Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	HIGH VOLTAGE ENGINEERING
COURSE CODE	:	BEF 45203 / BEV 40403
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS A (**ONLINE**) ASSESSMENT AND CONDUCTED VIA (**CLOSE 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 (a) Dielectric is a material in which electrostatic fields can remain almost indefinitely.

(i) With an appropriate illustration, describe the initiation of ionization process in a material.

(4 marks)

(ii) Explain **one (1)** key difference between Townsend and Streamer's theory.

(2 marks)

(iii) Suggest **two (2)** advantages of liquid dielectric as compared to the gas or solid dielectric.

(4 marks)

(b) A test to study breakdown phenomena is conducted inside a pressurized chamber occupied with air. The distance between electrodes is 1.5 cm and the temperature is maintained at 80 °C. The test is performed under two different pressure conditions at p1 = 1.5 bar and p2 = 2.5 bar.

(i) Estimate the breakdown voltage under both pressure conditions, Vb_1 and Vb_2 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.

(2 marks)

(iii) Analyse ~~and describe~~ the result obtained in **Q2(b)(ii).**

(2 marks)

(c) A small sample of cured silicone rubber with 50 mm of thickness is placed between electrodes. After applying a certain voltage magnitude, the original thickness of the sample is reduced by 2 mm. 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.

(2 marks)

Q2 (a) List and explain **two (2)** advantages of insulated enclosure type transformer as compared to the tank type transformer.

(4 marks)

(b) 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) Identify **two (2)** scenarios in which resonance may be utilised for a benefit.
(4 marks)

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

(i) Sketch waveform of 300 kVpeak standard lightning impulse waveform with T_1 and T_2 with appropriate labels.
(2 marks)

(ii) Propose an equivalent circuit to produce output waveform in **Q2(c)(i)** with Vc = 100 kV.
(3 marks)

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

Q3 (a) State **one (1)** test measurement that is categorised under the non-destructive test.
(2 marks)

(b) A single phase HVAC RLC series circuit consists of inductance, L = 75 mH, capacitance, C = 1020 μF and resistance, R = 0.3 Ω. The single phase supplied voltage, V_i = 1.5 $kV_{a.c.\ peak}$. Calculate:

(i) The maximum current, I_{max}, the voltage overshoot, V_L and Q factor of the circuit occurrence at the resonance frequency, f_r condition. Neglect any losses in the circuit.
(4 marks)

(ii) The new Q factor of the circuit occurrence at 50 Hz frequency condition.
(2 marks)

(c) Illustrate a standard waveform of single phase 1000 kV_{peak} fast front overvoltages (*FFO*) that having a rise time, T_1 and decay time, T_2 at their recommended maximum tolerances in accordance with Standard IEC 60071.
(4 marks)

(d) Marx generator circuit is commonly used to generate higher lightning or switching impulse voltages. Propose the general circuitry connections and logical working conditions of the two-stage Marx generator.
(6 marks)

(e) 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)

Q4 (a) Define the term insulation coordination according to the Standard IEC 60071.

(2 marks)

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

(4 marks)

(c) According to Standard IEC 60071, types of overvoltages are classified based on their voltage magnitude and the duration. Sketch with appropriate labels and time scale (voltage p.u *vs.* duration) to indicate these types of overvoltages classification.

(4 marks)

(d) 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) As an engineer, 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.

(4 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)

(e) 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(e)** shows the cloud to ground conditions associated with the creation of first stroke phenomenon.

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

(3 marks)

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

(5 marks)

– END OF QUESTIONS –

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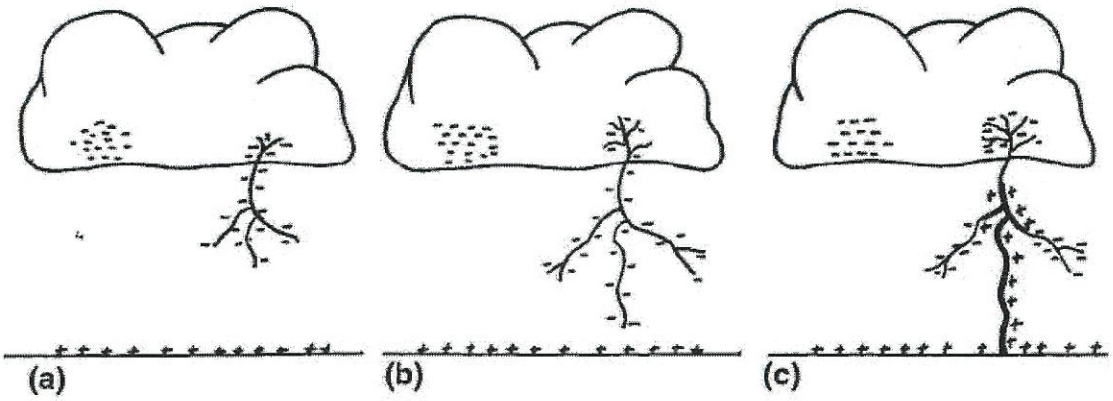

Figure 1 The first stroke. (a) Stepped leader starts. (b) Stepped leader reaches ground. (c) Upward channel moves toward cloud.

Figure Q4(e)

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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

$$E_{r\_V/m} = \frac{\varepsilon e^{\alpha d}}{4\pi\varepsilon_0 r_d^{\,2}}$$

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) Equation

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

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Frequency at Resonant

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

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

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

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

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