UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE	:	HIGH VOLTAGE ENGINEERING
COURSE CODE	:	BEF 45203
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	DECEMBER 2018/ JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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Q1 (a) High voltage AC are categorised based on the range of voltage levels, for example low voltage (LV): 12V, 240V, 415V. List other system voltage levels and state a typical voltage rating used in Malaysia.

(3 marks)

(b) Breakdown in gaseous dielectric can be described by Townsend and Streamer's mechanism.

(i) Describe the mechanism that lead to Streamer's breakdown. Include relevant illustration of the phenomenon.

(10 marks)

(ii) Differentiate between Townsend and Streamer's mechanisms.

(4 marks)

(c) A uniform static field is created between 5.5 cm parallel plate electrodes system in an enclosed chamber that contains Argon at pressure of 300 mmHg. The space charge created by an avalanche is nearly 3.5 cm in radius when an external electric field, E_0 of 125 kV/cm is applied across the electrode plates.

(i) Estimate the value of first ionisation coeficient, α under favorable condition for the formation of streamers in the Argon gap.

(6 marks)

(ii) State your assumption(s) in estimating α in **Q1(c)(i)**.

(2 marks)

Q2 (a) Dielectric is a material in which electrostatic fields can remain almost indefinitely.

(i) State three (3) advantages of liquid dielectric as compared to gas and solid dielectric.

(3 marks)

(ii) Describe two (2) important characteristics of dielectric materials that need to be considered for high voltage insulation purposes.

(4 marks)

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(b) A test to study breakdown phenomena is conducted inside a pressurised 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 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) Sketch and label the output graph of breakdown voltage, V_b against Pressure, p.

(2 marks)

(iii) Explain the result obtained **Q2(b)(i)** in terms of percentage increment or decrement.

(2 marks)

(c) A small sample of cured silicone rubber with 0.05 m of thickness is placed between electrodes. After applying a certain voltage magnitude, the original thickness of the sample is reduced by 0.002 m. 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)

(iii) Predict thickness of the sample after deformation if the applied voltage in **Q2(c)(i)** is doubled.

(3 marks)

Q3 (a) Transformer is a key equipment in high voltage systems. Discuss general characteristics of testing transformer used in laboratories as compared to the power transformers used in substations.

(4 mark)

(b) Impulse waveform is characterised by the rise time, T_1 and decay time, T_2. Sketch with appropriate labels waveform of 145 kV$_{peak}$ standard lightning impulse waveform with T_1 and T_2 at their recommended maximum tolerances.

(4 marks)

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(c) The use of the straight transformer with particular capacitance load may lead to resonance phenomenon. Consider a single phase HVAC RLC series circuit consists of inductance L = 70 mH, capacitance C = 1500 pF and resistance of R = 0.75 ohm. The supply voltage, V_i is at 1.5 kV rms.

(i) Determine the maximum current, I_{max}, the voltage overshoot, V_L and the Q factor of the circuit during the resonance frequency condition. Neglect any losses in the circuit

(6 marks)

(ii) Determine the frequency at which the circuit will give Q factor of 85 p.u

(3 marks)

(iii) Suggest a condition in which resonance phenomenon may be developed.

(2 marks)

(d) Tests on insulation systems using HVAC can be categorised as:

- Whole scale insulation tests
- Small scale insulation tests
- Long duration insulation test

Briefly describe each of the listed test methods with appropriate examples.

(6 marks)

Q4 (a) Insulation coordination is a process of bringing the insulation strengths of electrical equipment into a proper relationship with expected overvoltages based on the characteristic of surge protective devices.

(i) Classify three (3) types of overvoltages.

(3 marks)

(ii) Discuss two (2) importance of good insulation coordination based on appropriate example of high voltage applications.

(4 mark)

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

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(i) Analyse the required electrical clearance between 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 at power frequency is 0.55 m. Use altitude correction factor, $K_A = 1.15$

(3 marks)

(c) Lightning flash is created based on the interaction of charge separation in the thunderhead cloud. The creation of the flash can be divided into two stages, the first stroke and the second stroke. **Figure Q4(c)** shows the cloud drawings illustrating the first stroke phenomenon.

(i) Illustrate (draw and label) the second stroke phenomenon.

(3 marks)

(ii) Based on illustrations in **Figure Q4(c)** and your answer in **Q4(c)(i)**, briefly describe both the first stroke and second stroke phenomenon.

(6 marks)

- END OF QUESTION -

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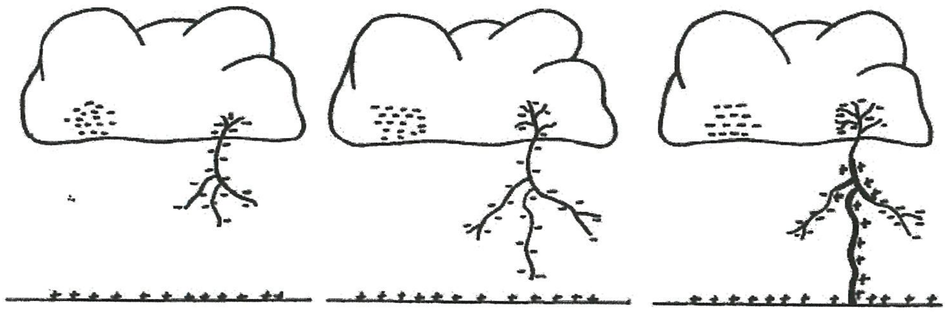

FIGURE Q4(c)

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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

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

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) 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)

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

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

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

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