

Project Presentation

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1 Overview

The purpose of the project is to simulate the motion of celestial bodies and see how the theory of classical physics (both at a high-school and university level) is applied. The whole project has been done on Python, using only the standard libraries Numpy, Scipy and Matplotlib.

The specific aims of the project are firstly to further understand the physics behind celestial motion of the bodies under various gravitational fields:

- Analyse how planetary orbits look like by input of various parameters
- Check how Kepler and Newton's laws are applied
- Work out how the orbits of some planets may shift after each full rotation (effect called eccentricity)
- Simulate on computer how the planetary dynamics would look if the attractive force between the planets would take other shape (such as logarithmic, sinusoidal or exponential form)
- Understand, in some cases, how heavy planets also move in binary planetary systems, hence grasp the physical concept of mass center
- Study how the energy conservation is applied every time, and realize how the kinetic and potential energies vary

However, the project can also be used for computational learning, as anyone who uses the program can upgrade the coding skills:

- Understand largely or in full detail how the code is designed
- Learn elementary Object-Oriented Programming design, vital for further Informatics projects and courses in any branch

2 Theoretical background

When a body rotates with respect to another stationary object, there is a force acting **radially** from the moving block with respect to the static one. This case is shown below:

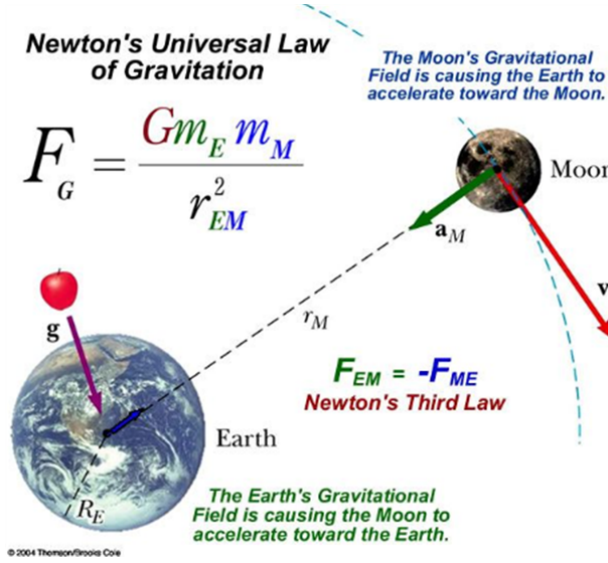


Figure 1: The moon is radially attracted towards Earth. Hence, it has a circular motion

In the case of celestial motion, they are all under the gravitational field influence. As a result, the attractive force between two bodies of masses M and m , at distance r with respect to each other, has the familiar expression:

$$F_g = \frac{GMm}{r^2} \quad (1)$$

If the motion is perfectly circular, this force represents the centripetal force, acting towards the center of the stationary body:

$$F_g = m\omega^2 r, \text{ where } \omega = \frac{V}{r} \quad (2)$$

As a result, the two expressions can be used to work out the speed of the planet necessary to maintain circular trajectory at a specific orbit (radius):

$$V(r) = \sqrt{\frac{GM}{r}} \quad (3)$$

However, at the specific radius r , if the speed of the planet is different from $v(r)$, then the trajectory is still enclosed and curved, but no longer circular. This is the case to almost all the interspatial blocks and planets, as the existence of

perfectly circular trajectory is hindered by galactic collisions, heating from stars and so on. As specified above, the given project plots some shapes which the orbital planets can take.

3 Python files

There are two Python files - Body.py and Simulation.py. They have to be downloaded both in the same file for the simulation to work. Body.py builds the attributes for one particular object - the body. Simulation.py takes as input some parameters shown in the next section, builds up all the objects and runs the simulation. It is this file which has to be played

4 Running the project and putting the parameters

- Open the Simulation.py file
- Run the file and plug in the desired parameters

The required parameters are:

- Number of planets: simply select the number
- Color: choose from the following colors: y,b,r,g,c,m, y stands for yellow, r for red, and so on
- Mass: choose the required mass. It is in Earth Units, so as this adjustment makes it easier to understand the celestial motion. For instance, it would be more helpful to say that planet X has the mass equal to two time the Earth mass, rather than plugging in the actual value. Note: $M_{Earth} = 6 * 10^{24} kg$
- Distance: choose the required distance. Again, the distance is measured in astronomical units (1AU represents the distance from Earth to Sun which is $1.5 * 10^{11} m$)
- For the first body, the program asks only for color and mass. This is considered the frame of reference, hence it is placed in the center of the animation. It can be the Sun, or any other kind of body. Note: for a realistic animation, choose the first mass as 333000 times the Earth mass (actual Sun mass)
- Fraction of circular trajectory speed: the circular trajectory speed is the $V(r)$ function defined above. In order to see how much the planetary orbit evolves depending on the initial parameters, it is more convenient to use fractions than plain numbers, especially for beginner level in physics. Simply choose the desired fractions, both for x and y - axis

5 Advantages

- Any values can be chosen. There is no restriction on the parameters, or positions of planets. Hence, all kinds of motions can be analysed.

6 Drawbacks

- Motion