Computing Methods for Physics – 11 February 2022

Your exam must be submitted via google classroom by 13:30 as a single `zip` file containing all relevant code files, plots, and datafiles.

Capacitors

A capacitor is a device that stores electrical energy in an electric field. A capacitor $\mathcal{C}$ is characterized by its capacitance C — measured in Farad [F] — which can be linked to the are A of its plates and to their separation s by the formula

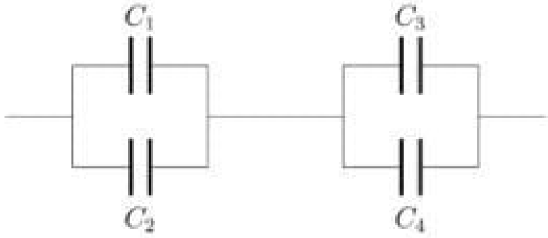
$$C = \epsilon_0 \epsilon_r \frac{A}{s}, \tag{1}$$

where $\epsilon_0 = 8.854 \cdot 10^{-12}\,\mathrm{F/m}$ is is the vacuum permittivity, and $\epsilon_r \geq 1$ is the relative permittivity of the material between the plates. By definition, $\epsilon_r = 1$ for vacuum.

You will have to use C++ to handle capacitors as objects, produce some data with operations on these objects, and fit and plot such data in Python.

Part 1 – C++

1. Design and write a class `Capacitor` with appropriate constructors, setters, and getters.
2. Write an application `app2.cpp` to showcase the methods of the class `Capacitor`.
3. Overload the plus (`+`) and or (`||`) operators so that they return a `Capacitor` instance representing the capacitor equivalent to the series and the parallel of two given capacitors, respectively.
4. Write an application `app4.cpp` where you set $C_2 = 10\,\mathrm{pF}$, $C_3 = 5\,\mathrm{pF}$, and $C_4 = 15\,\mathrm{pF}$, draw 10^3 random values for C_1 from a uniform distribution between $[1, 100]\,\mathrm{pF}$ and determine the set of corresponding 10^3 equivalent capacities for the configuration below.



Note: If you prefer, you can generate the random C_1 values with a Python script, store them as a text file, and read them in your C++ application `app4.cpp` in order to calculate the C_{eq} values.

Store the values of your C_1–C_{eq} pairs in a textfile called `true.dat`.

Part 2 – Python

Use Python for the following tasks.

1. Read in the true C_1–C_{eq} values and displace each C_1 and C_{eq} by an offset randomly drawn from a Gaussian distribution centered in 0, with standard deviation 0.5. Save these $\tilde{C}_1$–$\tilde{C}_{eq}$ values in a textfile called `offset.dat`.

2. Use `scipy.optimize.curve_fit` to fit the function $1/[1/(x+a)+b]$ to the $\tilde{C}_1$–$\tilde{C}_{eq}$ data. How do the results for a and b compare to your expectations? Plot your data and the result of your fit.

3. Read in the true C_{eq} values and this time associate an error value ΔC_{eq} to each C_{eq} by randomly drawing from a Gaussian distribution centered in 0, with standard deviation 3. Save these values in the textfile `errorbar.dat`.

4. Use a Monte Carlo package of your choice to fit the $\tilde{C}_1$ vs $C_{eq} \pm \Delta C_{eq}$ data with the function $1/[1/(x+a)+b]$. How do the results for a and b compare to your expectations? Plot the posterior distributions for a and b and comment your results.

Important Remarks

- C++ evaluation will be based on: correct syntax, proper return types, proper arguments of functions, data members and class interfaces, setters/getters, unnecessary void functions, comments throughout the code, separation of class implementations and interfaces.

- Python evaluation will be based on: correct syntax, avoiding C-style loops, using Python features in general, comments throughout the notebook/scripts, labels, legends and plot styling and clarity in general. The Python coding may be carried out in a notebook or in scripts, as you wish.

- The various `*.dat` output files you produce must be submitted.