



Student Worksheet for the Black Hole Orbits Instant Pack

This activity is conducted in a Python Notebook, a web-based interactive computational environment that contains code, text, and plots. In this Python Notebook, we will explore the motion of a particle as it orbits around a black hole to test our understanding of gravity! Using code to apply numerical integration we will be able to see whether Newton's law of gravity (e.g., the gravity we know) will help determine a particle's motion around a black hole or whether the gravitational law of general relativity would be better suited and why.

Activity 1: Newton's Law of Universal Gravitation

The first cell you will run in this section defines a function to calculate the acceleration due to gravity. You can explore the acceleration of various situations by changing the mass of the black hole and the distance between the objects.

1. What is the magnitude of the Newtonian acceleration 1 AU away from Sagittarius A*, the black hole at the center of the Milky Way galaxy? (Remember, 1 AU or astronomical unit is the distance between the Sun and Earth.)
2. a. How much greater is the gravitational acceleration or pull of an object orbiting a black hole at a distance of 1 AU than the acceleration of Earth due to the Sun (at 1 AU)?

b. If you double the mass of the black hole, what happens to the value of the acceleration?

Activity 2: Introduction to Numerical Integration

Activity 2.1: To Start With

The first cell in this section defines a function called ConstantBall to determine the distance a ball has traveled over time. You can explore new results by using different values for velocity and time.

3. What is the distance traveled by the ball at time τ later?

Activity 2.2: Ball with Changing Velocity

In this section, you will experiment with numerical integration to graph different starting positions of a ball vs time.

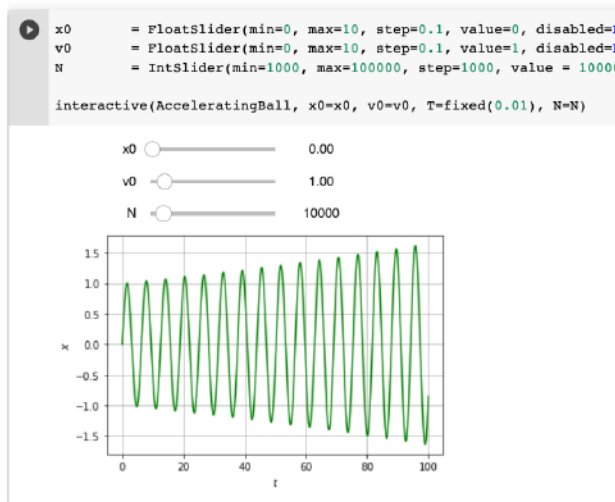
4. In what direction is α , the gravitational acceleration (or gravity), pointed in the above diagram?



5. When is it appropriate to use this technique?
6. What is the ball's position as a function of time?
7. Play around with x_0 and N . How do these parameters change the plot?

Activity 2.3: Ball on a Spring

In this activity, you will apply numerical integration to a ball on a spring and observe some of the technique's limitations.

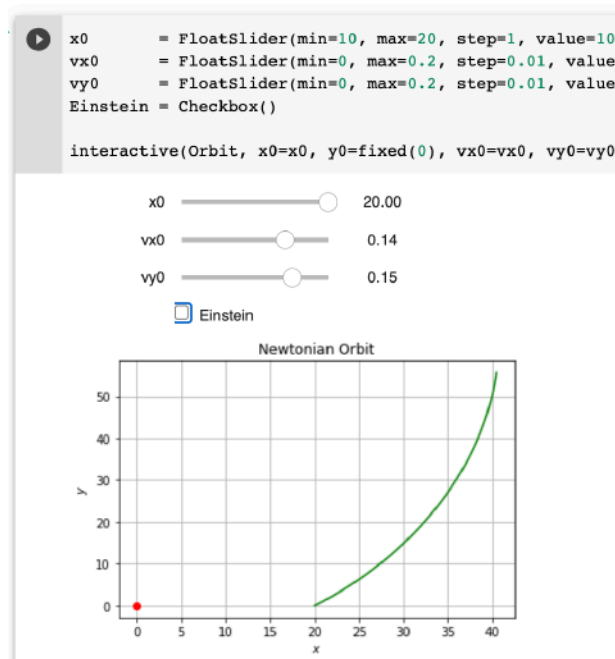


8. Why is there a negative sign?

9. What is the motion of a ball with this acceleration?

Activity 3: The Gravity We Know: Newton's Law, Integrated

In this section, you will revisit Newton's Law of Gravitation from Activity 1 and apply the numerical integration technique, changing the sliders to observe how the different parameters affect the object's orbit.



Activity 4: The Gravity Near A Black Hole: Orbits In General Relativity

In this activity, you will explore the differences between Newtonian gravity and General Relativity.

10. Can you make qualitative statements about the differences between Newtonian and Einsteinian orbits?

11. How far do you need to go from the black hole for the Einsteinian orbit to look like the Newtonian one?