PHYS580 Lab 5, Sep 19, 2019

Assignment:

1. Observe and display motion along circular, parabolic, and hyperbolic orbits in our Solar System, using the provided starter program (*planet_EulerCromer.m*) or your own equivalent. First set initial conditions that would match the orbit of one of the solar system planets, and then calculate the (real) orbit of that planet. Next, change the initial velocity to take the planet to a hypothetical new orbit of a different type (if you start from a planet with a significantly elliptical orbit, such as Pluto or Mercury, this could be more challenging). Make sure to first theoretically estimate the necessary initial velocities that would be needed for circular and parabolic orbits.

2. Repeat the orbit calculation but with values appropriate for a comet - specifically, the *Shoemaker-Levy 2* that has a perihelion of 1.933 AU and eccentricity of 0.572. Obtain its period by keeping track of time in your simulation, and crosscheck against the theoretical prediction and also, if you can, against actual measurements. What about Halley's comet with perihelion of 0.589 AU and eccentricity of 0.967? Do these two comets follow Kepler's third law, $T^2 / a^3 = const.$, according to your simulations?

3. Modify the starter program (*two_planets.m*, or create your own equivalent) to observe and display how planet 2 affects (perturbs) the orbital motion of planet 1. The starter program assumes that the Sun is stationary, which is fine when the planets are much less massive than the Sun (true for the Solar System). Find out how much more massive Jupiter would have to be for its influence to make Earth's orbit visibly precess and eventually make it non-periodic, or even eject(!) Earth from the Solar System. Jupiter's orbit may be approximated as circular with radius 5.20 AU (the actual eccentricity is only about 0.048). Then, verify how the result changes, if at all, if you properly treat all 3 bodies (Sun, Earth, Jupiter) as mobile.

Discussions in Section 4.2 of the textbook may be helpful for getting started. In particular, for elliptical orbits,

$$v_{\min} = \sqrt{GM_S}\sqrt{\frac{1-e}{a(1+e)}\left(1+\frac{M_P}{M_S}\right)}\ ,\ v_{\max} = \sqrt{GM_S}\sqrt{\frac{1+e}{a(1-e)}\left(1+\frac{M_P}{M_S}\right)}$$

$$r_{\min} = a(1-e)\ ,\ r_{\max} = a(1+e)$$

Also, do not forget to simplify things by using Solar system units: AU for distances and Earth year for time.

Planet	Orb. Period (yr)	Eccentricity	Perihelion (AU)	Aphelion (AU)	Mass (kg)
Mercury	0.241	0.206	0.307	0.467	3.30×10^{23}
Venus	0.615	0.007	0.718	0.728	4.87×10^{24}
Earth	1.000	0.017	0.983	1.017	5.97×10^{24}
Mars	1.881	0.093	1.382	1.666	6.42×10^{23}
Jupiter	11.86	0.048	4.953	5.453	1.90×10^{27}
Saturn	29.46	0.056	9.005	10.07	5.68×10^{26}
Uranus	84.02	0.047	18.29	20.09	8.68×10^{25}
Neptune	164.8	0.009	29.79	30.33	1.02×10^{26}
Pluto	247.7	0.249	29.63	49.29	1.27×10^{22}

Please note errors in Table 4.1 on p.98 of our text. The solar mass is about 1.99×10^{30} kg.