COMPUTING METHODS FNEEOR PHYSICS
6 MAY 2020

Version 1

You must submit your exam by following the instructions at http://www.roma1.infn.it/people/rahatlou/cmp/

Atoms and Molecules (C++) (100 pt)

Implement two polymorphic classes **`Atom`** and **`Molecule`** using the Composite Pattern. An **`Atom`** is characterised but its mass number A and the charge number Z. A **`Molecule`** is an aggregate of one or more **`Atoms`** and/or **`Molecules`**.

Provide functions **`A()`** and **`Z()`** (with proper types and arguments) for each class.

Provide **`add()`** and **`remove()`** functions (with proper types and arguments if any) as needed in the Composite Pattern.

Provide **`{Atom,Molecule}.{hh,cc}`** for evaluation. You will be asked to discuss the functions and the implementation choices, possible extensions, and a test application during the oral discussion.

Evaluation will be based on: correct implementation of polymorphic functions and the Composite Pattern, correct C++ syntax, return type and arguments of functions, data members and interface of classes, unnecessary void functions, correct mathematical operations, correct physics units.

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Bethe-Bloch with Numpy (python) (50 pt)

The average energy lost by a charged particle with charge z_p going through a material with charge Z and mass number A is given by the Bethe-Bloch formula $-\frac{1}{\rho}\frac{dE}{dx} = C\frac{{z_p}^2}{\beta^2}\frac{Z}{A}(\ln\frac{2m_e\beta^2\gamma^2}{\bar{I}} - \beta^2)$ (for simplicity we ignore the density correction), where β and γ are the Lorentz parameters of the charged particle, $m_e = 0.5\,\mathrm{M}eV, \bar{I} \approx 10\,\mathrm{Z}$ (in eV) is the average ionisation energy of the material and ρ its density, and $C = 0.3\,\mathrm{M}eV/\mathrm{g}/\mathrm{c}m^{-2}$.

Implement a **BetheBloch** function with proper arguments and return value.

Make two separate plots of the average energy loss as a function of $\beta\gamma$ (in the range from 0.1 to 1000) using the following two methods

1. Use comprehensions
2. Use numpy

Measure the time required to evaluate the energy loss values with each method and print them in output. Is there any difference between the two methods?

Provide a python or Jupyter notebook file (**`bethebloch.py`** or **`bethebloch.ipynb`**).

The correct name of the file and proper use of numpy and comprehensions will be important evaluation criteria. Evaluation will be based on use of python features and data structures, comprehensions (instead of C-style for loops), NumPy objects, labels, units, clarity ad correctness of plots.