TechLab: Worlds of Wonder

an investigation of orbital mechanics

PERIOD	1.		
	2.		
GROUP	3.		
	4.		

• Purpose •

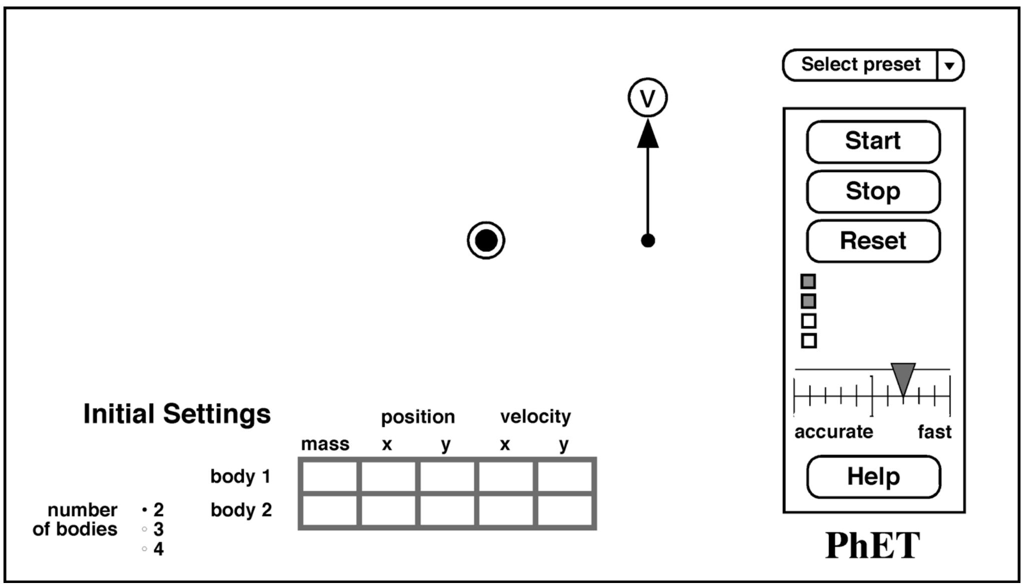
In this activity, you will control the universe! Well you'll control a simulated solar system, anyway. You will investigate elliptical and circular orbits and determine the relationship between orbital radius and orbital speed.

• Apparatus •

___ computer (Phyz MacBook or equivalent)
___ PhET simulation: "My Solar System" (PhET sims are available at http://phet.colorado.edu.)

• Setup •

1. Turn the computer on and allow it to complete its start-up sequence.
2. Open the PhET simulations index page.
3. Select the simulation "My Solar System." Click the on-screen Run Now! button to activate the simulator.



• Procedure •

1. NEWTON'S CANNON

a. Set the on-screen accurate/fast slider control to the midpoint.

b. Set the initial values for body 1 (the yellow sun) as shown below.

Mass	Position x	Position y	Velocity x	Velocity y
200	0	0	0	0

c. Set the initial values for body 2 (the pink planet) as shown below (note: Position y is the orbital radius).

Mass	Position x	Position y	Velocity x	Velocity y
0.1	0	100	0	0

d. Click the on-screen Start button. Observe and record the result.

e. Click the on-screen Reset button to stop the sequence and reset everything to the start condition.

f. Change the initial Velocity x of the pink planet to 40 and play the motion. Observe and record what happens. How is this different from the previous observation?

g. Click Reset. Change the planet's initial Velocity x to 80 and play the motion. Observe and record what happens. How is this different from the previous observation?

h. Click Reset. Change the planet's initial Velocity x to 160 and play the motion. Observe and record what happens. How is this different from the previous observation?

2. MAKE IT SO

a. Through trial and error experimentation, determine the minimum initial speed (Velocity x) that will allow the planet to get around the sun (rather than crashing into it). Record that minimum speed.

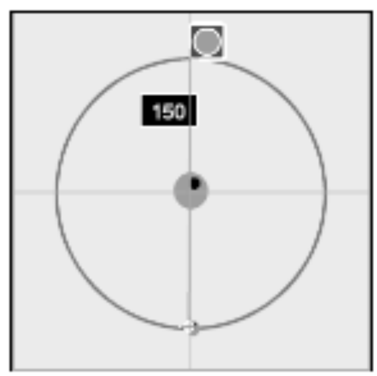
b. Through trial and error experimentation, determine the initial speed (Velocity x) that will allow the planet to sustain a circular orbit at R = 100. Turn on the grid for this activity; it will help you see when you've obtained a circular orbit. Record the corresponding speed.

3. A PLANET OF YOUR OWN PART 1: ORBITAL RADIUS

a. Click the on-screen Reset button to stop the simulation. Obtain **your group's** given orbital radius R from the table on the next page. Enter that radius value as the pink planet's Position y.

b. Through trial and error experimentation, determine the initial speed (Velocity x) that will allow the planet to sustain a circular orbit.

You will find the tape measure useful here. Place the tape measure at the starting point of the planet. Now click the "free" end of the tape and stretch it vertically downward through the sun so that the end of the tape is 2R from planet. So if your given radius were 75, the far end of the tape would be 150 below the launch point. If the launched planet passes through the end of the tape, the orbit is circular. Record the given radius and the correct speed you discovered.



4. A PLANET OF YOUR OWN PART 2: ORBITAL SPEED

a. Click the on-screen Reset button to stop the simulation. Obtain **your group's** given orbital speed from the table on the next page. Set the pink planet's speed (Velocity x) to that value.

b. Through trial and error experimentation, determine the orbital radius (Position y) that will allow the planet to sustain a circular orbit. Record the correct radius you discovered and the speed you were given.

5. YOUR SOLAR SYSTEM

a. If the simulator is running, click the on-screen Reset button.

b. In the Initial Settings area of the simulator, select 3 bodies.

c. Set the sun as before (200, 0, 0, 0, 0). Then set the other bodies with the values of the worlds you found in parts 3 and 4. Remember to set both masses to 0.1, both Position x values and Speed y values to 0.

d. Click the on-screen Start button.

e. Is your system stable? That is, do the planets maintain their circular orbits as the "years" go by? If not, recheck your values and try again. Once your System is stable, secure a PhyzBlessing from your instructor.

6. CRACKING THE CODE

a. Record the data generated by all the groups in the class. Each group should have placed/set the speed for two planets. For the first planet, a radius was given and a speed was determined. For the second planet, the speed was given and the radius was determined.

	Radius (R)	Speed (v)
A	50	
		100
B	75	
		133
C	150	
		167
D	200	
		200

	Radius (R)	Speed (v)
E	50	
		100
F	75	
		133
G	150	
		167
H	200	
		200

b. Identify the functions. Note: functions i and iv have been solved for you.

i.	**x**	1	2	3	4	
	y	1	2	3	4	y = x
ii.	**x**	1	2	3	4	
	y	1	4	9	16	y =
iii.	**x**	1	2	3	4	
	y	1.00	1.41	1.73	2.00	y =
iv.	**x**	1	2	3	4	
	y	1.0	0.50	0.33	0.25	y = 1/x
v.	**x**	1	2	3	4	
	y	1.0	0.25	0.11	0.063	y =
vi.	**x**	1	2	3	4	
	y	1.0	0.71	0.58	0.50	y =

c. Use the data collected by the class to complete the table.

	1.00			
Radius	50	100	150	200
Speed				
	1.00			

d. Simplify the pattern to determine the function. To simplify the pattern, follow the hints given below.

i. In the row above the radius values, rewrite the radius values as multiples of the first radius value.

For example, 50 is equal to 1.00 x 50. So 100 is _______ x 50, and so on. Label the row "Radius*"

ii. In the row below the speed values, rewrite the speed values as multiples of the first speed value.

For example, 200 is 1.00 x 200. So 142 is _______ x 200, and so on. Label the row "Speed*"

e. Examine the simplified pattern and identify the proportionality that best matches it.

__$v \propto R$ __$v \propto R^2$ __$v \propto \sqrt{R}$ __$v \propto 1/R$ __$v \propto 1/R^2$ __$v \propto \sqrt{1/R}$

f. Rewrite the proportionality, solving for R.

7. VERIFY THE CODE

a. Use the data collected by the class to record radius values that correspond to the speed values given below.

Radius*	1.00			
Radius				
Speed	100	133	167	200
Speed*	1.00			
1/Speed*^{2}	1.00			

b. Simplify the pattern using the technique applied to the table above.

c. In the additional space below the line of **speed** values, record the square of the simplified speed values: Speed*^{2}. These values should closely match the **simplified** radius values. $R^* \propto 1/v^{*2}$.

8. KEPLER'S RULE

a. Rewrite the selected expression from 6.f. replacing v with R/T. (Actually, $v = 2\pi R/T$. But since this is a proportionality, we can omit the constants.) Rearrange and simplify to get a relationship between R and T. Johannes Kepler found that the cube of orbital radius was proportional to the square of orbital period. Do your findings confirm or contradict Kepler's Rule?