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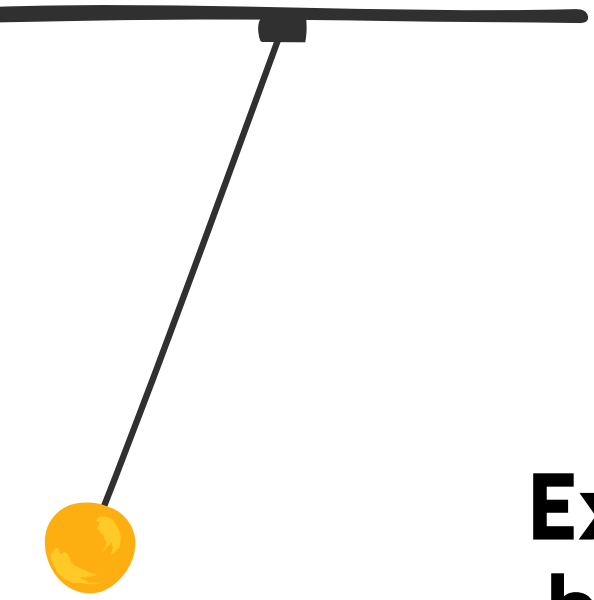

12-16

Dynamical systems

Experiment guide

Exploring chaos with a homemade pendulum

There is chaos everywhere...

Have you ever wondered why accurately predicting the weather, earthquakes, traffic flow, asteroid paths, or the next pandemic is so challenging? In this experiment, we look at the unpredictable nature of a seemingly simple system: a magnetic pendulum. This activity will highlight the widespread presence of 'chaos' even in day-to-day life.

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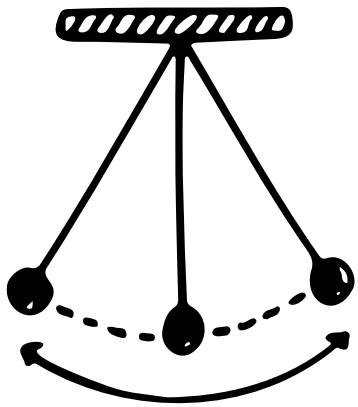
Build your own pendulum and explore the unpredictable



How does it work?

In our experiment, we will construct a pendulum –similar to those in traditional clocks – but with a twist: it's influenced by nearby magnets. This small modification shifts its motion from regular, rhythmic movement (called 'periodic oscillation') to erratic, wild swings. The pendulum's path becomes virtually unpredictable when released from a point far from the magnets.

Did you know?

The 'butterfly effect' is a foundational idea in chaos theory suggesting that the flapping of a butterfly's wings in Brazil could set off a tornado in Texas. It's just a dramatic way of saying small changes in starting conditions can lead to vastly different results in the long run.

Explore the chaos!

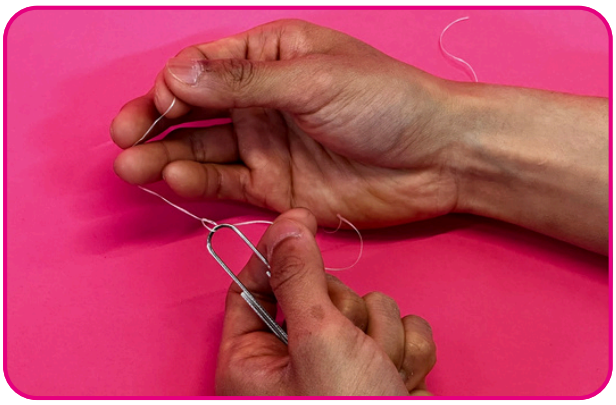
You need:

- a carton box (one side is 15-30cm)
- two paper clips
- 2-3 magnets of the same size and strength
- a piece of string ~ 25cm long
- some scotch tape
- a BBQ skewer (or anything that can make a hole on the carton box)
- a pair of scissors

Let's start!

Step by step:

1 Make a hole using the skewer at the center of a side surface of the box. Place the box so the hole is on top.

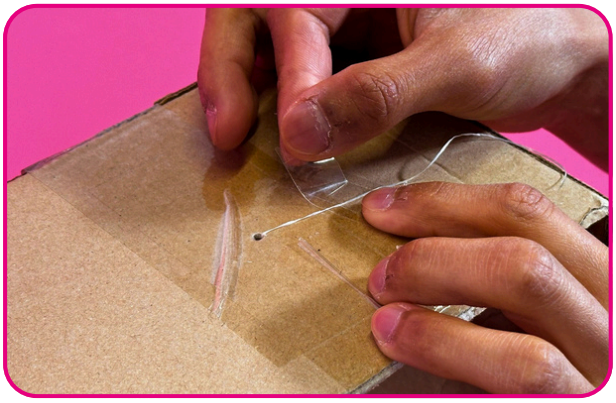


2 Tie one end of the string to one paper clip.

3 Pass the other end of the string through the hole. Make sure the paper clip can swing freely like a pendulum.

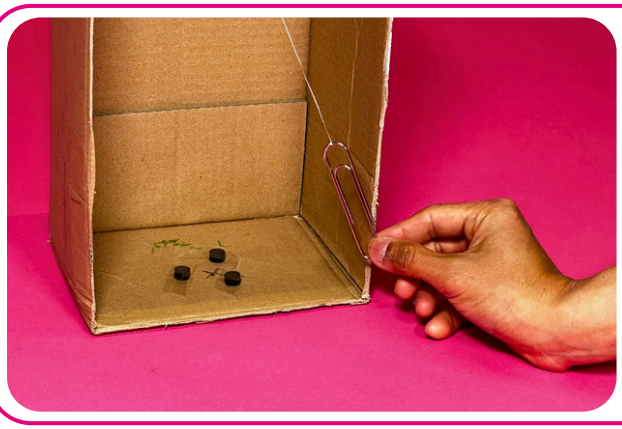
4 Glue the magnets in equal distance (~1-2cm) to one another directly below the resting position of the paper clip.

5 Adjust the string so that the paper clip is attracted by one of the magnets, yet not be able to touch it. Make sure that if the paper clip is released near any magnet it is able to stay on top of that magnet by magnetic attraction.



6 Once adjustment is finished, attach the other end of the string with some tape.

Time to explore



Release the paper clip pendulum from somewhere far from the magnets. Observe its motion. Try to release the pendulum again and again from the same starting position and observe.

It should be virtually impossible to repeat the same path the second time, or to predict which magnet the paper clip eventually comes to rest on.

Ask yourself:

- How does the starting position of the pendulum affect its trajectory?
- Are there regions where the motions are more 'predictable' than other regions?
- Can small changes in the initial angle lead to significantly different paths?
- Other than the attractive forces of the magnets, what are the other factors influencing the pendulum's motion?

Background knowledge

Chaos is a notion within a broader field called dynamical systems. In essence, a dynamical system is a set of rules or equations that describe how things evolve over time. While such systems have well-understood short-term behavior, their long-term behavior can be quite complicated. At ISTA, the Kaloshin group investigates problems arising from various dynamical systems, from pendulums to asteroids. Their collective pursuit is to contribute new insights to the fascinating field of dynamical systems.

Here is an exciting computer simulation:

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