Name:____________________________________ Period ___ Date:________

Lab 70-2 Orbital Motion using Python. (The Black Hole) V2 (Halverson 6/20/2017)

Important: Some of these steps should be done only once. Don't do them again when you continue the lab after logging out and logging back in again.

- Firefox > halverscience.net > Physics - Halverson > Python for Physics > black_hole_orbit.py Save the file. (Do once.)
- Move the file to Desktop > my_python. (Use mouse to drag it from the Downloads folder.) (Do once)
- Run Terminal

cd Desktop (Do every time after you log in.)

cd my_python (Do every time after you log in.)

python black_hole_orbit.py (You should get a spaceship that drifts at constant speed)

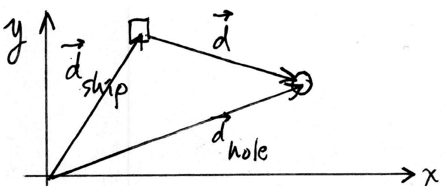
cp black_hole_orbit.py black_hole_orbit2.py (This makes a copy and now you will modify the copy)

(Do once)

edit black_hole_orbit 2.py (Do every time after you log in.)

Study the code. In physics coding there are many vectors, which are represented by their x and y components. For example a velocity vector **v** could be represented by v_x and v_y which are typically written v_x and v_y in a program.

1. Reverse-engineer the code and write down the formula for the vector **d** that represents the displacement you would need to get from the ship to the black hole. This diagram shows how the ship's position vector, the hole's position vector and the d vector relate to each other. Hint: it's simple.



d=( )**i** + ( )**j**

2. Reverse-engineer the code and write down the formula for the magnitude of **d** which equals the distance between the ship and the black hole. Note: In python "x**2" means x^2 and "x**0.5" means "square root of x."

|**d**| =

3. We need a unit vector that points in the direction of **d**. I'll call it **u**. Mathematically, **u** = **d** / |**d**|.

For this program to work we need the x and y components of **u**. I deliberately messed up part of the code for calculating them. Repair the code. (No need to write anything here.)

4. We will need the acceleration of the ship, as it is pulled by the black hole. We need to use Newton's 2nd Law, **a**=**F**/m

Fix and/or add code that computes a_x and a_y, the x and y components of the ship's acceleration.

Hint: The easiest way is to (1) find the magnitude |**a**| and (2) use the unit vector so **a**= **u**a.

5. Add to the code calculations for the updated x and y components of the ship's velocity, taking into account the acceleration . Use something like $\mathbf{v}_{new} = \mathbf{v}_{old} + \mathbf{a}\Delta t$

6. Write down the formula for displacement under constant acceleration: It uses v_0, t and a.

$x(t) = x_0 +$ (Finish the formulas)

$y(t) = y_0 +$ (Put the formulas into your code)

7. Use the formulas in #6 to implement updated x and y locations for the ship. Note that $t = \Delta t = 1.0$ loop times. Save your work then run it by typing "python black_hole_orbit2.py" in the Terminal. Show the result for credit. (Check: According to Kepler, orbits should be square / circular / elliptical ?)

8. Alter the code so that it shows the path of the ship. **GET STAMP ---->**

9. Notice that this code makes an approximation: it assumes that during each loop the acceleration is unchanging, but this is not actually true. The acceleration is constantly changing. Therefore the orbits are not perfect. Describe the problems you see in the orbits.

10. There is a tricky way to mostly fix the inaccuracy mentioned above. You update the velocity with 1/2 of the acceleration before moving the ship, move the ship and then update again the velocity with the other half of the acceleration. I think it works because the acceleration is increasing roughly linearly. I will help you implement the fix. The orbits become very accurate.

11. In real physics life, the back hole can move. We will add this feature.

Copy black_hole_orbit2.py to black_hole3.py. Then edit and modify it to allow the black hole to move. You will need to add code for its acceleration and velocity.

Make the path of the hole appear. **GET STAMP ---->**

12. To prevent the ship/hole system from drifting down, adjust the initial velocity of the black hole so that the system's center-of-mass velocity is zero. (In other words, give the black hole a small upward momentum that cancels the ship's downward momentum.) . **GET STAMP ---->**

13. Challenge question: Real black holes have a lot of dust and gas around them. How would you add friction from that gas, which would slow the ship?