Exercises on High Voltage Engineering (April 3, 2025)

Lecture 7: Liquid and Solid Dielectrics

**Exercise 4-2: 为什么气体的𝝐𝒓比液体和固体的小？**

The distance between gas molecules is large, and their density is low. As a result, the polarization of gases is minimal, and the relative permittivity of all gases is close to 1.

In contrast, liquids and solids do not exhibit intense molecular thermal motion. Therefore, when their particles become polarized, their dipole moments align and add up, making the polarization effect significant.

**Exercise 4-3: 极性液体或极性固体电介质的介电常数与温度、电压、频率的关系如何？**

Temperature: As temperature increases, the dielectric constant first rises and then decreases.

Voltage: The relationship is negligible.

Frequency: At lower temperatures, the dielectric constant decreases as frequency increases. At higher temperatures, frequency has almost no effect on the dielectric constant.

**Exercise 4-4: 电介质在交流和直流电压下的损耗是否有区别？**

DC voltage: The dielectric losses consist solely of conductive (leakage) losses.

AC voltage: The dielectric losses include both conductive (leakage) losses and polarization losses.

**Exercise 4-7: 测定电介质或电气设备的绝缘电阻时，规定取加压 1min 时的数值，为什么？**

The absorption current typically requires several minutes or longer to fully decay to a steady-state value. Therefore, in engineering practice, a fixed measurement duration (1 minute) is conventionally adopted.

**Exercise 4-10: 直流和交流电场下的电介质损耗有何差别？选择交流电气设备的绝缘材料一般应注意什么问题？**

Dielectric Loss Mechanisms:

In DC fields, dielectric loss solely comprises leakage conduction loss, whereas in AC fields, it includes both leakage conduction loss and polarization loss. The volume resistivity (ρv) and surface resistivity (ρs) alone become insufficient descriptors, necessitating additional characteristic quantities to represent dielectric energy dissipation under alternating voltages.

AC Electrical Equipment Selection Criteria:

1. Dielectric loss tangent (tan δ):

"Excessive tan δ causes severe dielectric heating and may lead to thermal breakdown. Thus, materials with minimal tan δ values should be prioritized."

1. Insulation material selection:

Capacitors require dielectrics with high relative permittivity (εr).

Power cables demand dielectrics with low εr to minimize charging currents.

1. Multilayered dielectric design:

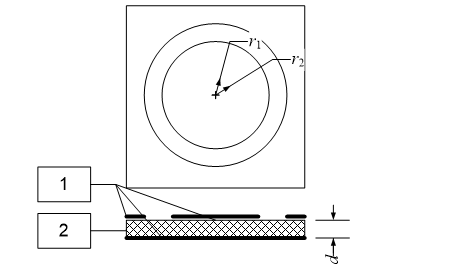
Strategic combination of dielectric layers with properly graded εr values is essential to achieve uniform electric field distribution.

**Exercise 4-15: 高压单芯电缆共 20m，𝐭𝐚𝐧 𝜹 = 𝟎. 𝟎𝟎𝟓，𝝐𝒓 = 𝟑. 𝟖，现其中有 1m 因发生局部损坏，该部位的𝐭𝐚𝐧 𝜹增至 0.05，𝝐𝒓基本不变，问这时电缆的𝐭𝐚𝐧 𝜹应为多少？**

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**Supplementary Exercise 1:** The sample for measuring the volume resistivity *ρ*V and surface resistivity *ρ*S of the solid dielectric is as shown in the figure. The aluminum foil electrode is glued to the dielectric with Vaseline. The shape and size of the electrode are also shown in the figure. Assume that the measured volume resistance is *R*V and the surface resistance is *R*S. How to determine *ρ*V and *ρ*S?



1 - Aluminum foil electrode; 2 - Dielectric

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**Supplementary Exercise 2:** A cable is 100 m long, and the inner and outer radii of insulation layer are 5 cm and 15 cm respectively. The volume resistivity of the insulation at 20°C is *ρ*V = 3×1012 Ω·cm, and the temperature coefficient α = -0.02°C-1. Questions:

1.The insulation volume resistance of the cable at 20°C.

2.If the temperatures of the cable insulation layer are 10°C and 30°C, what are the resistances?

3.If the length of the cable is 200 m, what is the insulation volume resistance at 20°C?

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**Supplementary Exercise 3:** A smooth porcelain rod with a radius of 5 cm has metal flanges at the top and bottom, with an insulation distance of 1 m. The volume resistivity is *ρ*V = 1×1013 Ω·cm, and the surface resistivity is *ρ*S = 3×1012 Ω. Questions:

1.Without and with a guard ring (auxiliary electrode), what are the measured insulation resistances?

2.If the surface resistivity *ρ*S decreases to 1×109 Ω due to moisture, what are the resistances in the above two cases?

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