HW II.1 (4 points): Pillbox cavity

(a) Calculate the RF surface resistance and skin depth of room-temperature copper at 500 MHz. Use DC resistivity $\rho = 1.7 \cdot 10^{-8}$ Ohm·m.

(b) Calculate the RF surface resistance of superconducting niobium at 500 MHz at $T = 4.2$ K and $T = 2$ K. Assume a residual resistance $R_{res} = 10 \cdot 10^{-9}$ Ohm. What is the ratio of superconducting niobium to that of room-temperature copper?

(c) Design a cylindrical (pillbox) cavity that operates in the TM_{010} mode at 500 MHz with an axial electric field of $E_0 = 1$ MV/m, and a length $l = \lambda/2$, where λ is the RF wavelength in free space. Calculate the length and diameter of the cavity. Calculate the maximum H and E fields on the cavity wall. Where do they occur? Calculate the electromagnetic stored energy in the cavity.

(d) Calculate the power loss P_c, the quality factor Q_0, and the decay time τ for a room-temperature copper surface and for niobium surface at 4.2 K.

HW II.2 (1 point): Equivalent RLC circuit

A superconducting cavity with residual resistivity of 10 nOhm operates at a frequency of 1300 MHz. The geometry factor is 267 Ohm, and R/Q = 900 Ohm (*accelerator definition*). Calculate parameters of the equivalent parallel *RLC* lumped-*circuit* model of this cavity.

HW II.3 (2 points): Anomalous skin effect

(a) Determine the improvement factor that can be expected for the Q_0 of a 500 MHz copper cavity if it is cooled down from room temperature to liquid helium temperature (4.2 K). What is the quality factor of the pillbox cavity from problem *HW II.1* with copper walls cooled to 4.2 K? The ρl product of copper is $6.8 \cdot 10^{-16}$ Ohm·m^2. The resistivity of copper at room temperature is $1.7 \cdot 10^{-8}$ Ohm·m.

(b) Calculate the surface resistivity of niobium of RRR = 30 (reactor grade niobium) and RRR = 250 (high RRR niobium) at 500 MHz in the normal conducting state at 10 K (assume that RRR is given for this temperature.) What is the Q_0 of the pillbox cavity from problem *HW II.1* with niobium walls at room temperature? What is the improvement factor for a niobium cavity on cooling from room temperature to 10 K? The resistivity of niobium at room temperature is $15 \cdot 10^{-8}$ Ohm·m, and the ρl product of niobium is $6 \cdot 10^{-16}$ Ohm·m^2.