varepsilon_0\varepsilon_r}\ln\left(\frac{d_o}{d}\right)}$$

The Dielectric Dissipation Factor's (tan δ)

$$\tan\delta = \frac{W_{ac}\times 1.8\times 10^{12}}{E^2 f\varepsilon_r}$$

$$R_X = \frac{C_4}{C_s}\cdot R_3 \qquad\qquad C_X = \frac{R_4}{R_3}\cdot C_s$$

$$\tan\ \delta = \omega C_X R_X = \omega C_4 R_4$$

Voltage across void

$$V = V_v\left\{1 + \frac{1}{\varepsilon_r}\left(\frac{d}{t} - 1\right)\right\}$$

Frequency at Resonant

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

U50 Electrical Clearances (meter) in Accordance with IEC 60071-1 (1993)

$$d_{\_ffo} = \frac{U50_{ffo}}{530\times(0.74+0.26K_g)\times K_A}$$

$$d_{\_sfo} = \frac{e^{\left(\frac{U50_{sfo}}{1080\times K_g\times K_A}\right)}-1}{0.46}$$

$$d_{\_pf} = \left(\frac{e^{\left(\frac{U50_{pf}}{750\sqrt{2}\times K_g\times K_A}\right)}-1}{0.55}\right)^{0.833}$$