ques_01

December 28, 2020

[2]:
```
import numpy as np
from matplotlib import pyplot as plt
```

[10]:
```
def euler_cp(x , x_0 , y_0 , z_0, fy , fz , tol=1e-5):

    def rk4_next_val(f,x_0 , y_0 , h):
        y_next = y_0+h*f(x_0 , y_0 )
        return y_next

    def calc(h):
        n = int(abs((x_0-x)/h))
        x_next,y_next ,z_next = x_0, y_0 , z_0
        for i in range(n):
            y_next = rk4_next_val(fy(z_next) , x_next , y_next , h)
            z_next = rk4_next_val(fz(y_next) , x_next , z_next , h)
            x_next += h
        return [y_next , z_next]

    del_x = 1e-5
    return calc(del_x)
```

[11]:
```
def rk4_cp(x , x_0 , y_0 , z_0, fy , fz , tol=1e-5):

    def rk4_next_val(f,x_0 , y_0 , h):
        f0 = f(x_0,y_0)
        f1 = f(x_0+h/2 ,  y_0+(h/2)*f0)
        f2 = f(x_0+h/2 , y_0+(h/2)*f1)
        f3 = f(x_0+h , y_0+h*f2)
        y_next = y_0+(h/6)*(f0+2*f1+2*f2+f3)
        return y_next

    def calc(h):
        n = int(abs((x_0-x)/h))
        x_next,y_next ,z_next = x_0, y_0 , z_0
        for i in range(n):
            y_next = rk4_next_val(fy(z_next) , x_next , y_next , h)
            z_next = rk4_next_val(fz(y_next) , x_next , z_next , h)
```

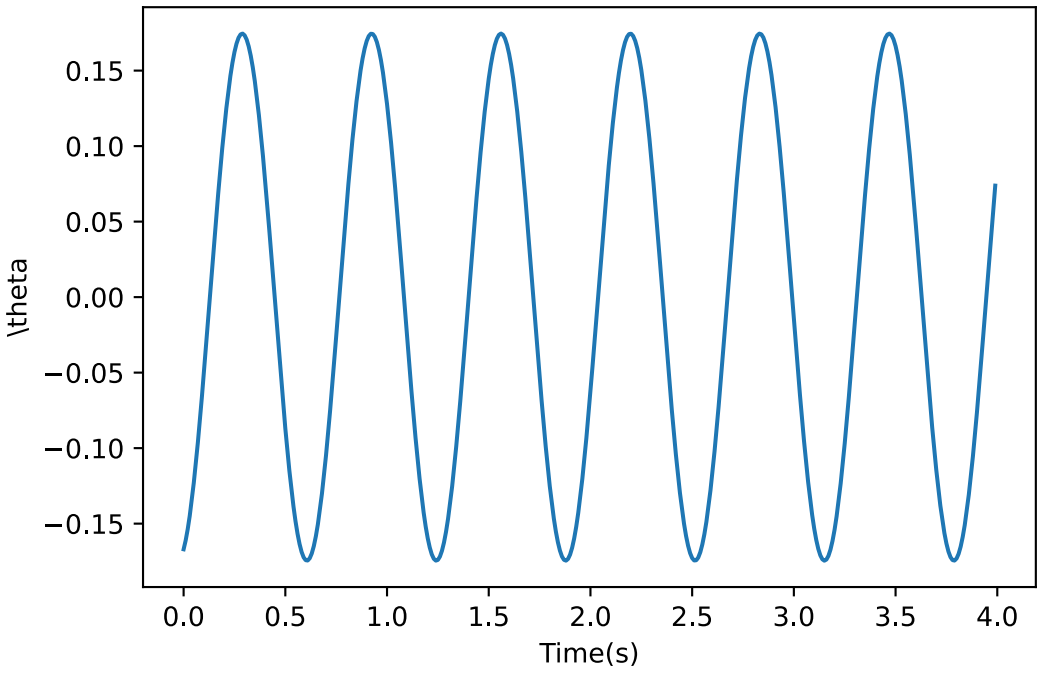
```
            x_next += h
        return [y_next , z_next]

    del_x = 1e-5
    return calc(del_x)
```

[12]:
```
def fy(z):
    def f_in(x , y):
        return z
    return f_in

def fz(y):
    def f_in(x , z):
        return (-g/L)*np.sin(y)
    return f_in
```

[13]:
```
g = 9.8
L = 10/100
theta_0  = np.radians(10)
z_0 = 0
t_0 = 0
y_0 = theta_0
```

0.1 q 02 , Using Euler

[18]:
```
t = np.arange(0, 4 , step = 0.01)

theta = []
theta_dot = []
for ti in t:
    soln = euler_cp( ti , t_0 , y_0 , z_0 , fy , fz)
    t_0 = ti
    th = soln[0]
    th_dot = soln[1]
    theta.append(th)
    theta_dot.append(th_dot)
    y_0 = th
    z_0 = th_dot
plt.plot(t, theta)
plt.xlabel("Time(s)")
plt.ylabel(r"\theta")
plt.show()
```



0.2 Estimate Time Period

FInding zero crossing successive zero crossing will give half of time period.

[19]:
```
def find_avg_time(theta , time):
    zero_cross = []
    for i in range(len(theta)-1):
        prev = theta[i]
        nxt = theta[i+1]
        if(prev*nxt<0):
            zero_cross.append(time[i])
    #print(zero_cross)
    z_odd = zero_cross[0::2]
    z_even = zero_cross[1::2]

    t_avg_list = [(z2-z1)*2 for z1, z2 in zip(z_odd, z_even)]
    t_avg = sum(t_avg_list)/len(t_avg_list)
    return t_avg
```

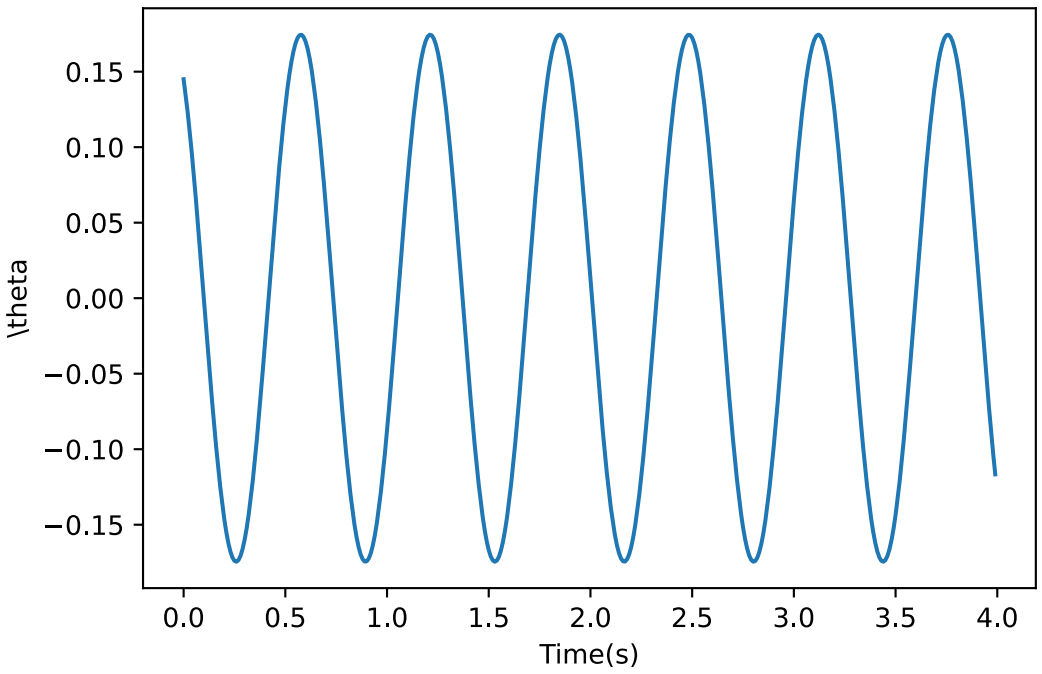
[20]:
```
period = find_avg_time(theta , t)
print("Period :{:.2f} ".format (period))
```

```
Period :0.64
```

0.3 Using RK4

[22]:
```
t = np.arange(0, 4 , step = 0.01)
theta = []
theta_dot = []
for ti in t:
    soln = rk4_cp( ti , t_0 , y_0 , z_0 , fy , fz)
    t_0 = ti
    th = soln[0]
    th_dot = soln[1]
    theta.append(th)
    theta_dot.append(th_dot)
    y_0 = th
    z_0 = th_dot

plt.plot(t, theta)
plt.xlabel("Time(s)")
plt.ylabel(r"\theta")
```

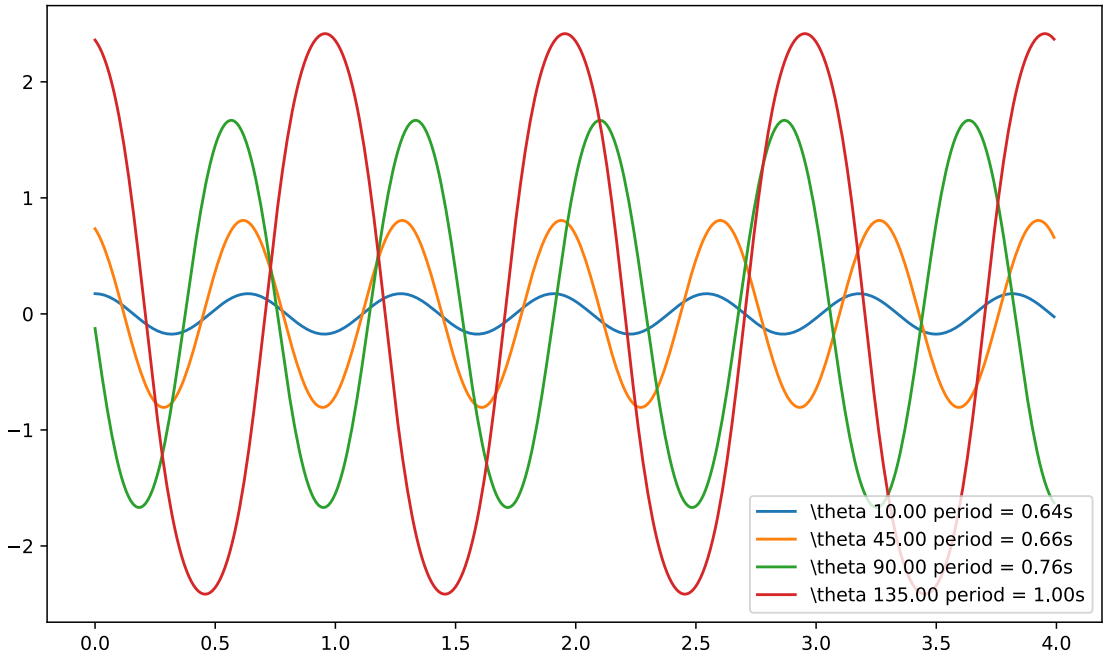
[22]:
```
Text(0, 0.5, '\\theta')
```



[ ]:
```
t = np.arange(0, 4 , step = 0.01)
theta_0_collection = np.radians([10 , 45 , 90 , 135])
theta_collection = [t]
```

```
for theta_0 in theta_0_collection:
    #theta_0  = np.radians(10)
    y_0 = theta_0
    theta = []
    theta_dot = []
    for ti in t:
        soln = rk4_cp( ti , t_0 , y_0 , z_0 , fy , fz)
        t_0 = ti
        th = soln[0]
        th_dot = soln[1]
        theta.append(th)
        theta_dot.append(th_dot)
        y_0 = th
        z_0 = th_dot

    theta_collection.append(theta)

np.savetxt('theta_rk4_all_v2.csv' , theta_collection)
```

[29]:
```
data = np.loadtxt('theta_rk4_all_v2.csv')
time = data[0,:]
theta_all = data[1:,:]

fig = plt.figure(figsize=(10,6))
period = []
for th in theta_all:
    plt.plot(time , th)
    p = find_avg_time(th, time)
    period.append(p)
    #plt.title('Period  = {:.2f}'.format(p))
    #plt.show()
    #plt.plot(time , theta_all[3])
theta = [10 , 45 , 90 , 135]
leg = [r'\theta {:.2f} period = {:.2f}s'.format(t, p) for t, p in␣
 ↪zip(theta,period)]
#print(leg)
plt.legend(leg)
plt.savefig('rk4_solutions_v2.png')
plt.show()
```


2
1
0
−1
−2
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
\theta 10.00 period = 0.64s
\theta 45.00 period = 0.66s
\theta 90.00 period = 0.76s
\theta 135.00 period = 1.00s