# Exercise Class 5

## Exercise 1

Consider a quantum harmonic oscillator with C = 200 fF, L = 50 nH. Calculate the single electron charging energy $E_C$, the inductive energy $E_L$, and the resonance frequency $\omega_0$.

## Exercise 2

Consider two quantum harmonic oscillators with $C_1$ = 700 fF, $L_1$ = 15 nH, and $C_2$ = 15 fF, $L_2$ = 700 nH. For each oscillator, estimate the uncertainties $\Delta N$, $\Delta\varphi$ on the number of Cooper pairs $N$ and superconducting phase $\varphi$ for the state $|0\rangle$ and determine whether the oscillator would be most suited for a *charge* qubit or a *phase* qubit, neglecting leakage to the upper states.

## Exercise 3

Consider an Al/$Al_2O_3$/Al Josephson junction ($\varepsilon_{Al_2O_3} = 9$) with critical current density $J_0$ = 10 A/cm$^2$, W = 2 µm, L = 1 µm, t = 1nm.

1. Calculate the equivalent capacitance $C_J$ and minimum equivalent inductance $L_{J0}$.
2. Draw a plot of the equivalent inductance $L_J(\varphi)$ as a function of the junction phase $\varphi$.
3. Estimate the frequencies of the $|0\rangle \rightarrow |1\rangle$ and $|1\rangle \rightarrow |2\rangle$ transitions.

## Exercise 4

Determine the operational temperature for a Nb-based superconducting qubit ($T_{C,Nb} = 9.2\ K$) operating at a frequency of 5 GHz.