Computational Physics

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Project 2, due October 6, 2021 at 11:59 p.m.
to be uploaded to https://elearning.jacobs-university.de

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2. Solar System [10 points]

The planetary motion is governed by Newtonian gravity with the force law

$$\vec{F}_{12} = -\frac{Gm_1m_2}{|\vec{r}_1 - \vec{r}_2|^3}(\vec{r}_1 - \vec{r}_2)$$

where $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} . Notice that all planets in the solar system move in (approximately) the same plane; therefore a two- dimensional simulation will be sufficient. In the first part of the project, the motion of a single planet is investigated.
a) Write a program which integrates Newton's equation of motion for a single planet under the influence of the gravitation of the sun (which you can assume not to be moving) from time t_{min} to time t_{max} using a time step Δt. Record the position, velocity, kinetic energy, potential energy and total energy as functions of time and make sensible plots.
b) Determine a reasonable value for the time step Δt. For two particular planets (e.g., the Earth and Uranus), optimize Δt using the requirement of total energy conservation. To this end, calculate the energy change over one orbit and plot it as a function of Δt . What type of behavior do you expect? Choose an appropriate way of plotting the result.

Planetary Data:

planet	mass(kg)	radius (AU)	eccentricity
Mercury	2.4×10^{23}	0.39	0.206
Venus	4.9×10^{24}	0.72	0.007
Earth	6.0×10^{24}	1.00	0.017
Mars	6.6×10^{23}	1.52	0.093
Jupiter	1.9×10^{27}	5.20	0.048
Saturn	5.7×10^{26}	9.54	0.056
Uranus	8.8×10^{25}	19.19	0.046
Neptune	1.0×10^{26}	30.06	0.010
Pluto	1.3×10^{22}	39.26	0.248
Sun	2.0×10^{30}		

General remarks for all Projects

You will have to (i) analyze the problem, (ii) select an algorithm (if not specified), (iii) write a Python program, (iv) run the program, (v) visualize the data numerical data, and (vi) extract an answer to the physics question from the data.
Which checks did you perform to validate the code? State the results you got for these tests.
For each project you will submit a short report describing the physics problem, your way of attacking it, and the results you obtained. Provide the documented Python code in such a form that we can run the code. A Jupyter Notebook including the code and report is fine but not necessary.