DRIPPING FAUCET AND CHAOS

An experimental study by-
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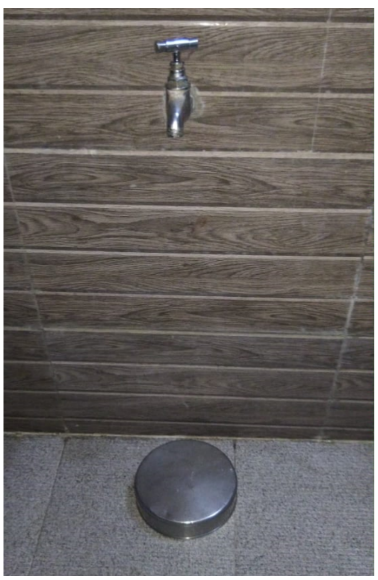
Overview

This is one of the classical experiments in the history of mankind.This is a great example of a simple experiment which behaves as predicted initially but later becomes unpredictable or to be precise,chaotic.

Aim

To study the behaviour of a dripping faucet by calculating the time interval between two simultaneous drops dripping from the faucet when the flow rates are changed.



Experimental Setup and Procedure

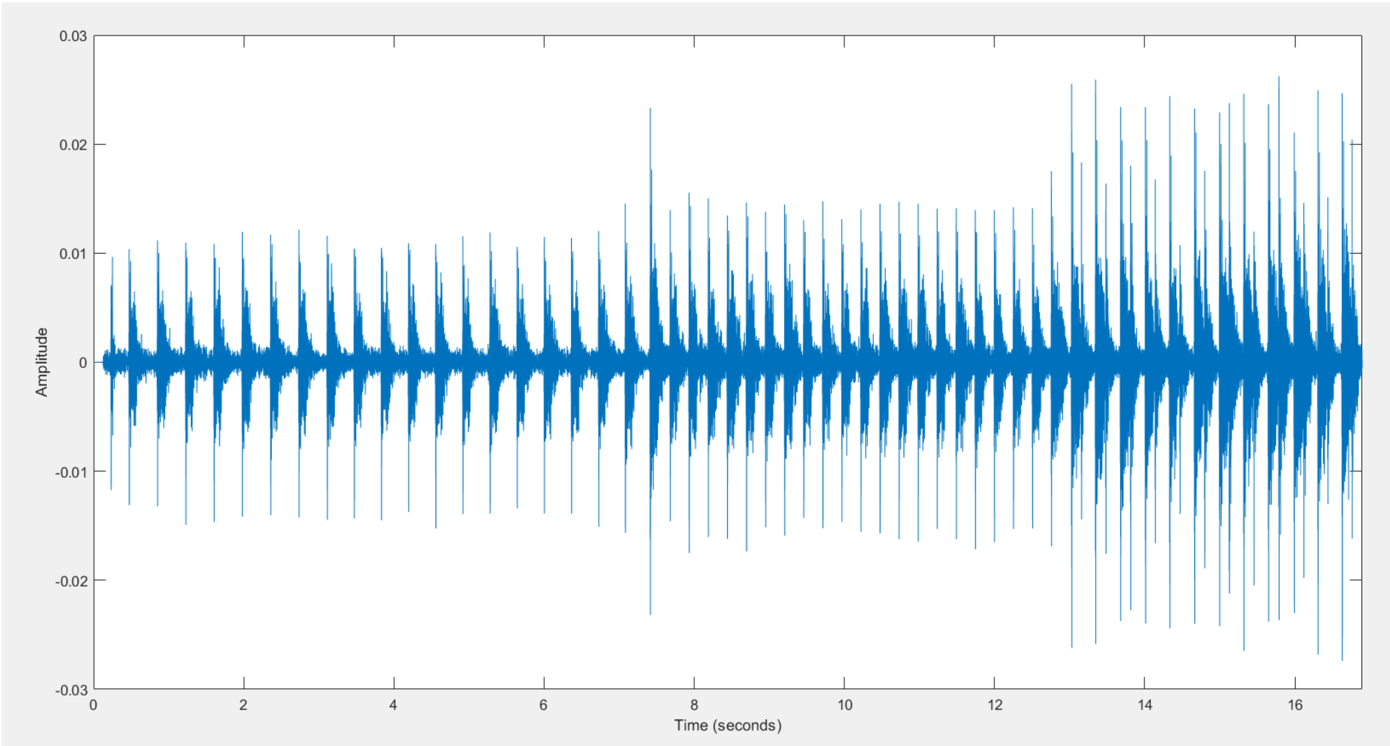
The drops falling from the faucet are allowed to fall on a steel plate in order to amplify the sound coming from it when it hits the bowl.These sounds are captured using a simple microphone and the audio signal is then visualized and studied to calculate the time period between two adjacent peaks using some predefined functions in MATLAB.

Later graphs are plotted for a specific flow rates with the following axes:

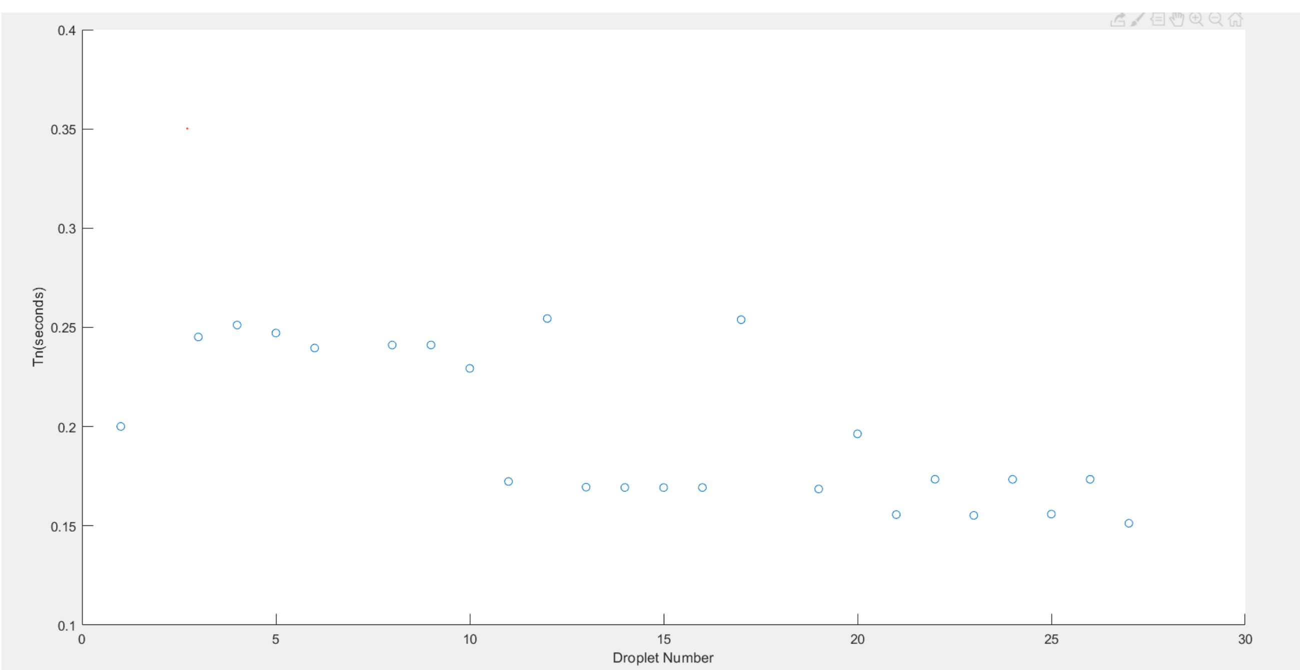
a) T_{n+1} vs T_n
b) T_n vs Droplet number.
   where T_n denotes the time interval between the n^{th} and $(n-1)^{th}$ drop.

Observations and Plots

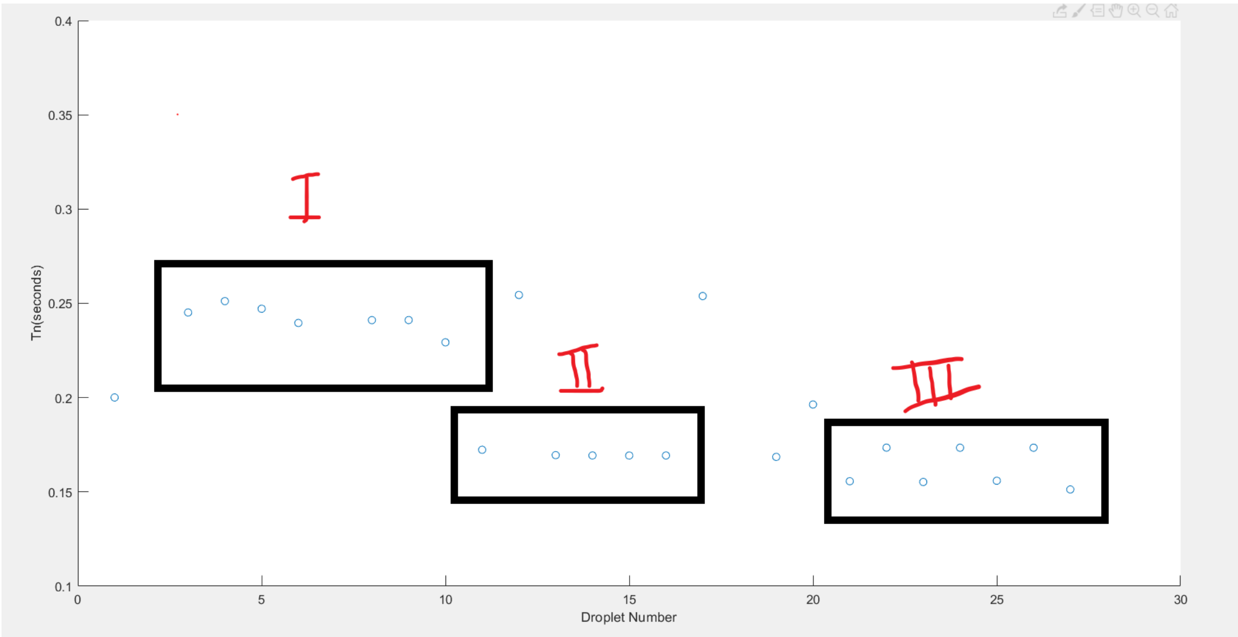
First of all a recording is taken varying the flow rate by opening the valve at roughly equal time steps ~10sec. Here is the obtained graph.



The above plot shows the audio signal note that all those sharp peaks correspond to the time when the drop hits the steel bowl.It could be clearly seen when the valve is open a bit more (at ~8sec and ~13sec) the time interval between two drops reduces. The same audio signal is now plotted for T_n vs Droplet number.



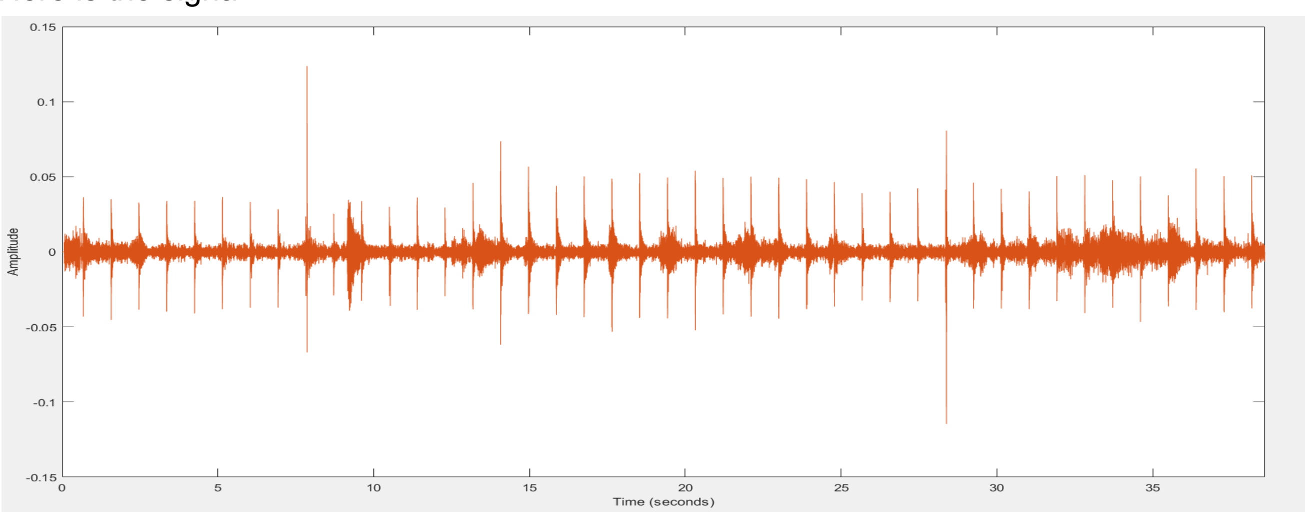
Let us now see what is happening over here.

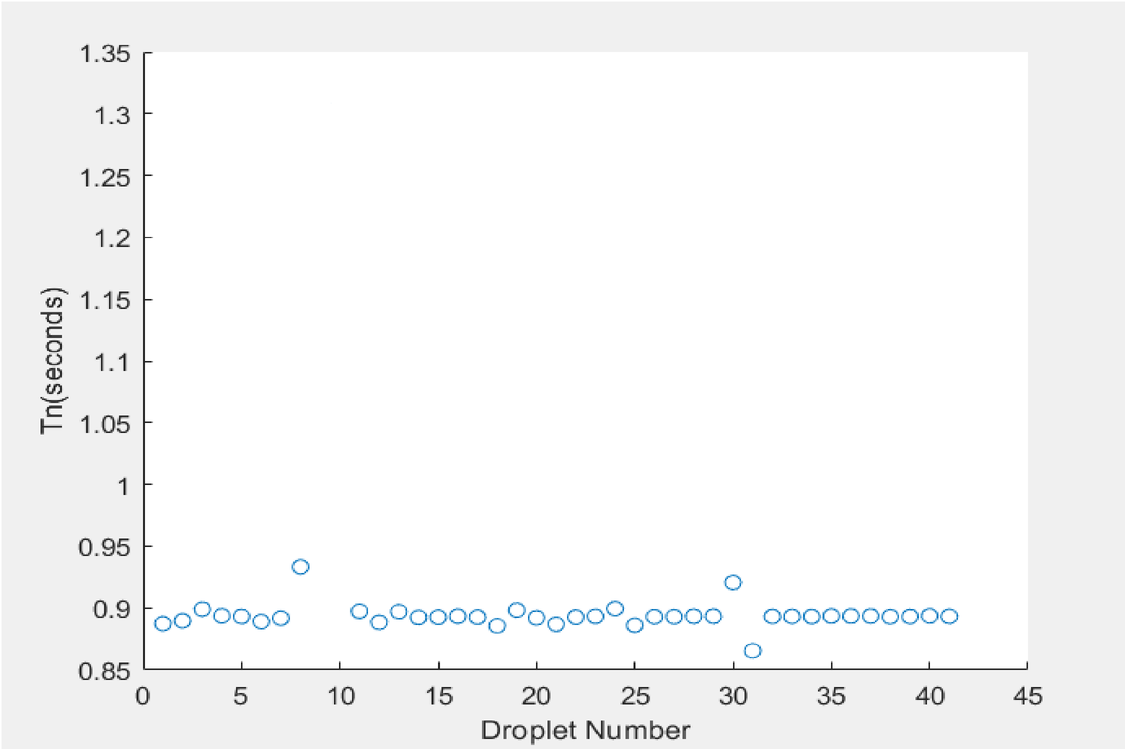


The regions marked I, II, III correspond to three different flow rates.Here the flow is increased from I to II and from II to III. As we can see the transition from one two two is quite intuitive i.e if you increase the flow rate the time interval should decrease. But unlike to that something else is observed while going from II to III. Here we see a period doubling i.e instead of having a single period now we have two different periods which are alternate to.This is quite an interesting observation.

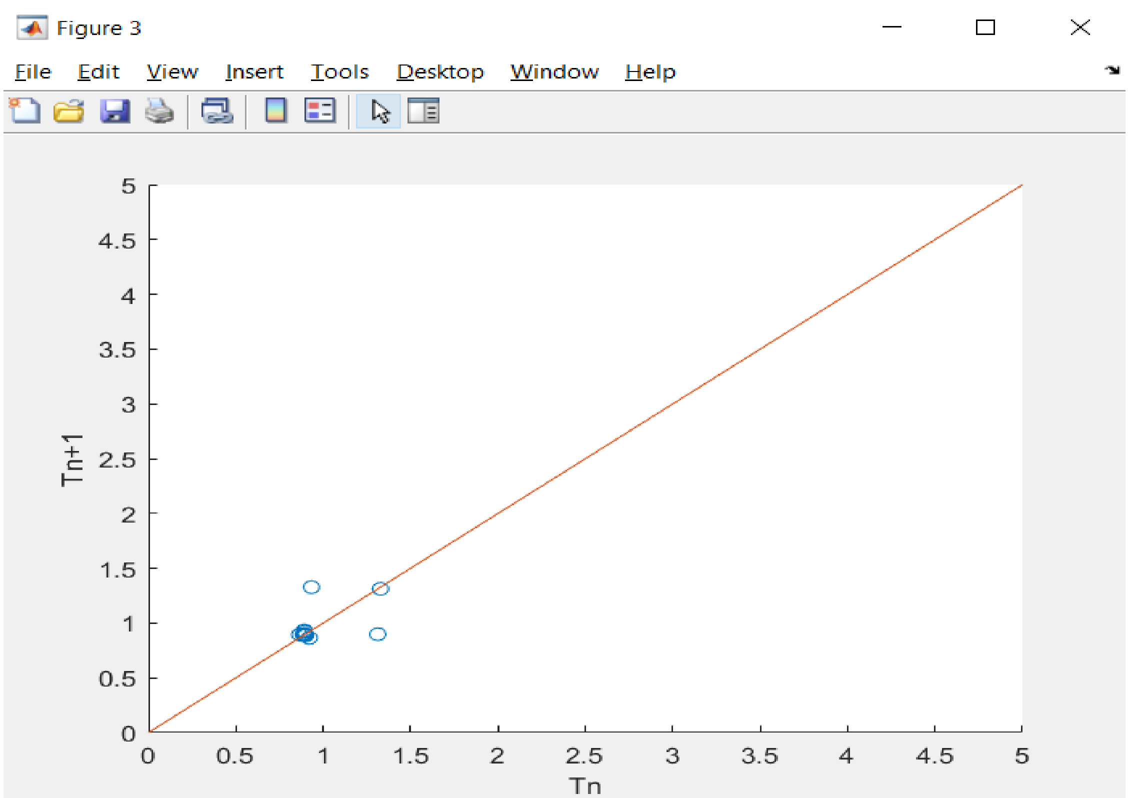
Let us now see a signal for Period 1 only.

Here is the signal



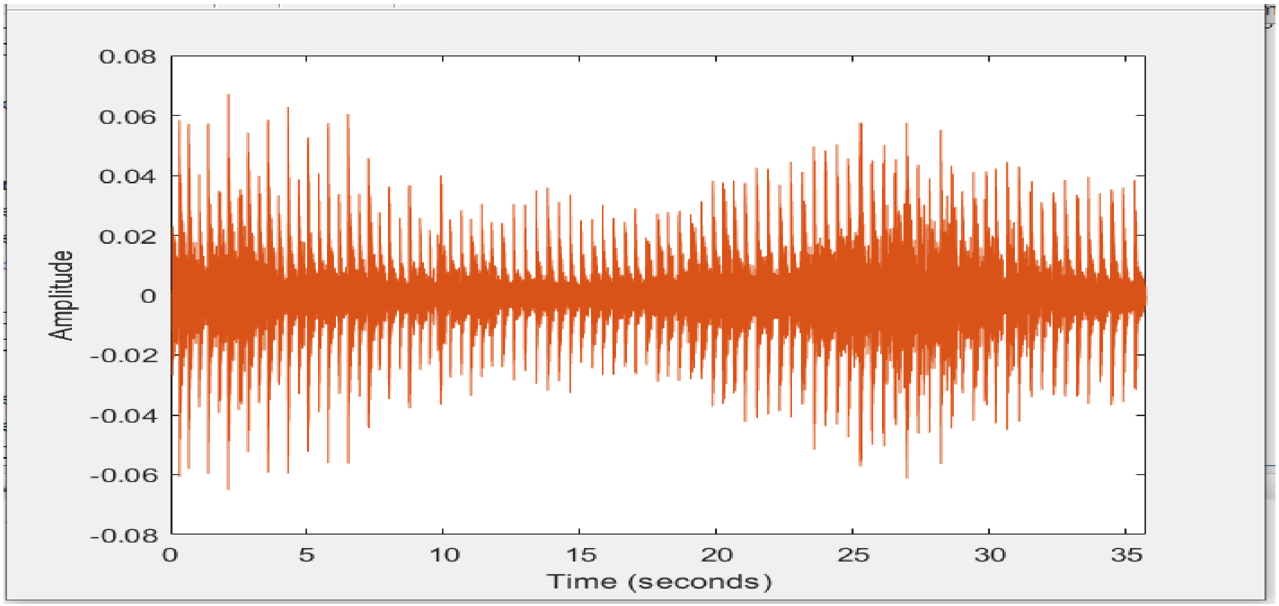


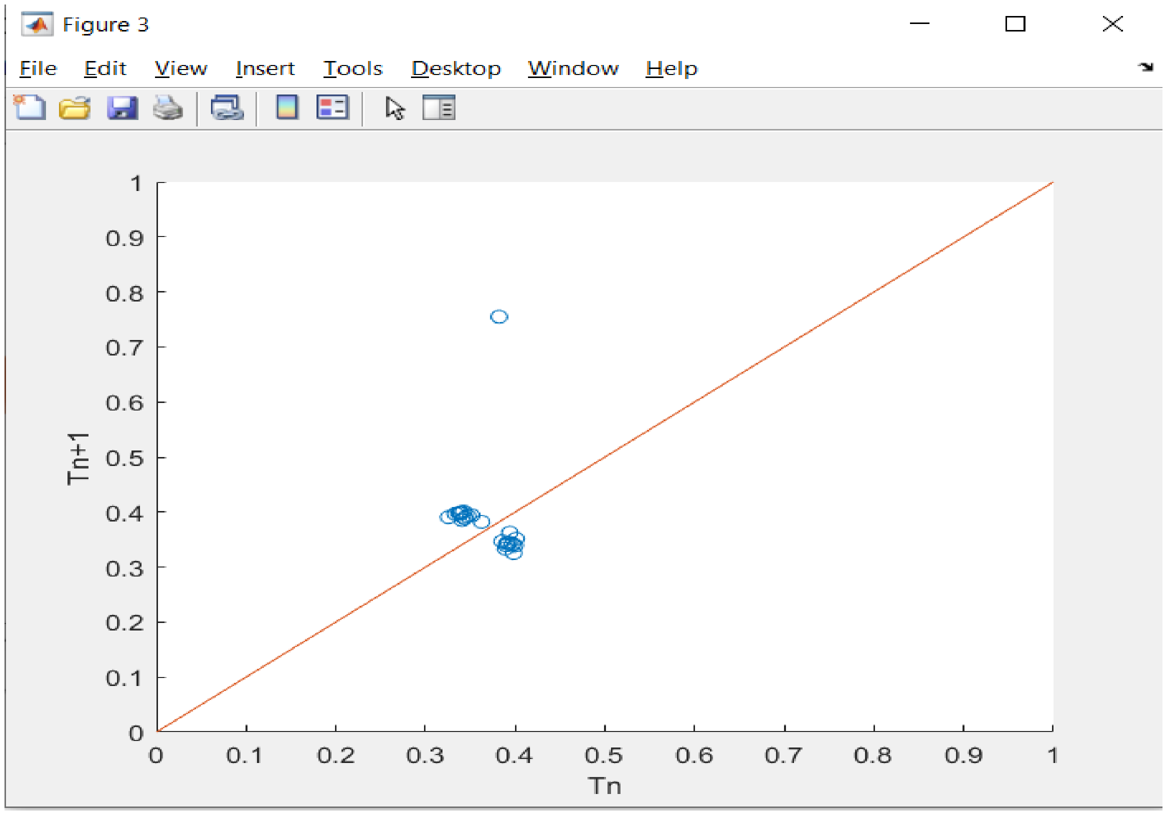
As we can see all the drops lie on the same horizontal line i.e.all have the same period. From here we can have an a guess on how the plot of T_{n+1} vs T_n should look like:



Here we can clearly see that almost every drop falls over that straight line passing through the origin (x=y).

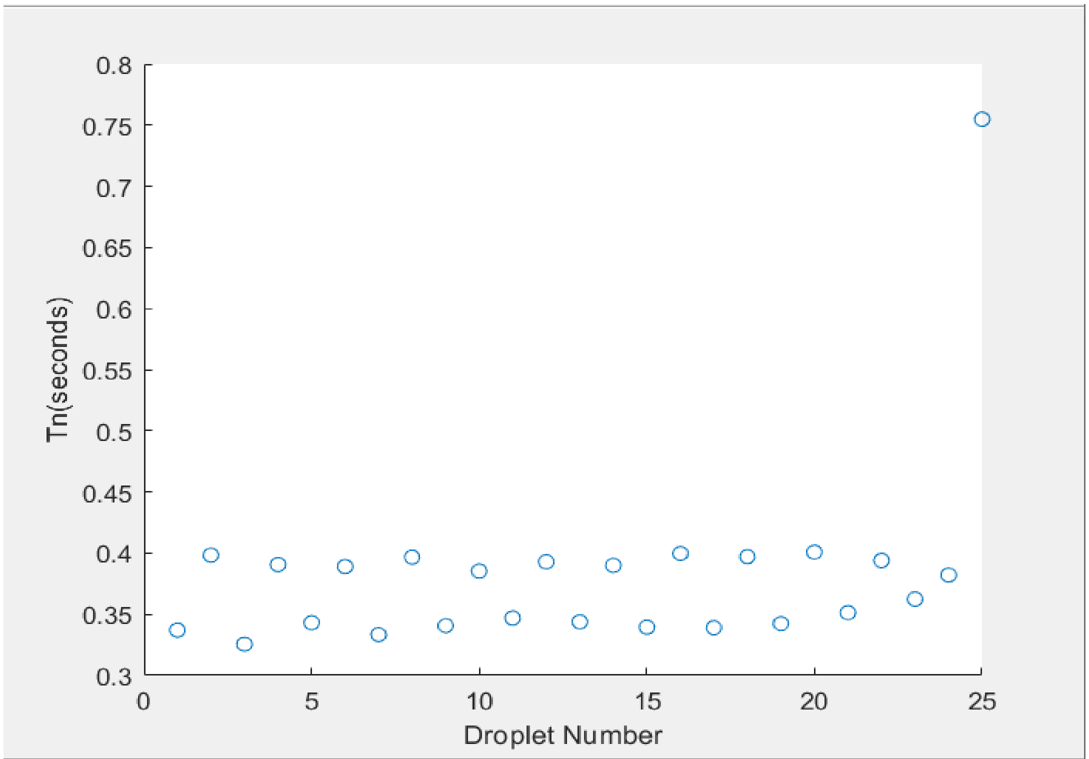
The interesting plots are for a period two dripping which I recorded separately having fine adjustments whose plots are given below.





From the above graph one can have a clear look at the double period for dripping (all the droplets fall under two blobs).

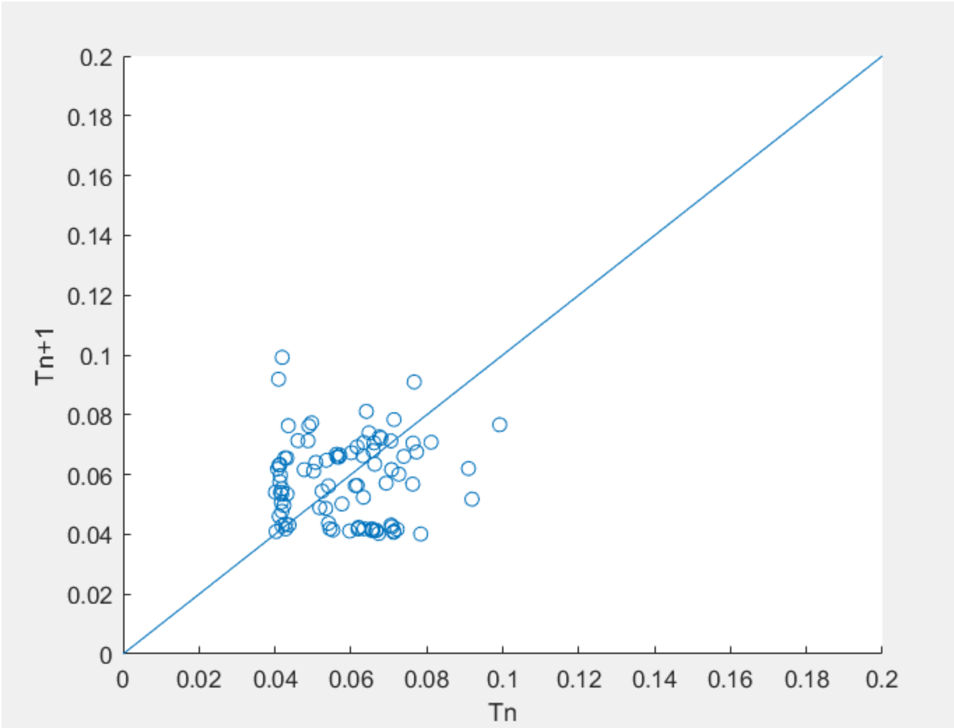
One may conclude the same from the following graph too:

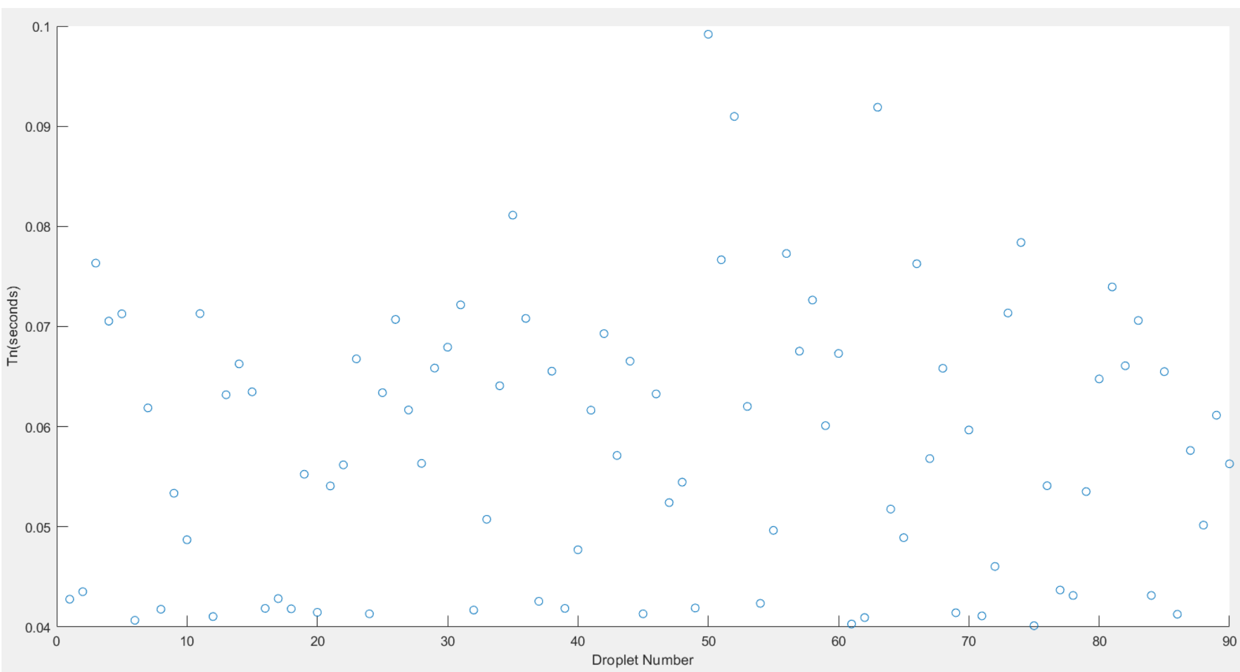


Here we can see two horizontal lines on which the drops fall.

This period doubling is not at all intuitive.But the question is what happens next? Can we see a period three behaviour or a period four or more? The answer is YES. Though I was not able to record a period four dripping as that needs very small and precise opening in the valve which could not be made possible with a household water faucet due to variable flow rates from the back supply.

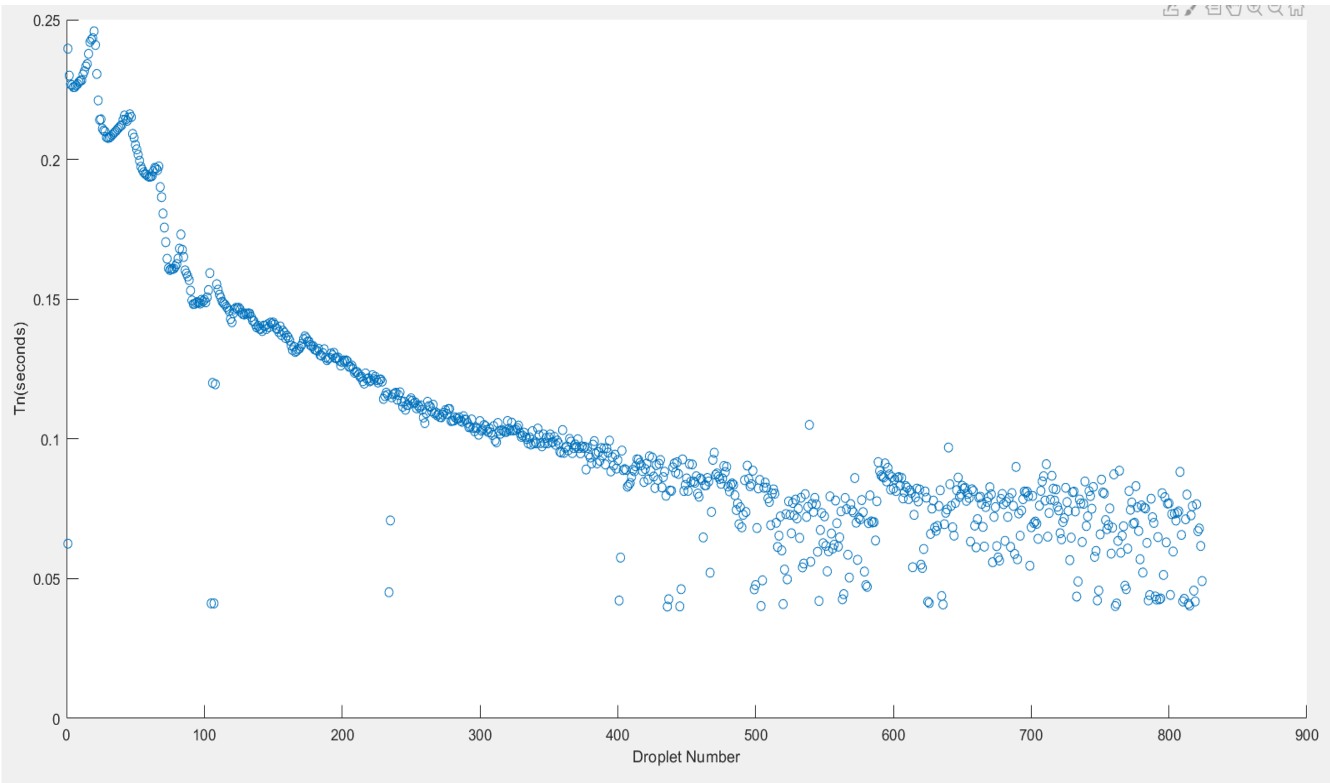
Yet another phenomena that could be captured is the chaos of dripping faucets. Now there is no more periodicity which was seen earlier but the data plotted is chaotic i.e. very much sensitive to the initial conditions.
The same may be infer from the following plots





As we can see no other conclusion or no patterns can be drawn from the above plots apart from them being random(which they are actually not).

Moving Towards the end of the I thought of recording a longer dripping by varying the flow rates by opening the valve very slowly and what I obtained is as follows.



At a first glance it looks like some weird plot full of errors and I too regarded this as a trash recording but I realised later that if we look carefully we can draw some similarities with the henon map (which has a lot of respect in studies of chaotic systems).
Towards the starting of the graph (till 200 drops) we can see a decay in time interval (T_n).Later in the graph (from 200 to 450 drops) can be regarded as the period doubling regime i.e from period 1 to period 2 to period 4 to period 8 and so on and towards the last part (450 drops onwards) we can see the chaotic behaviour.

Conclusions and Discussion

From this experiment I have confirmed the period doubling as well as chaos of the dripping faucet system. Even though my data could not provide much insights into the study of this topic further, we have seen how nature plays its own games. Even a simple looking system could be very much complex.We looked at some similarities of this system with the henon map.

This is the limit of this experiment if carried out at home.In future I would love to work on this experiment for some more time taking more data and understanding the behaviour more accurately and with a hope of getting a look into period 4 and above regimes by a more advanced experimental setup,a setup in which i would be able to control the flow rates with much precision.

Lastly have a look at the henon map for reference: