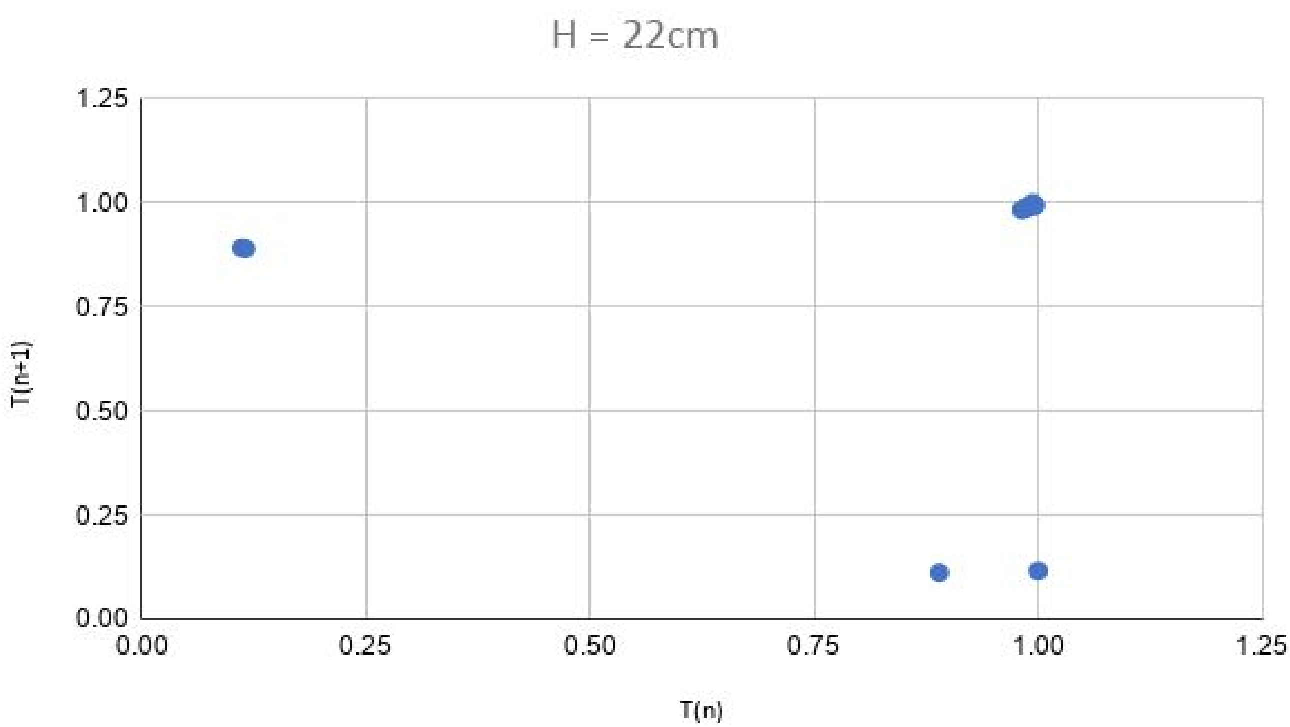
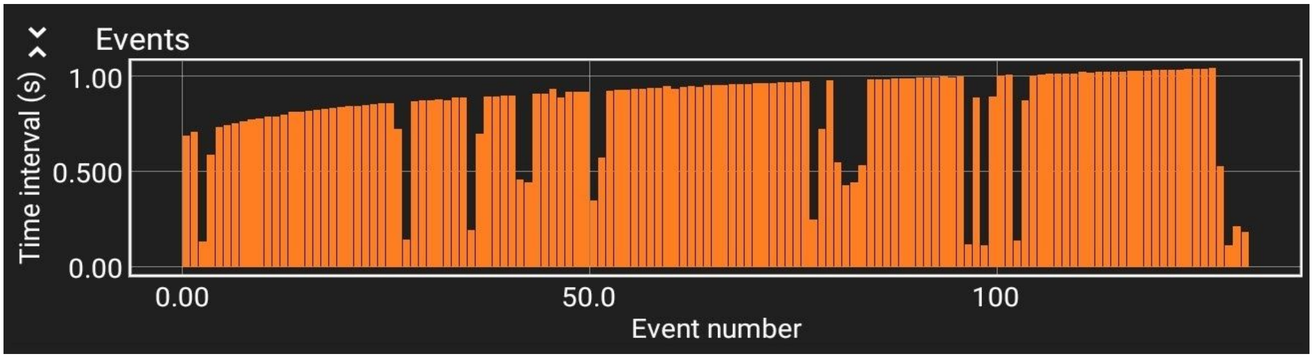
Observations (IMT2019084 Shrey Tripathi)

- The plots of t_{n+1} vs t_n have been plotted based on the datasets obtained from the acoustic stopwatch from the Phyphox mobile app.
- Inaccuracies in the experimental data are inevitable, because of the disturbances in the surroundings. Still, the observations have been tried to be made as close as possible to the ideal (theoretical) data.
- Due to non-ideal conditions and environmental disturbances, period doubling has only been observed once in the setup.
- **Setup:** We obtain different plots for different values of *H,* where *H* is the height of water level in the reservoir, to which a tap is attached, and the time elapsed is measured between subsequent drops of water dripping from the tap on the reservoir.
- The control parameter (*r*) in the setup is *H*, which, as has been described above, is the height of water level in the reservoir.
- Hence, the graphs are plotted keeping with *H* being the control parameter.
- The behaviour exhibited by the leaking tap can be compared with that of a logistic map.

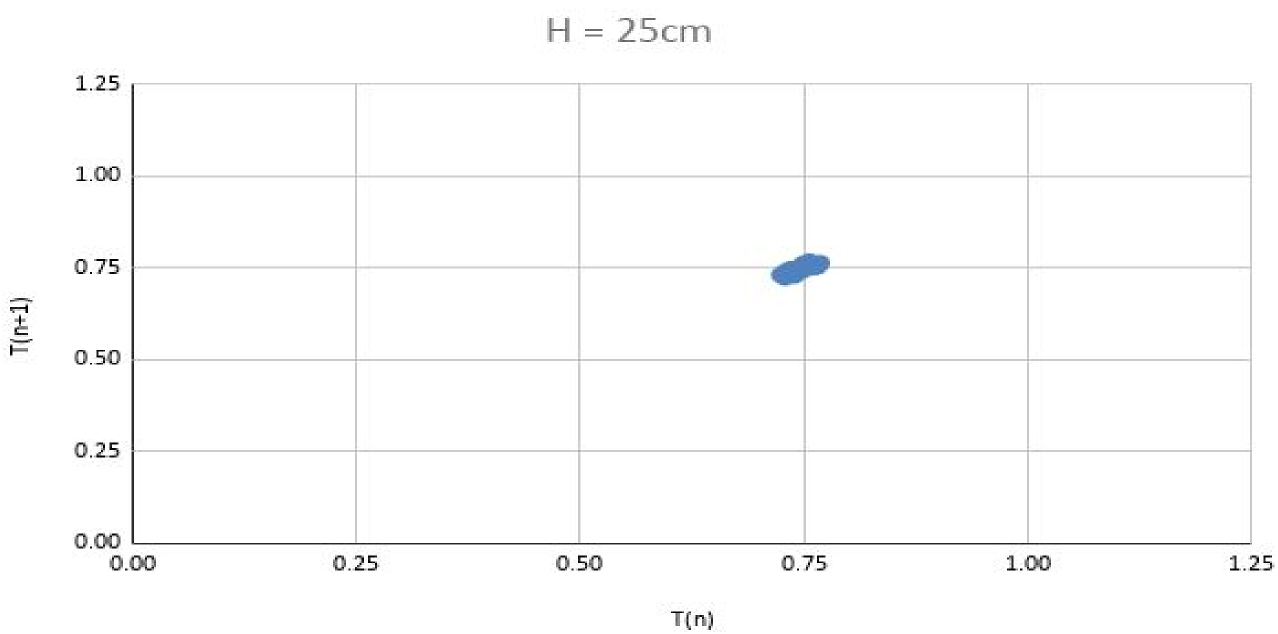
1. **H = 22cm**

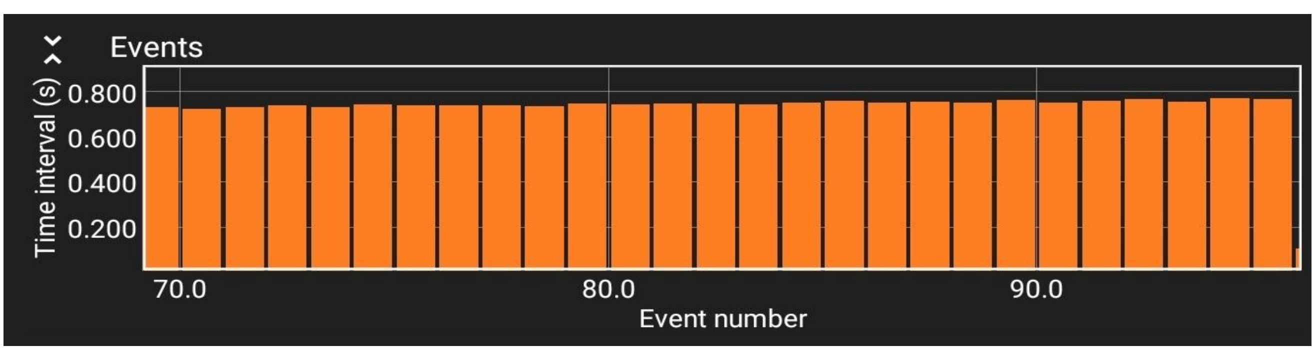




We observe, from the data in this case, that the scatter plot of T_{n+1} vs T_n, over a short time span (between events 86 and 100), is almost constant (approximately 1 second). So, in this case, the drops are falling at the same rate, with a constant time elapsed. Hence, for this height, the time elapsed will tend to remain the same forever.

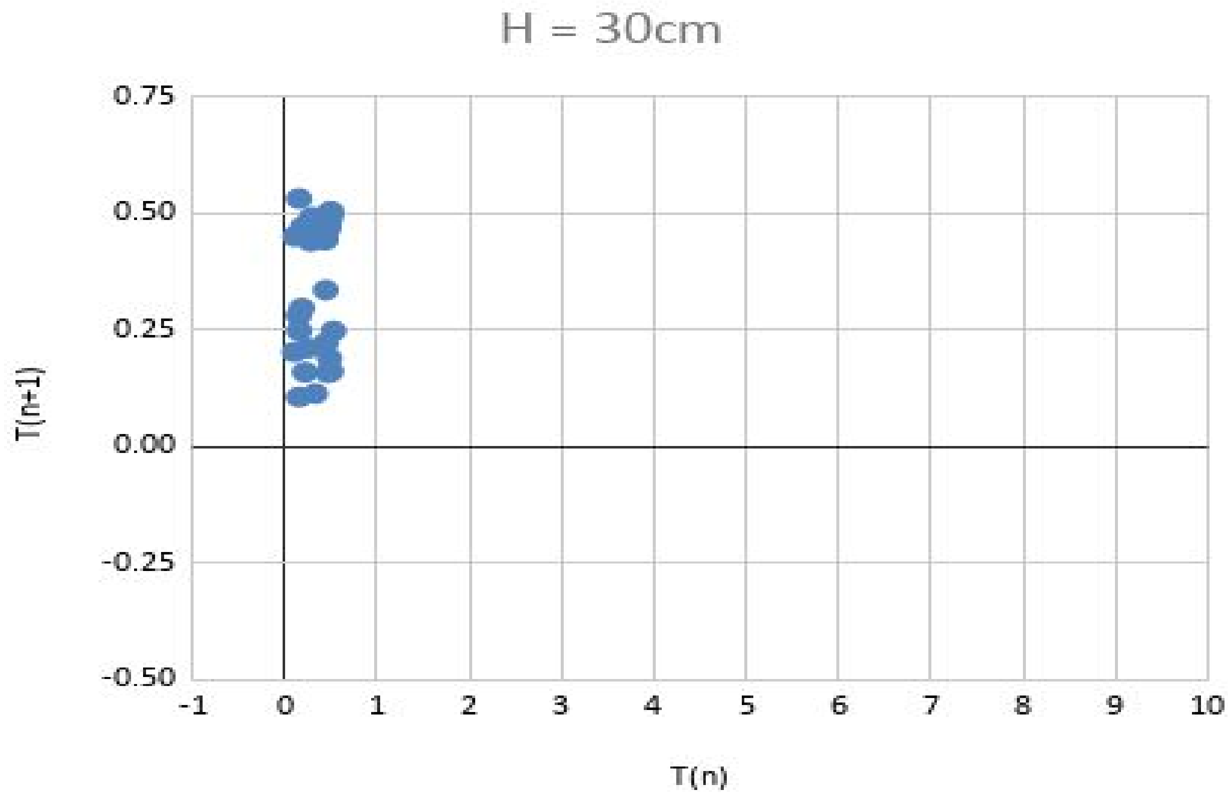
2. **H = 25cm**

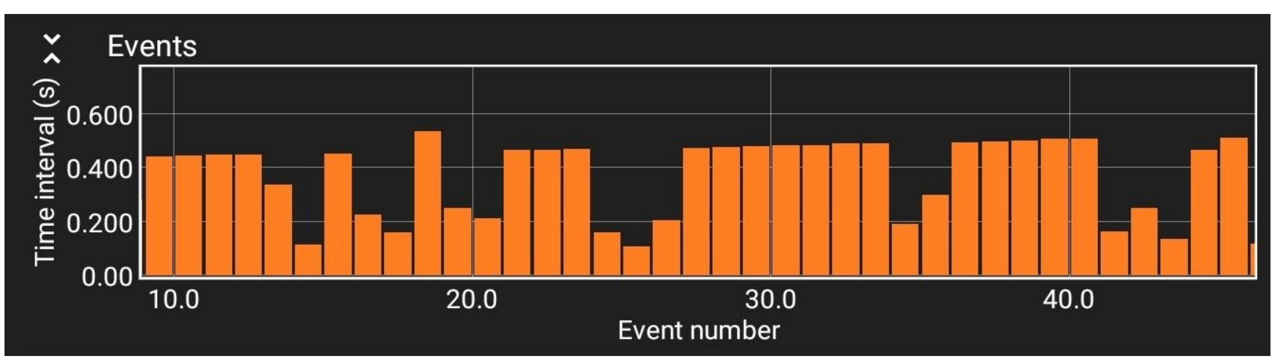




In this case, we observe that the scatter plot of T_{n+1} vs T_n, over a short time span (between events 71 and 96), is also almost constant (approximately 0.75 second), but is less than that in the previous case. Hence, the time elapsed decreases as the height increases. Also, in this case too, the time elapsed remains constant forever.

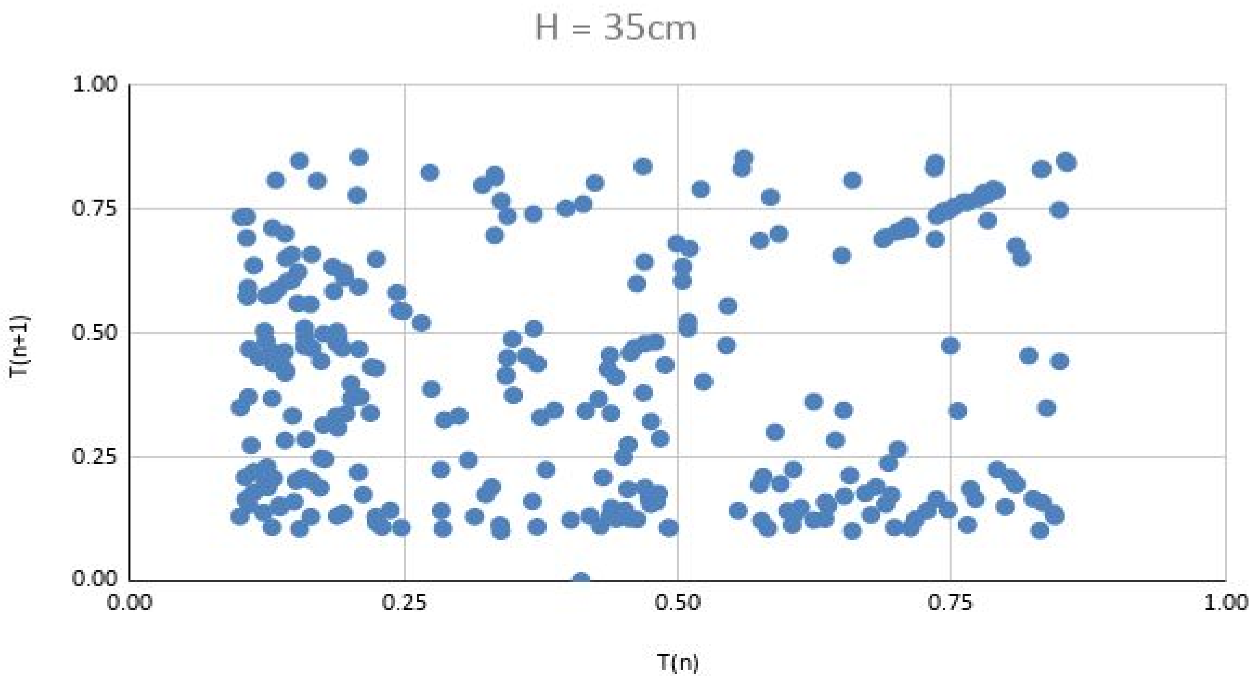
3. **H = 30cm**

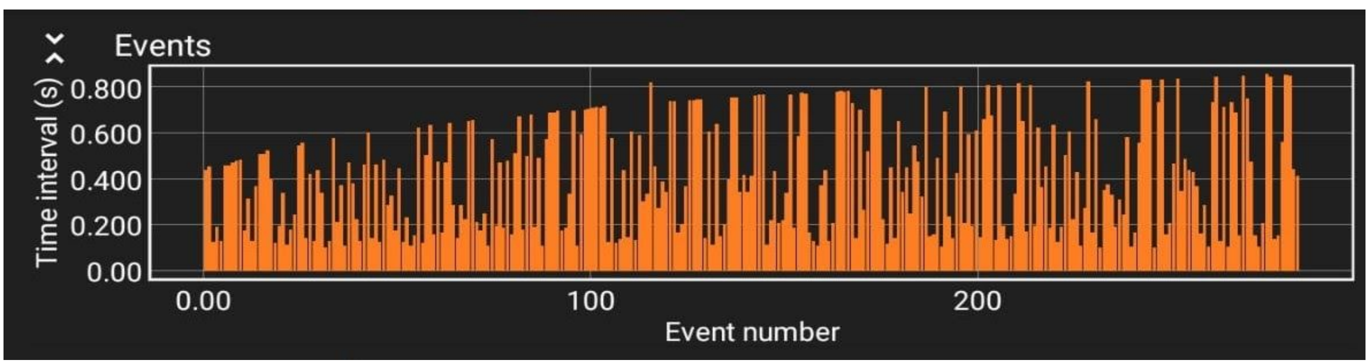




In this case, we observe that the time elapsed between two drops roughly converge to two values (0.23 and 0.5 approximately), and both are less than the previous cases. So, we can observe that the period has doubled.

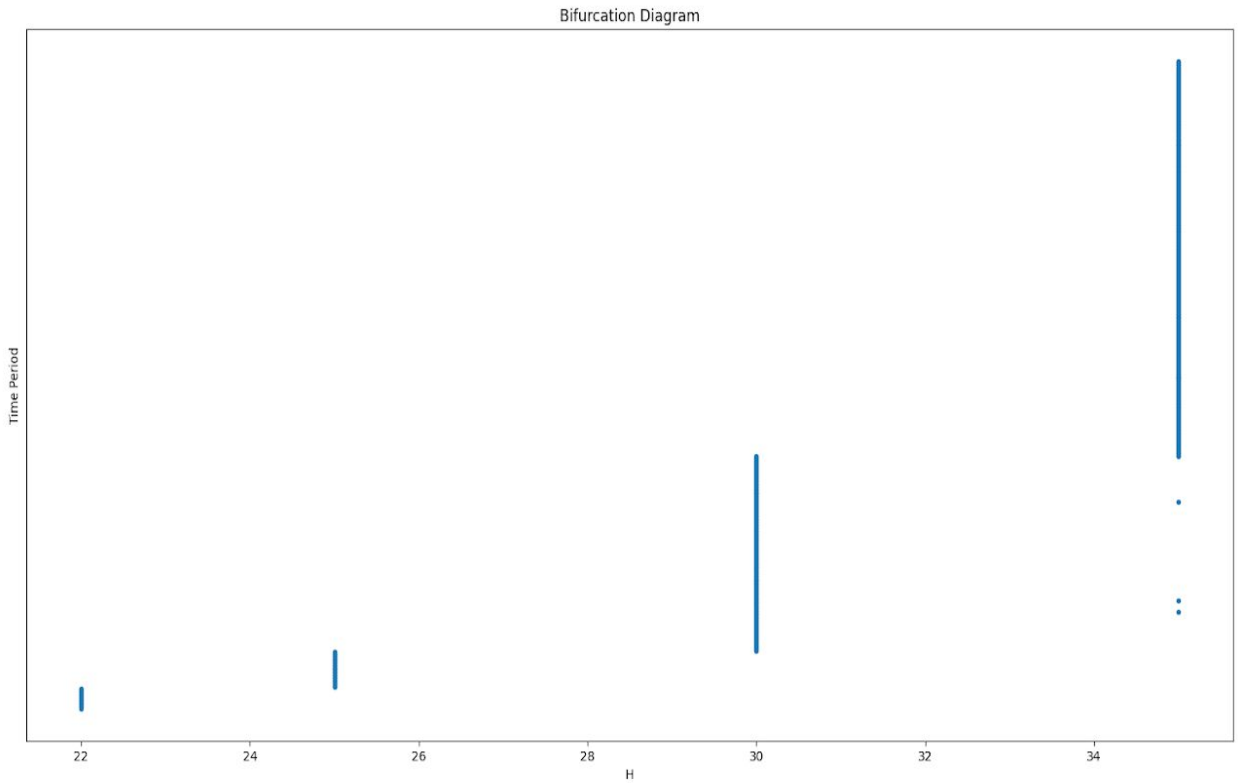
4. **H = 35cm**





Here, we observe that the time elapsed between two drops doesn't converge to a single value. It is irregular, and has random values. It is impossible to predict how much time will the *nth* drop take, if we know previous values. This is a representation of **chaos**.

Bifurcation Diagram



This is the bifurcation diagram (*T* vs *H*), where *H* is the control parameter (height of the water level) and *T* is the time elapsed between two droplets. It shows a similar trend as shown previously, albeit a little bit less clear. We can see that for *H = 22cm* and *H = 25cm,* the time elapsed is around a single value. For *H = 30cm,* the time elapsed converges around two values (this is not much clear from the diagram due to closeness of different points), and hence, the first bifurcation occurs. And for *H = 35cm,* the time elapsed takes multiple values, all of which are random. This denotes the state of chaos.

Error Possibilities

Some possible sources of error are:

- There are major distractions in sound due to disturbances in the environment. These disturbances may be due to birds chirping in the background, footsteps, or even heavy breathing if the threshold is kept low.
- Echo also causes a lot of disturbances in the experiment, since echo is also counted as an acoustic sound, and hence unnecessarily comes in the dataset.
- The water level in the reservoir also does not remain fixed if the experiment is carried out for a long enough time, which may cause fluctuations in the control parameter, *H,* during a trial.
- Inbuilt tap filtering may play a role in the errors coming.

Diagram of Apparatus

I used a reservoir with a tap attached to its bottom as the apparatus. The water level inside the reservoir can be controlled using external means. Here are some of the snaps of the apparatus: