Team ANYmation

Scripting Subsystem

Instructions

- This is the coding assignment for scripting subsystem. You also have to do the other assignment (animation).
- This assignment has 3 questions. The points corresponding to each question/sub-part is given in the right side margin. The assignment is for a maximum of **150 p**.
- **You are free to use the internet (obviously) and any other resources**.
- The questions are based on some interesting phenomemon in astronomy. **There are no prerequisites for this assignment**. If you do not understand some concept or teminology, use internet!
- All questions have coding component, so, any coding knowledge would be helpful. Coding **must be done in `python`**. You will mainly be needing `Numpy` and `Matplotlib` libraries, but you are free to use any other python library. For those who are not familiar with `python`, here are some tutorials (click).
- Please use `jupyter` notebooks or Google colab (`.ipynb` extension). Please explain the steps and the chosen variable names clearly. Name the files `Q<question number>.ipynb`.
- We will be using Git Classroom for taking the submissions. Create a GitHub account if you do not already have one. Here is the link to the assignment.
- If you have any comments/clarifications/doubts regarding the questions, contact us on our WhatsApp group.

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1. **Cosmology** 40 p

   Hubbles' law states that a galaxy's recessional velocity v is proportional to the distance d.

   $$v = H_0 d$$

   Where $H_0 = 70$ kms^{-1}/Mpc is called as the Hubble's parameter/constant. However this law is not a strict law, especially for nearby galaxies. Nearby galaxies have a random velocity v_r over the Hubble velocity with an RMS of σ. That is

   $$v = H_0 d + v_r$$

   Assuming that the number density of galaxies is constant in the distance range 1 Mpc to 100 Mpc, plot the velocity (magnitude) vs distance graph for the galaxies.
   Hint: v_r is drawn from a Gaussian with zero mean and SD σ. Also note that v_r can be in any random direction but the v due to Hubble's law is radially outward.

2. **Transit Simulation** 50 p

   Given a bright circle of radius r_1, uniformly emitting light, let another circle of radius r_2 pass in front of it with uniform velocity. The circles start out separate (no overlap) and end separate. The second circle is opaque and does not emit light, hence it causes a drop in total light intensity when it passes in front. Simulate this situation and plot out the light intensity over the whole period of the transit. Note that you can choose arbitrary units for intensity.

   Hint: Calculating the area via integration will be complex. Instead, try to maintain an array of points over the whole larger sphere and keep track of which points are emitting light at the given timestep. Take the shadow into account by simply switching off the points within the shadow. Let the light intensity be some constant multiplied by the number of points emitting light. As your grid becomes finer, your answer will become more precise.

3. **Co-orbital Satellites** 60 p

   Suppose that two small satellites of masses m_1 and m_2 are approximately co-orbital (moving on very similar orbits) around a large central body of mass M , with $m_1, m_2 \ll M$. At any instant, the orbits of the satellites may be approximated as circular Keplerian orbits with radii r_1 and r_2 respectively, although r_1 and r_2 will vary slightly over time due to the mutual gravitational interaction between the satellites.

   Assume the planet is not affected by the gravity of the satellites. Simulate the motion of these satellites in the rotating reference frame centered at the planet, such that the total angular momentum of the system is zero in this frame.

   Let it be given that both satellites have the same initial orbital radius and they start off on opposite sides of the earth. Take the radius where the period would be 6 hours if calculated using the radius. Let both satellites start with velocities corresponding to perfect keplerian orbits at that radius. Run the simulation for a long period and plot the trajectories in the given frame of reference in a plot. Use the python library, matplotlib. Describe the kind of motion you observe.