A student taking High Voltage Engineering Master course at Department of Energy Technology at AAU wants to do some measurement in the HV lab.

Q1: The student wants to design a single stage impulse generator in the HV lab. He chooses the type b circuit.

(1) Explain why the discharge capacitance C_1 is chosen be larger than the load capacitance C_2.

$\eta \approx \frac{1}{1+\frac{C_2}{C_1}}$, thus a bigger C1 can enhance the efficiency of the circuit.

(2) Now the values of C_1, C_2 are given as 20nF and 2nF respectively. The student plans to generate a standard switching impulse waveform. Please decide the values of R_1 and R_2 in the circuit.

Eqn(2.38, 2.39) and table on page 58 in the Kuffel book are used.

$R_1 = 59.25k\Omega$

$R_2 = 130k\Omega$

(3) The charging voltage on C_1 is 50 kV. Based on parameters defined in (2), write down the voltage V(t) on the load capacitor and draw the impulse curve by Matlab or other software. Calculate the front time T_1 and the time to half-value T_2 based on the curve of V(t). State whether T_1 and T_2 fulfill the requirement of the standard switching impulse waveform.

$V(\mathrm{t}) = 4.55\times10^4 \left(e^{-347.58t} - e^{-9615.38t}\right)$

$V_{\max} = 38.7208kV$

$30\%V_{\max} = 11.61kV, t1 = 32\mu s$

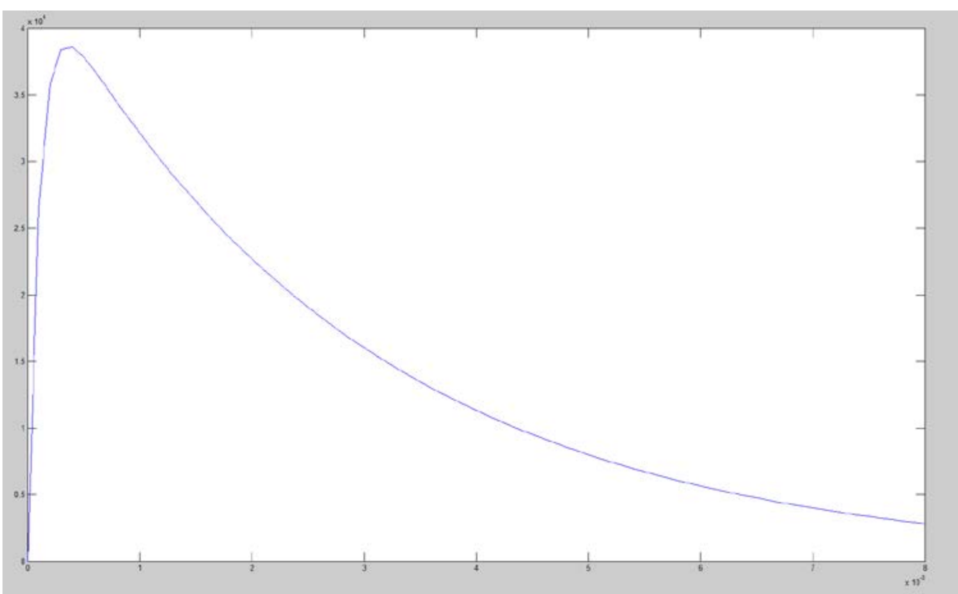
$90\%V_{\max} = 34.84872kV, t`2 = 182\mu s$

$T_1 = 1.67\times(t2 - t1) = 250.5\mu s$

$50\%V_{\max} = 19.36kV$

Substitute 50%Vmax into V(t),

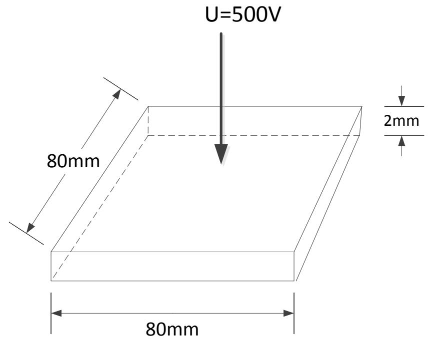
$T_2 =$ 2500μs



Q2:

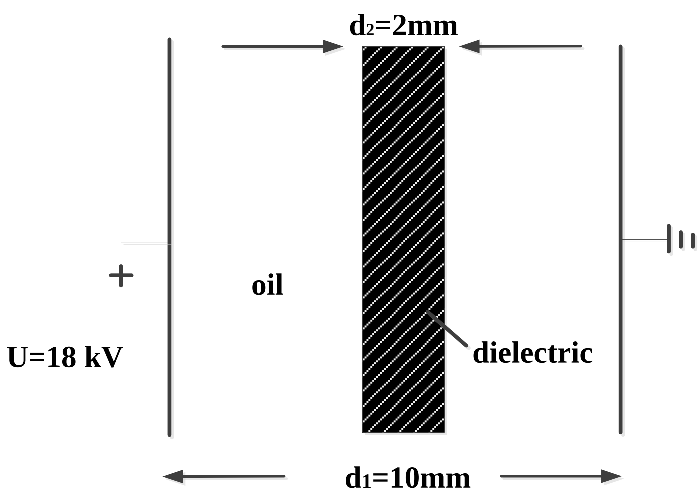
(1)The volume resistivity of a dielectric plane is to be measured. Shall the student choose AC voltage source or DC voltage source in the test? And explain why.
DC. If AC is used, the polarized current will be included.

(2) Now the voltage U= 500V is applied on the dielectric. After 1 minute, the current flow through the dielectric bulk is recorded as I = 20nA. The dimensions of the dielectric are shown in the following figure. Calculate the volume resistivity of the dielectric.



The surface area of the dielectric: A=0.0064m^2;
The volume resistance of the dielectric: R=2.5*10^{10}Ω;
Thus the volume resistivity: $\gamma = R * \frac{A}{d} = 2.5*10^{10} * \frac{0.0064}{0.002} = 8*10^{10}\Omega \bullet m$

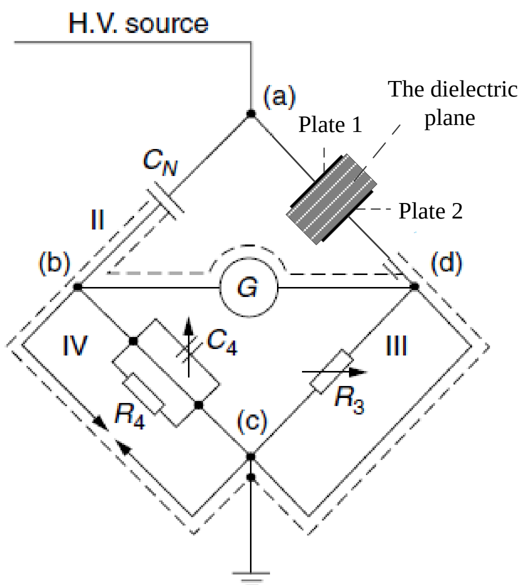
(3)Now the dielectric is inserted into a tank of transformer oil. A sinusoidal voltage U= 18 kV is applied on the tank. The arrangement is shown in the following figure. The relative permittivity of the oil and the dielectric are $\varepsilon_1 = 2, \varepsilon_2 = 4$ respectively. The thickness of the tank and the dielectric plane are $d_1 = 10mm, d_2 = 2mm$ respectively. Calculate the electric field magnitude in the oil before and after inserting the dielectric and explain why the value changes. Assume an ideal uniform electric field exists in the oil and the dielectric.



Before inserting the dielectric: $E_{before} = 1.8kV / \text{mm}$
After inserting the dielectric:
$$\frac{U_1}{U_2} = \frac{E_1 d_1'}{E_2 d_2} = \frac{\varepsilon_2 d_1'}{\varepsilon_1 d_2} = 8$$
Thus:
$$9U_2 = 18kV$$
So:
$$E_{after} = \frac{U_1}{d_1'} = \frac{16kV}{8mm} = 2kV / \text{mm}$$

The electric field magnitude increases in the oil after inserting the dielectric. Because the dielectric has a high relative permittivity, thus with the same thickness of oil and the dielectric, the electric field is lower in the latter thus the voltage drop is lower in the latter. Then more voltage drop is added on the rest of the oil.

(4)Now the student installs the dielectric between two capacitor plates. The plates contact with each surface of the dielectric ideally, i.e. there is no air between the dielectric and plates. Then the student installs the capacitor plates with the dielectric into the Schering bridge and measures the properties of the dielectric. The schematic of the test circuit is shown in the following figure. The standard capacitor C_N has a value of 37.2 pF. When the voltage drop at the dielectric equals 200kV, the zero-indicator indicates zero. The values of R_3 and R_4 are 242Ω and 652Ω respectively, and the dissipation factor tanδ = 0.006. Please calculate the active power dissipated by the dielectric and explain what causes this power loss.



Use series connection.

$$C_x = C_N \cdot \frac{R_4}{R_3} = 100\,pF$$

$$\omega R_X C_x = \tan\delta$$

$$R_x = 190k\Omega$$

$$Z = 190k - j\frac{1}{\omega C_x}$$

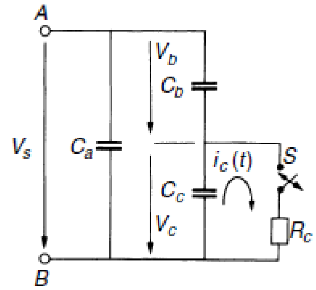
$$|I| = \frac{U}{Z} = 3.7679 \times 10^{-4}$$

$$P = I^2 R_x = 7.49W$$

The dielectric conductivity and the polarization cause the power loss.

Q3: The student wants to measure the PD activity in a home-made capacitor with the electrical current pulse method.

(1) The equivalent circuit of the capacitor under test is shown in the following figure. C_c stands for a void filled with air in the capacitor. When the applied voltage between the capacitor exceeds a certain level, the student measured a PD signal with a certain quantity of q_0. Explain whether the charge quantity measured equals the quantity involved in the void during PD happens.



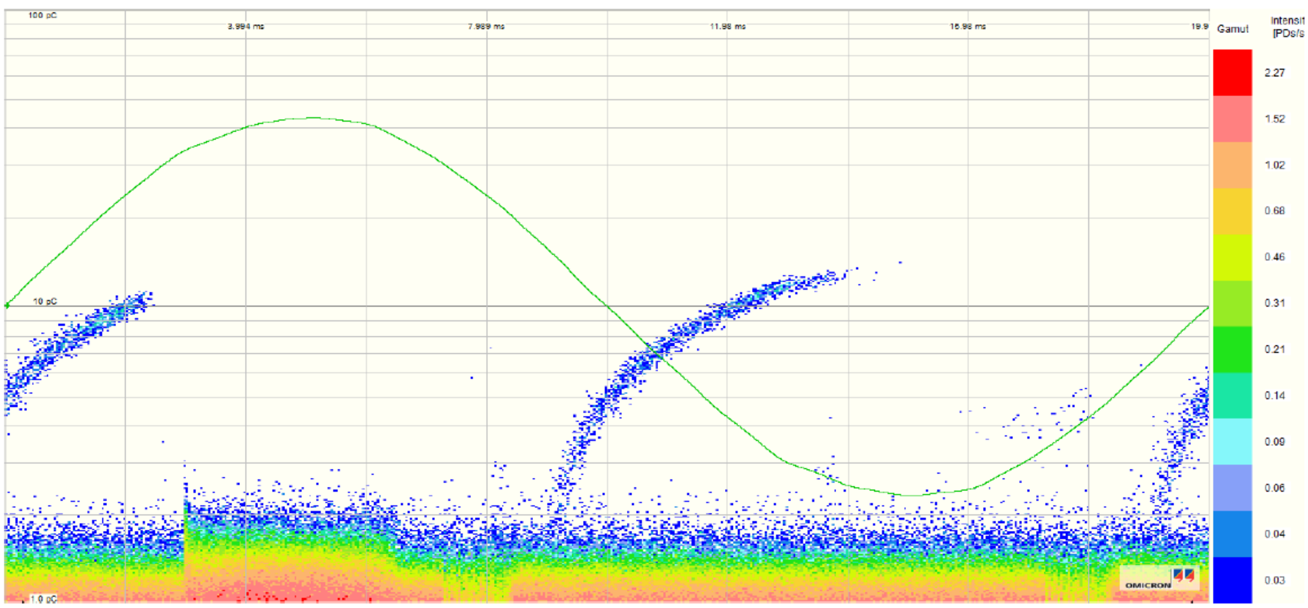
The measured PD magnitude is lower than the real PD magnitude involved in the void. Page 427 in Kuffel book.

(2) The following figure shows phase resolved partial discharge (PRPD) in the capacitor with U = 30 kV. Explain the content of x and y axis.

X is the phase angle of applied voltage.

Y is the magnitude of apparent charge.

(3)Based on the following figure, explain which type of PD happens with the capacitor. Internal PD happens.



(4) Explain the importance for the dielectric of the type of PD from (3).

Continuous internal partial discharge leads to degradation of the dielectric and make the electrical breakdown happen.