Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	HIGH VOLTAGE ENGINEERING
COURSE CODE	:	BEV 40403
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY/ AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **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 **SIX (6)** PAGES

Q1 (a) Name **two (2)** main international bodies and **one (1)** local authority agency related to the High Voltage field.

(3 marks)

(b) An experiment to examine breakdown phenomena of gas is conducted inside a pressurized chamber occupied with air. Distance between electrodes is set to be 1.5 cm and the temperature is maintained at 80°C. The experiment is conducted under two different pressure conditions at $P_1 = 1.5$ bar and $P_2 = 2.5$ bar.

(i) Estimate the breakdown voltage under both pressure conditions, V_{b1} and V_{b2} by using the Paschen's Law. Use 1 bar = 750.06 mmHg.

(6 marks)

(ii) Plot a graph of Breakdown Voltage, V_b against Pressure, p.

(3 marks)

(iii) Analyse the result obtained in **Q1(b)(ii).**

(3 marks)

(c) In a breakdown test, a sample of cured silicone rubber with 50 mm of thickness is placed between electrodes. The thickness of the sample becomes 48 cm when energised with a high voltage source. Given that relative permittivity, ε_r of silicone rubber is 4.7 and constant Young Modulus = 170 kN/m^2.

(i) Determine the applied voltage, V_s that caused the deformation.

(3 marks)

(ii) Estimate the highest electric stress, E_{max} of the sample.

(3 marks)

(iii) Explain **two (2)** common characteristics and **two (2)** differences between electrical treeing vs. water treeing phenomenon.

(4 marks)

Q2 (a) A single phase HVAC *RLC* circuit, with 1.5 kV AC peak applied voltage, consists of a capacitor, inductance $L = 75$ mH and resistor $R_1 = 0.1$ ohm in series with $R_2 = 0.2$ ohm. If the resonance phenomenon is found to occur at 18.2 Hz.

(i) Calculate the value of capacitance, C used in the circuit.

(3 marks)

(ii) Determine the overshoot voltage, V_L and Q factor during the resonance.

(5 marks)

(iii) Evaluate the Q factor of the circuit at frequency of 50 Hz.

(3 marks)

(b) High voltage impulse source exceeding 500kV can be generated by using Marx Generator.

(i) Propose an equivalent circuit with appropriate labelling for two (2) stages Marx generator during charging and discharging cycle.

(6 marks)

(ii) Briefly explain the operation of the circuit in **Q2(b)(ii)**.

(4 marks)

(iii) Describe the role of damping resistor, R_D and front capacitor, C_f , respectively.

(4 marks)

Q3 (a) A 1500 kV/μs steep propagating wave is approaching a transformer along a 123 kV line as shown in **Figure Q3(a)**. The voltage withstand level of the transformer is 550 kV. The arrestor is located 10 m away from the transformer and has a protection level of 380 kV. Voltage drop Δu_1 caused by joint and earthing coupling (d_1, d_2) is assumed to be 20 kV.

(i) Calculate the effective protection level, $u_{p(eff)}$ for this arrestor placement.

(7 marks)

(ii) Briefly explain if the effective protection level, $u_{p(eff)}$ is adequate to protect the transformer from the impulse.

(5 marks)

(iii) If the level exceeds transformer's withstand level, identify **two (2)** methods that can be performed to protect against steep impulse.

(4 marks)

(b) Impulse waveform is characterised by the rise time, T_1 and decay time, T_2.

(i) Sketch waveform of 1000 kV_{peak} standard lightning impulse waveform with T_1 and T_2 with appropriate labels.

(2 marks)

(ii) Propose an equivalent circuit to produce standard lightning impulse waveform.

(3 marks)

(iii) List **two (2)** purposes for the need of impulse generator in the high voltage engineering.

(4 marks)

Q4 (a) State **one (1)** test measurement that is categorised under the non-destructive test and name **one (1)** high voltage equipment is used in the non-destructive test.

(4 marks)

(b) An insulator is composed of two parallel connected plane capacitors C_1 of 100 nF and C_2 of 200 nF as shown in **Figure Q4(b)**. The loss angles (dissipation angles) for each of the plane capacitors are $\delta_1 = 4.6°$ and $\delta_2 = 5.7°$. Between the insulation, there are two electrodes and the distance between them is 3 mm. The electrode is supplied with RMS voltage, V of 6 kV at 50 Hz.

(i) Determine the dissipation factor (tan δ) of the insulator.

(6 marks)

(ii) Determine the dielectric losses (W) and capacitive reactive power (Q) of the insulator.

(6 marks)

(iii) Conclude the dissipation factor (tan δ) value if the insulation condition further degrades and producing more loss.

(2 marks)

(c) The tracking test usually being used to verify the durability of the insulation material in withstanding severe electrical stresses. The test can represent the acceleration aging processes that typically occur at outdoor environment over the years in service. Propose **one (1)** comprehensive experiment setup and the working concept of the test.

(7 marks)

– END OF QUESTIONS –

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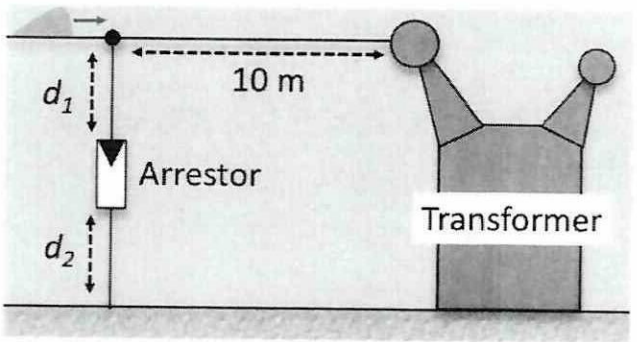

Figure Q3(a)

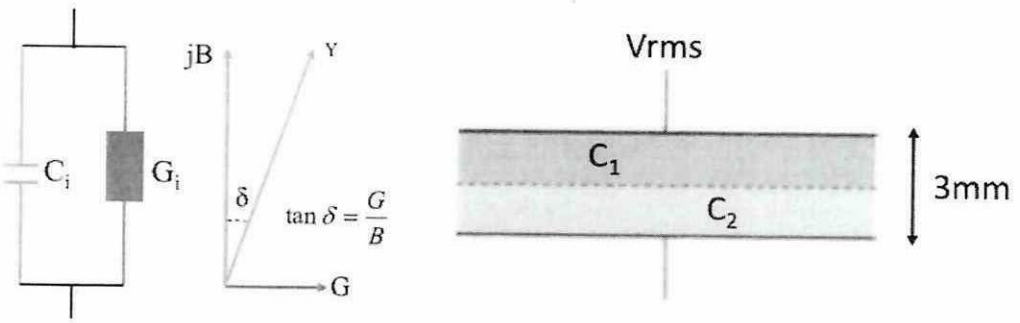

Figure Q4(b)

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SELECTED FORMULAE

$$V_b = 24.22\frac{293p}{760T}d + 6.08\sqrt{\left(\frac{293p}{760T}d\right)}$$

$$\varepsilon_r\varepsilon_0\frac{V^2}{2d^2} = Y\ln\left(\frac{d_0}{d}\right)$$

$$V = d\sqrt{\frac{2Y}{\varepsilon_0\varepsilon_r}\ln\left(\frac{d_0}{d}\right)}$$

$$\frac{V_m}{d} = \sqrt{\frac{Y}{\varepsilon_0\varepsilon_r}}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

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

$$B = \omega C$$

$$G = \omega(C_1 tan\delta_1 + C_2 tan\delta_2 + \ldots)$$

$$Y = G + jB$$

$$tan\delta = \frac{G}{B}$$

$$S = P + jQ = UI^* = U(U^*Y^*) = U^2Y^*$$