CALIFORNIA INSITUTE OF TECHNOLOGY

# Ph20 Assignment 1

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# 1 Introduction

In my first python program I used lists to store the values of x,y,z,t. Using a for loop I appended each function individually and the lists were populated by the corresponding functions. In my second program, I used numpy arrays to store the values of x,y,z,t, which made things easier and faster. In a fewer lines and without using a for loop I managed to get the same result.

For plotting I used matplotlib and plotted two different graphs, x against y and z against t. For exporting I imported the DataFrame package, which I used to export the different lists to csv files.

# 2 Question 2

## 2.1 Observing Rational and Irrational Numbers

It was observed that when $\frac{fx}{fy}$ was a rational number, the output curve of X(t) against Y(t) was closed. Examples below include 1,2, $\frac{1}{3}$.

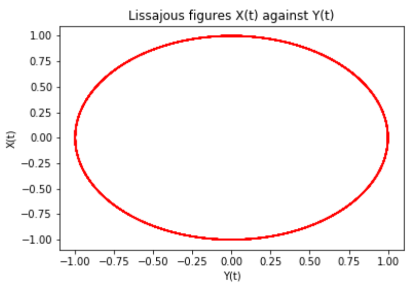
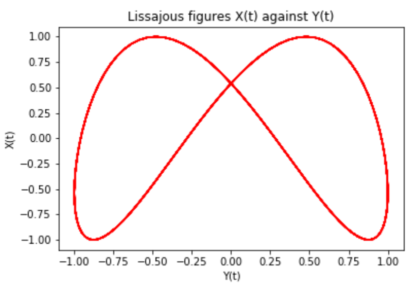
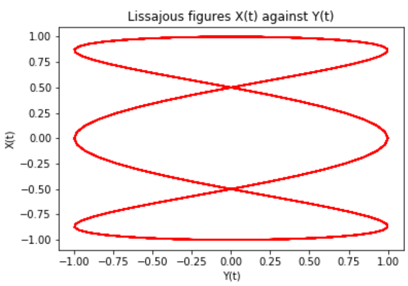



Figure 2.1: fx=1, fy=1




(a) fx=2, fy=1




(b) fx=1, fy=3

However when $\frac{fx}{fy}$ was an irrational number, the curve of X(t) against Y(t) was open. Examples below include $\pi$ and $\sqrt{2}$.

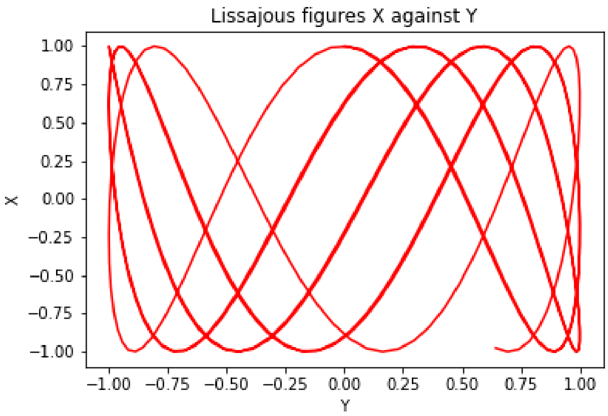



Figure 2.3: fx=pi, fy=1

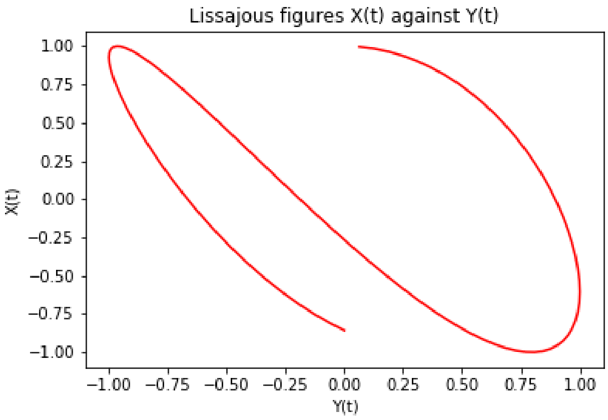
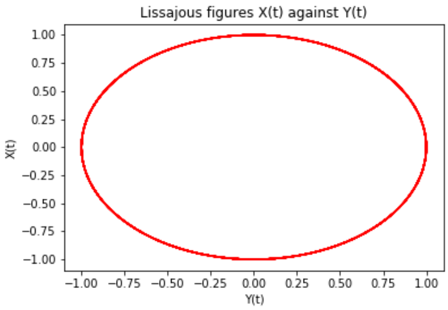


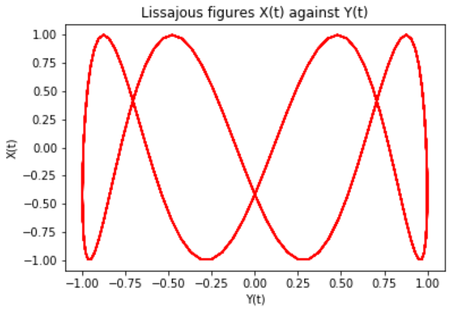

Figure 2.4: fx=$\sqrt{2}$, $fy = 1$

## 2.2 INVESTIGATING THE RATIO

It was interesting to investigate the ratio between fx and fy. It was observed that the ratio determines the number of "lobes" of the figure. When the ratio was increased the number of lobes increased by the same amount. The figures below show the ratio of 1 (1 lobe), ratio of 4 (4 lobes) and ratio of 5 ( 5 lobes).




(a) fx=1, fy=1




(b) fx=4, fy=1

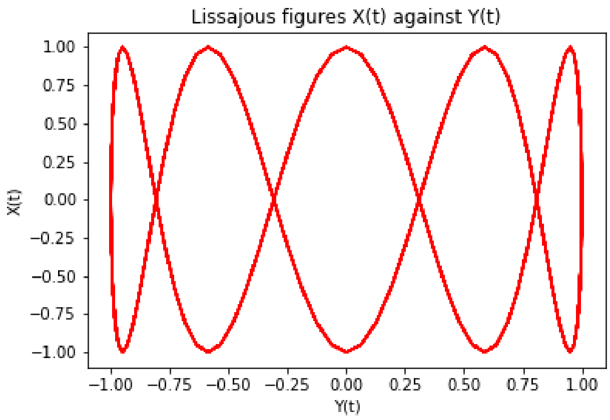
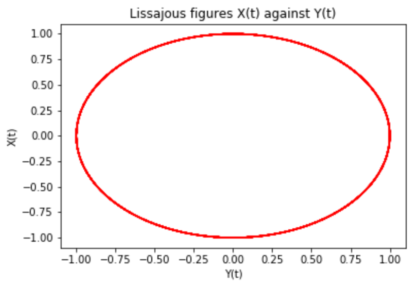


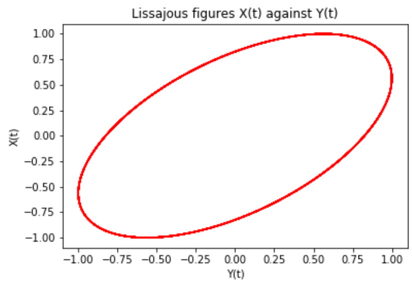

Figure 2.6: fx=5, fy=1

## 2.3 Relation between phase shift

Finally it was observed that the value of the face shift influences the rotation of the figure. When the phase angle is just 0, then X(t) and Y(t) are in phase. Trying any other value, the figure seems to be rotated and shrinked. Below there are examples of phase shift 0, 0.6 and $\frac{\pi}{2}$.




(a) phase = 0




(b) phase = 0.6

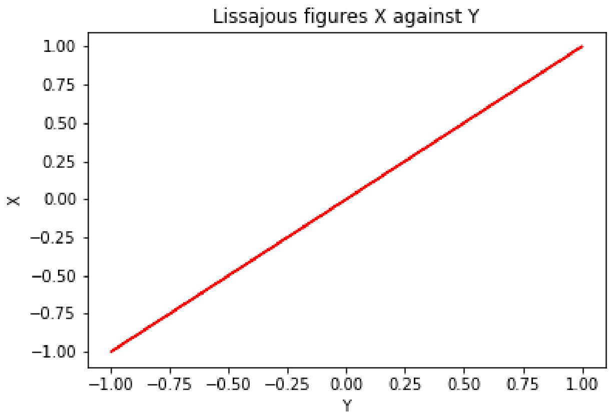
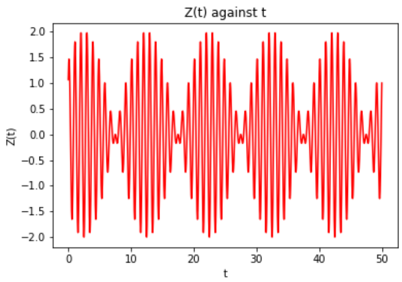



Figure 2.8: phase = $\pi/2$

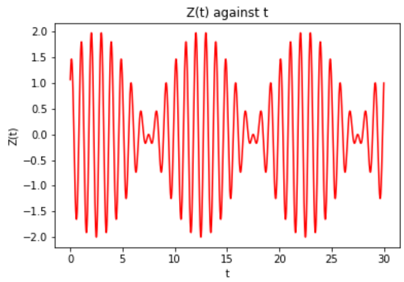
This observation can be used to tune an electronic circuit by altering the phase shift of the wave to match an electric signal on the oscilloscope. Taking into consideration the phase difference one can determine how much the electric wave should be altered in ordered to be tuned to a certain frequency.

# 3 QUESTION 3

In this question the phenomenon of beats was investigated. Below there are 2 figures with different frequencies that show this phenomenon. In the figures below it can be seen that there are multiple cycles at carrier frequency $\pi$fx + $\pi$fy and a few modulation cycles at the frequency 2$\pi$fx - 2$\pi$fy. Cycles of frequency $\pi$fx - $\pi$fy do not appear because they are modulated by the first cos term of the equation of beats.




(a) fx=1 , fy=1.1, N=3000




(b) fx=1, fy=1.2, N=1000