

COMPUTING METHODS FOR PHYSICS

16 JUNE 2020

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

Part 1: 2D Motion with Strategy Pattern (C++)

A body of mass m moves in a two-dimensional plane (x,y) with initial velocity (v_{x0}, v_{y0}) subject to gravity along the y axis $(-mg\hat{y})$ and to friction, modelled as $-\beta\vec{v}$. The equation for the velocity is

$$m\dot{v}_x = -\beta v_x$$

$$m\dot{v}_y = -mg - \beta v_y$$

The analytical solution of the problem is

$$v_x(t) = v_{x0}e^{-\beta t/m}$$

$$v_y(t) = v_{y0}e^{-\beta t/m} - \frac{mg}{\beta}(1 - e^{-\beta t/m})$$

Provide two classes, **Analytical** and **RungeKutta**, to implement the method **velocity()** of a base class **SpeedCalculator**, with proper arguments and return type. In the **Analytical** class you must use the exact solutions provided. In the **RungeKutta** class, you can use the iterative 2nd-order Runge-Kutta method for 1st order differential equations $\frac{dy}{dx} = f(x, y)$ with $y(0) = y_0$; given a value x , $y(x)$ is:

$$K_1 = h \cdot f(x_n, y_n)$$

$$K_2 = h \cdot f(x_n + h/2, y_n + K_1 \cdot h/2)$$

$$y_{n+1} = y_n + K_2$$

where h is the step size for the iterative method and must be one of the parameters to be passed to the method.

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

Part 2: Plots (ROOT or Python)

Assuming the initial values $v_{x0} = v_{y0} = 10 \text{ m/s}$, $m = 10 \text{ kg}$, and $\beta = 0.1 \text{ Ns/m}$, use ROOT or python to make 2 plots: plot $v_x(t)$ and $v_y(t)$ as a function of time t . In each plot, show both the analytical and the Runge-Kutta solutions. Use different line type and/or colours with proper legend.

If you use python, you must store the output of the C++ program and read the values in the python program.

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