Gravitation Simulation Lab

Name: ________________________________

Purpose: To gain familiarity with the nuances of the gravitational force; To understand what variables affect it's strength; To show how the gravitational force controls the motions of the planets; To understand how orbital velocity is affected by distance.

Background: According to Newton's Universal Law of Gravitation, the mass of an object, its distance from another object, and the mass of the other object all affect the magnitude of the gravitational force between them. For an object to maintain a stable orbit around another, it must have enough horizontal velocity to keep its radial acceleration from succeeding in pulling the object closer to the sun. Once defined, two objects orbiting each other are stable and will keep doing so indefinitely. Three or more bodies in orbit are inherently much less stable and often tend to keep colliding until only two are left.

Procedure: Go the the University of Colorado web site and run the "My Solar System" gravitation simulation (click on link or use http://phet.colorado.edu/simulations/sims.php?sim=My_Solar_System)! Set the "accurate-fast" slider to its middle position. Check the "system-centered" and "show traces" boxes. Then, use the program to set up the following situations and answer the following questions.

1) **Solar System**: Choose 4 bodies. Fill in the initial settings table with the following data. Start the simulation and observe it for a while.

a) What do you notice about the velocities of the three "planets"? What general rule can you state?

Solar System					
Body	Mass	x	y	v_x	v_y
1	800	-87	0	0	0
2	10	3	0	0	300
3	10	136	0	0	190
4	10	249	0	0	160

2) **Comet**: Choose two bodies. Fill in the initial settings table with the following data.

b) How does this orbit compare to that of a typical planet?

c) Use the tape measure and find the eccentricity of this orbit.

d) How does comet speed relate to the comet's position in the orbit?

Comet					
Body	Mass	x	y	v_x	v_y
1	800	-360	0	0	0
2	4	383	0	0	25

3) **Escape Velocity**: Choose four bodies. Fill in the initial settings table with the following data. This simulation shows the effect of different orbital velocities for planets at essentially the same distance from the sun.

e) How does speed affect the shape of an orbit (when r is constant)?

f) If enough speed is given, what will the object do?

Escape Velocity					
Body	Mass	x	y	v_x	v_y
1	500	212	-50	0	0
2	0.1	212	149	-70	0
3	0.1	212	162	-152	0
4	0.1	212	175	-220	0

4) **Moon on Moon**: Choose four bodies. Fill in the initial settings table with the following data. Notice the strange pattern traced by the smallest moon.

g) What causes the strange shape of the trace ?

h) What do the large moon and the planet rotate around?

Moon on Moon					
Body	Mass	x	y	v_x	v_y
1	400	-101	-32	0	0
2	60	169	-32	0	130
3	9	234	-32	0	30
4	.01	221	-32	0	-26

5) **Slingshot**: When space probes are sent out of the solar system, they do not leave earth with the 45km/s velocity needed to escape the sun's gravitational pull. Instead, they use the gravitational force to transfer some momentum (and KE) from a planet to themselves. Run this simulation and assume that the turquoise object is the space probe, while the purple object is a large planet (like Jupiter).

i) How is the probe's motion different before and after the planetary encounter? What happens to its mechanical energy?

j) What happens Jupiter's mechanical energy as a result of the encounter? How can you tell?

Slingshot					
Body	Mass	x	y	v_x	v_y
1	200	1	0	0	0
2	10	131	55	-55	115
3	1	-6	-128	80	0

6) **Chaos**: Choose four bodies. Give them the masses and positions indicated in the table. Start the simulation.

k) Describe what happens.

l) Is the sun's gravitational force on a planet the only force that affects its motion/orbit?

m) Could this ever happen in our own solar system? Why?

Chaos					
Body	Mass	x	y	v_x	v_y
1	800	-123	-60	0	-1
2	40	46	-60	0	148
3	40	170	-60	-1	126
4	40	304	-60	0	90

7) **Practice**: Choose four bodies. Give them the masses and positions indicated in the table. Start the simulation. What happens? Now try giving the three planets velocity. Start small then increase. After each increment, hit the start box and watch how your velocity adjustments have affected the motion of the planets. Aim at first for elliptical orbits and then try to get circular ones. When you have succeeded in producing planets with stable, circular orbits, record their velocities.

Practice					
Body	Mass	x	y	v_x	v_y
1	400	-217	-32		
2	20	-93	-32		
3	20	-430	-32		
4	20	177	-32		

8) **Three body system**: In this lab, it is your mission to invent a three body system that lasts for a minimum of 150 seconds. All three objects must be massive and they must not ever collide or be sent off forever into interstellar space. Create planets, assign them masses, and adjust their relative positions and velocities in order to achieve this end. ALL THREE OBJECTS MUST BE MASSIVE, with at least two of the bodies having a value of 500 or greater. The third must have a minimum mass of 100. When you have succeeded, record the data in the table.

Mine					
Body	Mass	x	y	v_x	v_y
1	500	-285	0	0	-120
2	800	85	0	0	170
3	600	210	0	0	-50

Three Body System					
Body	Mass	x	y	v_x	v_y
1					
2					
3					