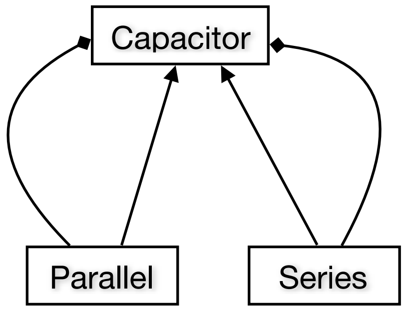
Computing Methods for Physics
8 July 2019

You must submit your exam by **Wednesday Jul 10 at 10:00** following the instruction at http://www.roma1.infn.it/people/rahatlou/cmp/



Capacitors with Composite Pattern

Use the composite pattern to implement a polymorphic hierarchy of classes to represent a **`Capacitor`** and composite **`Parallel`** and **`Series`** objects made of one or more **`Capacitor`**, **`Series`**, or **`Parallel`** objects.

- **`Capacitor`** must have 2 data members **`_C`** and **`_name`**
- Implement virtual methods **`value()`**, **`name()`**, **`print()`** for **`Capacitor`**
- Implement **`value()`**, **`name()`**, **`print()`** for **`Parallel`** and **`Series`**.
  - **`print()`** must also produce info about all components of the composite object and proper units for the capacitance
- Implement **`add()`** method (with proper signature and argument) for **`Parallel`** and **`Series`**
- Test your classes with an **`exam.cc`** application.
  - Create 3 capacitors of capacitance of C1 = 10 nF, C2 = 20 nF, C3 = 50 nF and print them.
  - Create a series S1 = C1 + C2, a parallel P1 = C2 II C3, a parallel P2 = C1 II P1, and a series S2 = S1 + P2 + C3.
  - Print S1, P1, P2, and P3
- No additional functions, classes or applications are needed. If additional functions are present, they will be evaluated and possible mistakes will decrease the total score.

Provide instructions for compiling your code in the comments at the beginning of **`exam.cc`** .

Evaluation will be based on: successful compilation, correct use of C++ syntax, polymorphism, return type and arguments of functions, data members and interface of classes, unnecessary void functions, use of unnecessary C features, correct calculation of capacitance.

Computing Methods for Physics

8 July 2019

Electromagnetic Shower in matter

The passage of a high-energy electron or photon in matter produces an electromagnetic shower until all energy of the incident particle is lost through Bremsstrahlung (when energy is above the critical energy E_c in the material) and ionisation for electrons (and positrons) and pair production for photons. Each material is characterised by a radiation length X_0 which causes the energy of the incident particles to decease as

$$E(x) = E_0 e^{-x/X_0}$$

where $\mathbf{E_0}$ is the initial energy of the incident particle and $\mathbf{E(x)}$ is its energy after traversing thickness $\mathbf{x}$ of material. (See for example William R. Leo, Techniques for Nuclear and Particle Physics Experiments or A. Das and T. Ferbel, Introduction to Nuclear and Particle Physics)

We want to study a simplified electromagnetic shower produced by an electron of 30 MeV hitting a NaI crystal of 5 cm x 5 cm x 50 cm. (NaI properties)

Simulate passage of 10000 electrons through the crystal. For each electron, positrons and photon an interaction can occur after thickness x assume. For simplicity assume steps of $x = X_0$. For electrons only Bremsstrahlung occurs while $E > Ec$, and for photons only pair production until energy is sufficient.

Use NumPy arrays to simulate the shower development for each incident electron and compute

1. maximum number N_{max} of particles produced in each simulation. Make a 1D plot of the distribution of N_{max} for all simulations
2. Depth x_{max} at which the maximum number of particles is in the shower. Make a 1D plot of the distribution of x_{max}
3. Depth x_{tot} where all electrons are below the critical energy Ec and no photon conversion can occur. Make a 1D plot of the distribution of x_{tot}

Save a PDF file for each of the above 3 plots. You need to use comprehensions and dictionaries to implement the simulation and plotting the required plots. Define a function `Interaction` (with proper arguments and return values) to simulate the interaction at each step for each particle.

Evaluation will be based on use of python features and data structures, comprehensions (instead of C-style for loops), NumPy objects, labels, units, and clarity of plots.