University of Moratuwa, Sri Lanka

Faculty of Engineering

Department of Electrical Engineering

B. Sc. Engineering Honours Degree Course

Level 4 – Semester 2 Examination

EE4270 – HIGH VOLTAGE BREAKDOWN & TESTING

Time Allowed: 2 Hours February 2009

Additional Material

Graph Paper will be provided if required.

Instructions to Candidates

This paper contains 5 questions in 4 pages.

This examination accounts for 70% of the module assessment.

Total marks for the paper is 70 marks.

The maximum marks attainable is indicated in square brackets.

Answer **All** Questions.

This is a closed book examination and only authorised Calculators will be permitted.

Technical Information for candidates

Permeability of free space $\mu_0 = 4 \pi \times 10^{-7}$ H/m

Permittivity of free space $\varepsilon_o = 8.854 \times 10^{-12}$ F/m

Velocity of light in free space = 2.998×10^{8} m/s

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Question 1

(a) Describe briefly, with the aid of suitable diagrams and equations, the avalanche process in the breakdown process of gaseous dielectrics. [*2 marks*]

(b) Explain the streamer mechanism for breakdown in gaseous dielectrics. [*3 marks*]

(c) Explain very briefly, considering the breakdown of gaseous dielectrics, why SF_6 is suitable in indoor substations. [*1 mark*]

(d) Show with the aid of suitable diagrams how the time lag characteristic of spark breakdown may be determined for the standard impulse voltage waveform. [*2 marks*]

(e) Explain why breakdown of liquids occur below their intrinsic strength, due to the 3 types of impurities. [*3 marks*]

(f) Explain the thermal breakdown of solid insulating materials. [*3 marks*]

Question 2

(a) A 132 kV, three-phase, 50Hz transmission line uses 18 mm diameter, equally spaced ACSR conductors. Determine the spacing between these conductors, if it is to be designed such that the corona inception voltage is 5% higher than the normal operating voltage of the line at 40^{o} C. *You may assume the expression relating the electric field and the voltage of the line as a starting point*. [*3 marks*]

(b) Describe briefly, with the aid of suitable diagrams the cascade arrangement of transformers to obtain high alternating voltage for testing purposes. [*3 marks*]

(c) A 100 kVA, 50 Hz, 230/50 kV testing transformer has an 10% leakage reactance and a 2% winding resistance. A cable of capacitance 100 nF is to be tested at 300 kV using this transformer as part of the resonance circuit. Determine the value of the inductance (with a Q-factor of 20) required to obtain resonance and the value of the input voltage required to obtain the required voltage. [*6 marks*]

(d) Describe briefly, with the aid of suitable diagrams the capacitor charging method of measuring the peak value of a high voltage waveform. [*2 marks*]

Question 3

(a) A single phase cable for a 3-phase, 72.5 kV system, is to be designed using 3 insulating materials A, B, and C with peak critical breakdown stresses of 200 kV/cm, 180 kV/cm and 250 kV/cm and corresponding relative permittivities of 4.4, 3.2 and 2.8 respectively. If the conductor radius is 10 mm, determine the order and thickness of the insulation for optimum dimensions of the cable. Take a safety factor as 2 in the design. [*7 marks*]

(b) By deriving the basis for sketching, sketch the field pattern in a three core belted type cable by considering a particular instant of time. [*4 marks*]

(c) Using sketches, explain cross-bonding of high voltage cables. [*3 marks*]

Question 4

(a) Show that the deflecting torque of an electrostatic voltmeter is proportional to the product of the square of the applied voltage and the rate of change of capacitance. [*3 marks*]

(b) Describe the principle of operation of the attracted disc electrostatic voltmeter. [*2 marks*]

(c) Describe briefly, with the aid of suitable diagrams why a resistive potential divider needs to be matched to the cable connecting it to an oscilloscope, and how the matching may be achieved. [*4 marks*]

(d) Describe with the aid of suitable diagrams how the dielectric loss in a lossy capacitor is measured in comparison with a standard lossless capacitor using the x-y mode in the oscilloscope. Show that the area of the ellipse displayed is proportional to the loss.

[*5 marks*]

Question 5

(a) Figure Q5 shows a circuit diagram of a high voltage Schering Bridge, with the values at the balance condition. If the dielectric has a cross-section area of 0.01 m^2 and the spacing of 2 cm, determine the relative permittivity and the resistivity of the material. [*7 mark*]

(b) Sketch the diagram of a typical standard capacitor as connected in a high voltage Schering Bridge. [*1 mark*]

(c) Using suitable diagrams briefly describe the test cell used in the measurement of dielectric constant and loss tangent of an insulating liquid. [*1 mark*]

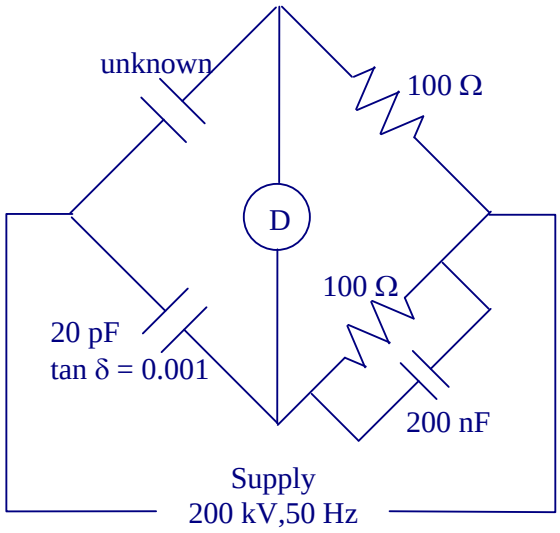

Figure Q5

(d) Describe how resonance is used to obtain the Q-factor using such a cell. [*2 marks*]

(e) Describe briefly why high voltage tests are generally classified into routine tests, sample tests and type tests (or acceptance tests) giving examples to illustrate it. [*3 marks*]

[END OF QUESTION PAPER]