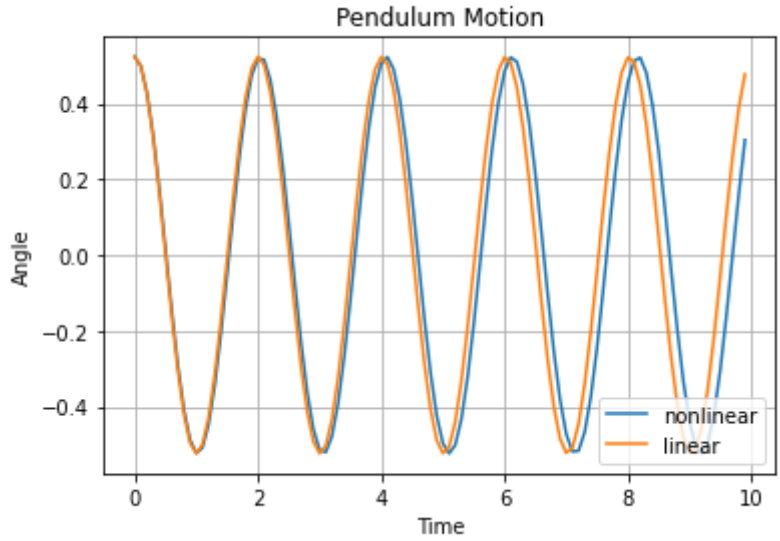
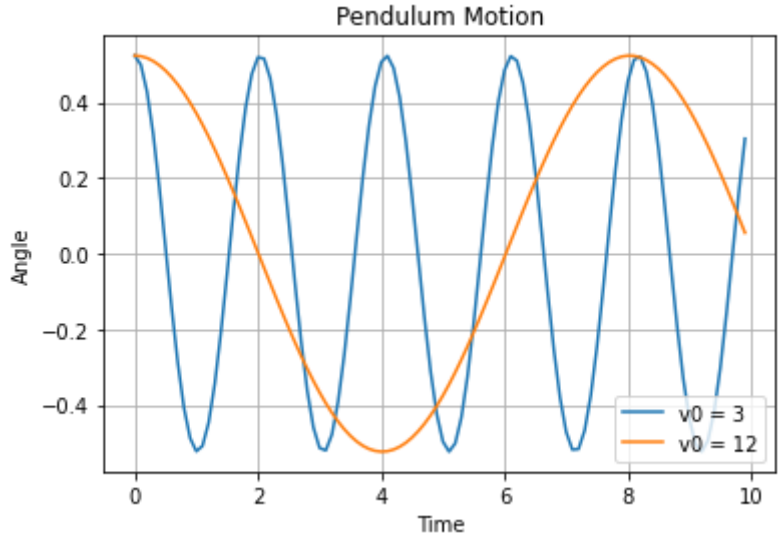
In [37]:
```
import numpy as np
from numpy import sin, cos
from scipy.integrate import odeint
from matplotlib import pyplot as plt

def equations(y0, t):
    theta, x = y0
    f = [x, -(g/l) * sin(theta)]
    return f

def plot_results(time, theta1, theta2, title1, title2):
    plt.plot(time, theta1[:,0])
    plt.plot(time, theta2)

    plt.title('Pendulum Motion')
    plt.xlabel('Time')
    plt.ylabel('Angle')
    plt.grid(True)
    plt.legend([title1, title2], loc='lower right')
    plt.show()

g = 9.8
l = 1.0

time = np.arange(0, 10.0, 0.1)

angle0 = 30
theta0 = math.radians(angle0)
x0 = math.radians(0.0)

theta1 = odeint(equations, [theta0, x0],  time)

w = math.sqrt(g/l)
theta2 = [theta0 * cos(w*t) for t in time]

theta3 = [(theta0) * cos((w/4)*t) for t in time]


print("b) and c)");
plot_results(time, theta1, theta2, 'nonlinear', 'linear')
print("d)");
plot_results(time, theta1, theta3, 'v0 = 3', 'v0 = 12')
print("e)");

time = np.arange(0, 30.0, 0.1)
theta1 = odeint(equations, [theta0, x0],  time)
theta4 = [(theta0 * cos(w*t -0.1*w*t)) for t in time]

plot_results(time, theta1, theta4, 'no friction', 'friction')
```

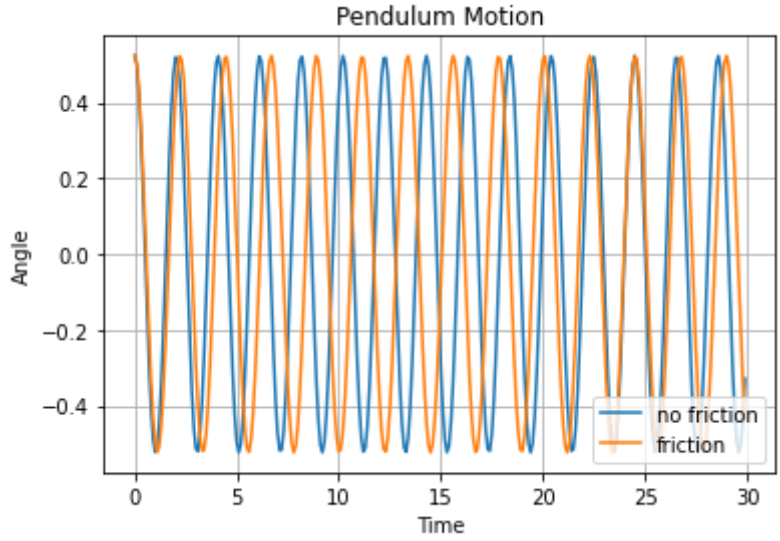
```
b) and c)
```


Pendulum Motion
Angle
Time
nonlinear
linear

d)


Pendulum Motion
Angle
Time
v0 = 3
v0 = 12

e)


Pendulum Motion
Angle
Time
no friction
friction

In [ ]: