UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2012/2013

COURSE	:	HIGH VOLTAGE ENGINEERING
COURSE CODE	:	BEX 44503 / BEK4113
PROGRAMME	:	4 BEE
EXAMINATION DATE	:	JUNE 2013
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) Name a device that is considered as a key to open the door to the high voltage engineering.

(1 mark)

(b) System levels of high voltage AC are categorised base on the range of voltage level, e.g. low voltage (LV): 12V, 240V, 415V. List three (3) other system voltage levels/ categories with their typical voltage magnitudes used in Malaysia.

(3 marks)

(c) With the help of appropriate illustration, describe the mechanism that lead to Streamer's breakdown.

(8 marks)

(d) A uniform static field was created between 55 mm parallel plate electrodes system in enclosed chamber contains Argon at 300 mm.Hg pressure. It was observed that the space charge created by an avalanche lay nearly in a sphere with radius, r_d = 35 mm when an external electric field, E_0 of 125 kV/cm applied across the electrode plates. Absolute permittivity, ε_0 of the test area is 8.854×10^{-12} Farad/m and the charge of electron is 1.6×10^{-19} Coulomb. Estimate the value of α under favorable condition for the formation of streamers in the Argon gap.

(7 marks)

(e) Discuss three (3) main problems that can cause abnormal flow of high voltage.

(6 marks)

Q2 (a) Define the term '*dielectric material*' and hence explain the primary function of this material in high voltage engineering.

(3 marks)

(b) Liquid dielectrics are used in many high voltage equipments such as power transformer and cables. Provide three (3) advantages of liquid dielectric as compared to other types of dielectric materials i.e. gas and solid dielectrics.

(3 marks)

(c) A test to study breakdown phenomena was conducted inside a pressurised chamber filled with air. The gap between electrodes was adjusted to be at 15 mm and the temperature was maintained at 80°C. The test was performed under two different pressure conditions at p_1 = 1.5 Bar and p_2 = 2.5 Bar.

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

(ii) Comment the results obtained in Q(2)(c)(i) in terms of percentage increment/decrement

(iii) Plot and label the output graph of breakdown voltage, Vb against pressure, p. Use 1 bar = 750.06 mm.Hg

(10 marks)

(d) Lower electric stress causes failure in longer period of time e.g. treeing and chemical, while higher electric stress cause breakdown in transient time e.g. avalanche. Sketch a curve i.e. breakdown field (V/cm) vs. duration (s) with appropriate label and time scale that illustrates different type of failure mechanisms occur in solid dielectrics.

(3 marks)

(e) A small sample of cured silicone rubber with 5.0 cm of thickness is place between electrodes. After applying a certain voltage magnitude, the original thickness of the sample is reduced by 2.0 mm. Given that relative permittivity, ε_r of silicone rubber is 4.7 and constant Young Modulus = 170 kN/m^2, hence

(i) Calculate the applied voltage, V_s that caused the deformation

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

(iii) Estimate the thickness of the sample after deformation if the applied voltage in Q2(e)(i) is doubled.

(6 marks)

Q3 (a) Give three (3) common types of HVAC transformer.

(3 mark)

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

(ii) Determine the frequency at which the circuit will give Q factor of 75 p.u

(7 marks)

(c) Transient impulse voltages can be classified as the fast front overvoltages (FFO), typically created by lightning and the slow front overvoltages (SFO), created by switching activities. The waveforms are characterised by the rise time, T_1 and decay time, T_2. Draw with appropriate labels

(i) A waveform of 145 kV_{peak} standard lightning impulse waveform with T_1 and T_2 at their recommended maximum tolerances

(ii) A waveform of 75 kV_{peak} standard lightning impulse waveform with T_1 and T_2 at their recommended minimum tolerances

(4 marks)

(d) An impulse circuit consists of two individual circuit components, namely i) '*charging*' circuit creating the wavefront and ii) '*discharging*' circuit creating the wavetail. Draw an equivalent circuit for each of these *charging* and *discharging* circuits, and hence design a complete equivalent circuit for a single-stage impulse generator.

(5 marks)

(e) Testing on the insulation system using HVAC can be categorised as:

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

Briefly describe each of the listed testing methods with appropriate example of testing.

(6 marks)

Q4 (a) State the definition of '*insulation coordination*' according to the Standard IEC60071.

(2 mark)

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

(4 marks)

(c) In the IEC standard, different type of overvoltages e.g. lightning (FFO) and switching (SFO) overvoltage are classified based on the voltage magnitude and the duration. Sketch a graph i.e. voltage (p.u.) vs. duration to indicate four (4) different type of overvoltage classifications.

(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, propose 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

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

(7 marks)

(e) The 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(e) shows the cloud drawings that illustrate the first stroke phenomenon. Hence

(iii) Construct (draw and label) the cloud drawings that illustrate the second stroke phenomenon.

(iv) Based on illustrations in Figure Q4(e) and your answer in Q4(e)(i), briefly explain both the first stroke and second stroke phenomenon.

(8 marks)

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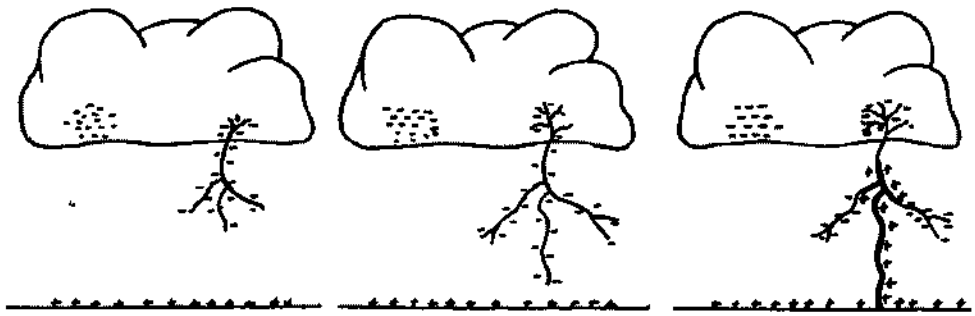

FIGURE Q4(e)

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

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

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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

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

Frequency at Resonant

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

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

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

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

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