CW4: A Ball on a String, 2D pendulum [function]

I. Some topics about Vpython and Python

1. Draw a string

```
from visual import *
scene = display(width=800, height=800,center = (0, -0.5, 0), background=(0.5,0.5,0))
string = cylinder(radius=0.006)
```

This code generates a cylinder, with radius = 0.006, as a string.

```
string.pos = vector(1, 0, 0)
string.axis = vector(2, -1,0)
```

The above two lines set the string to start at (1, 0, 0) and to stretch in vector (2, -1, 0).
More on cylinder is at http://vpython.org/contents/docs/cylinder.html.

2. *** Function and polymorphism

Very often, we need to reuse a section of codes in different parts of a program, then we can write this section of codes as a function. This also makes our codes more readable. And the same section of codes can be used in the future in other programs without re-writing it when you need it. Here is an example that yields the one with a larger length from two inputs.

```
from visual import *

def max_length(a,b):
    if abs(a)>abs(b):
        return a
    elif abs(b)>abs(a):
        return b
    else:
        return 'equal'

a, b = 5, -8
print max_length(a,b)

c = vector(3,4,5)
d = vector(2,8,7)
print max_length(c,d)

e = 5+3j
f = 3+5j
print max_length(e,f)
```

(1) define function

```
def max_length(a,b):
```

The first line defines the name of the function (max_length) and the parameters it needs (a and b). Below it the indented codes (indented codes are associated with the function) do the comparison.

```
    if abs(a)>abs(b):
        return a
    elif abs(b)>abs(a):
        return b
    else:
        return 'equal'
```

Here it fully demonstrates the “if” command. The first two lines says that if a’s absolute value is larger than b’s absolute value, then a is sent back to where the function is called. “elif” means “else if”. When the condition in “if” is not satisfied, this condition is tested and if it is true, the associated codes is executed, Here it means if abs(b) is larger, b is sent back. When both above conditions are not satisfied, the associated codes of “else” is executed, then a string of text, ‘equal’, is sent back.

(2) main program: After the function part, the following non-indented codes are the main program.

```
a, b = 5, -8
print max_length(a,b)
```

a and b are assigned values 5 and -8, respectively. And they are the parameters to be sent to the max_length function. After the function is executed, the returned value is printed. Similarly for the following codes,

```
c = vector(3,4,5)
d = vector(2,8,7)
print max_length(c,d)

e = 5+3j
f = 3+5j
print max_length(e,f)
```

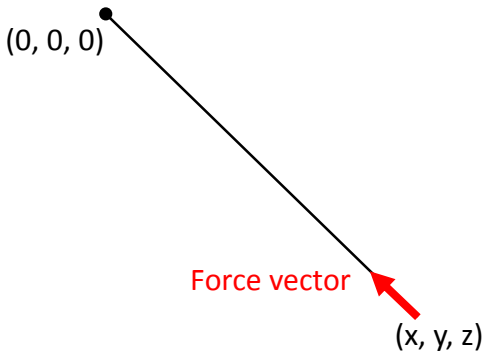
Here we can see the powerfulness of python. We write a simple function, but it works for integers, floats, vectors, as well as complex numbers (by the way, in Python, imaginary number $\sqrt{-1}$ =1j). This kind of function operation, wrote for one data type but works for other types, is called polymorphism. More features about python function will be introduced in the future.

II. Practice

In the following, we will construct a 3D pendulum. We will separate the physical problem into several parts.

(1) Force function: Write a force function, which returns the force strength, for a string when the length of the string is *r*, def force(r). The original length of the string is *L* = 1.0 m. And the tension constant is $k = 10^5$ N/m. (In Python, 10^5 is written as 1E5). Check the correctness of this function for several values of your choice of *r* and verify this with your calculator.

(2) Modify the function for the string with the fixed end at (0, 0, 0) and the other end at r = (x, y, z). The function force(r) now returns the tension vector on the end of (x, y, z). Check the correctness of this function for several of your choice of *r.*



(3) Draw a ceiling. Draw a ball of radius of 0.03 m. The mass of ball is 1kg. Let the original position of the ball at vector(L*sin(theta), -L*cos(theta), 0), the original velocity of the ball = vector(0, 0, 0). Draw the string from the fixed end (0,0,0) to the center of the ball. Use similar codes in previous homework and **do the simulation for the motion of the ball and the string and find the period of the oscillation. Compare the period with the theoretical value when the initial angle is small. What happens if the initial angle is large?**

This simulation is more "fundamental" than the pendulum analysis in the high school physics. The ball is exerted by two forces, one gravitational force and the other is the tension from the string. As the ball is swinging at the bottom of the string, it is doing a circular motion that requires a centripetal force. But how does the string "know" exactly how much force to exert on the string to make the ball to move in a circular motion as the ball velocity is changing all the time? A traditional way to analyze the pendulum never mentions this. By a careful examination, we will find actually the string must be stretched a little bit to provide the extra force as the centripetal force. This is what we do in this simulation.

III. Homework Submission:

In Practice (3), the pendulum swings in x-y plane. Now we want the pendulum to swing in three dimensions, meaning, when the ball is in x-y plane, it has non-zero z-component of its velocity. Now simulate for your own choice of theta, by using the velocity (0, 0, vz) (this vz is obtained from your physics knowledge) such that the ball will do a circular motion. Find, by the program, and print the period of this circular motion for every cycle of the motion and compare it to the theoretical value.