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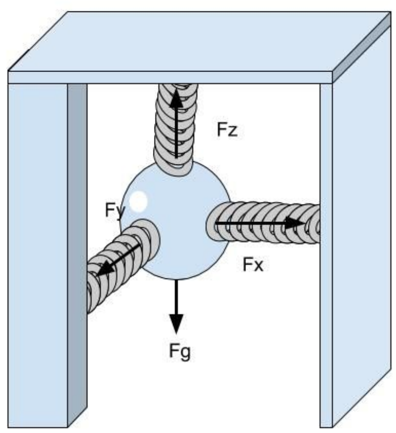
Assignment 4

1) In class we wrote code for our force-ball to emulate a mass on a spring under the influence of gravity.

Observe (plot) the behavior of the force ball with *and without* the force of gravity. How, quantitatively, does removing gravity from the system change the system? You do not need to submit your plot.

Solution - Removing the gravity does not change the system because it’s not dependent on gravity.

2) Consider the following situation:



a) Write the force vectors for $\overrightarrow{F_x}$ and $\overrightarrow{F_y}$ assuming that x_0 and y_0 are both 0.0

Solution -

```
    springX = Vector(-1*(own.position.x),0.0 , 0.0).mult(k)
    springY = Vector(0.0,-1*(own.position.y), 0.0).mult(k)
    springZ = Vector(0.0, 0.0 , 5.0-own.position.z).mult(k)


# Add forces

    mobject.applyForce(grav)
    mobject.applyForce(damp)
    mobject.applyForce(springX)
    mobject.applyForce(springY)
    mobject.applyForce(springZ)
```

b) Use the I,J,K,L,O and P keys to displace the mass in each direction. Plot the data for each axis and determine what affect displacing the mass has on the oscillations in the other directions (you don't need to submit your plot).

Solution - when mass is displaced on any one of 3 axis, it does not affect other 2 axis as they are independent when it comes to oscillating with mass.

3) Next week, we will explore some topics in 'non-linear dynamics'. We can experiment with some properties of non-linear dynamics right now!

The following equations describe a 'driven-damped oscillator:

$$\overrightarrow{F}_{drive} = m \cdot \gamma \cdot \omega_o^2 \cdot cos\left(v_z \cdot t\right)$$

$$\overrightarrow{F}_{osc} = -m \cdot \omega_o^2 \cdot sin\left(z\right)$$

$$F_{damp} = -b \cdot v_z$$

where ***m** is mass, γ is a 'driving co-efficient',* ω_o^2 is the "natural frequency" of the oscillator and **b** is the damping co-efficient.

a) Remove any forces currently in your code (comment them out) and add a damping, driving and oscillator force as discussed above. Set ω_o^2 to 9.8/1.0 -- (g/l), γ to a value > 1.4 and b to 0.3 and provide your code.

b) Run the simulation. The force-ball will probably oscillate wildly. Go make some coffee or something for a few minutes. When you come back, make a phase-space plot of your system (simply plot z-position vs z-velocity) and save your plot.

c) Repeat b, but change the damping co-efficient by 0.1. Again, let the system run and do a phase-space plot.

What do you observe? Did the plot change significantly? Submit your plots with your comments.

Solution -

```
omega = 9.8/1.0
y = 1.5
b = 0.3
```

```
driveForce = Vector(0.0,0.0,(m*y*omega*math.cos(mobject.vely.z*t)))
oscForce = Vector(0.0,0.0,(-m*omega*(math.sin(own.position.z))))
dampForce = -b*mobject.vely.z
```