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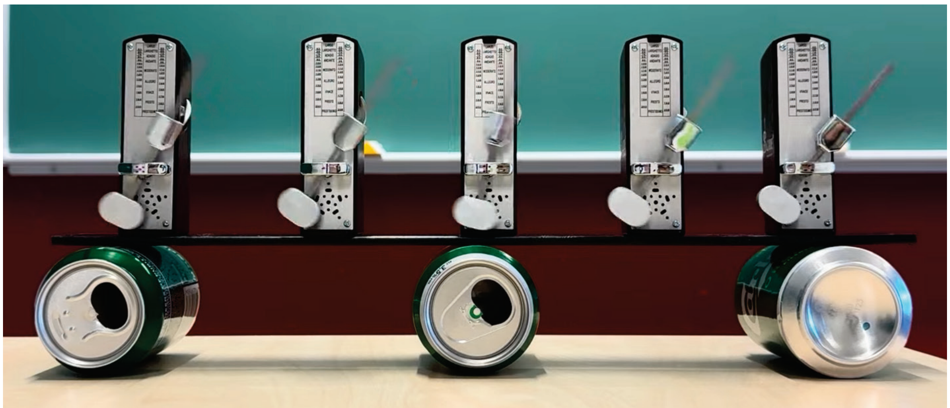
From birds to photons: collective phenomena in materials science

Metronome synchronization experiment

Try the classic metronome experiment to see synchronization in action.



Synchronization of metronomes
Image courtesy of the author

Materials

- 3–5 mechanical metronomes
- A light, rigid plank long and wide enough to hold the metronomes (e.g., 45 cm × 6 cm)
- 2–3 empty soda cans (undented, so they roll smoothly)
- A smooth, level surface for the setup

Procedure

1. Place the plank on the cans so that it provides a level surface. You might need to play around with the setup to get it level and stable.
2. Ensure the metronomes are fully wound/charged and set them to the same tempo.
3. Place them at equal distances, and all facing the long side of the plank (perpendicular to the rolling direction of the cans).
4. Set the metronomes ticking. The timing/order isn't important as long as the metronomes start off unsynchronized.
5. Observe what happens over time.

Optional extensions

1. Once all metronomes are in sync, what happens if one is intentionally knocked out of sync (e.g., by lightly touching its pendulum)? Formulate and test a hypothesis.
2. How would synchronization be affected if the metronomes are turned by 90° to face the short end of the plank instead of the long side? Formulate and test a hypothesis.
3. What happens if only three out of five metronomes are started initially? Will they synchronize? Will the idle ones start on their own? Formulate and test a hypothesis.

Tips

- Avoid using thick, soft, or heavy planks, as they may prevent effective coupling and synchronization
- Use a faster tempo to see quicker synchronization.

Discussion

How are the metronomes coupled?

What provides feedback?

What is the emergent property / collective behaviour in this case?

Can this collective ticking of metronomes be used for anything practical?

Why do the suggested tips help ensure synchronization?

The connection between metronomes, light bulbs, and a laser

The synchronizing metronomes offer a useful analogy for understanding light emission. Imagine replacing metronomes with electrons in atoms or molecules, each oscillating and emitting light. If these oscillations happen randomly, e.g., when the metronomes are ticking out of sync, the result is a diffuse light, like what we see from a light bulb.

But when coupling and feedback are introduced, the oscillations synchronize. The metronomes all begin ticking together in step, and in the case of oscillating electrons, the emitted light changes: it becomes directional, intense, and single-coloured, like in a laser.

While laser physics and device engineering involve many additional complexities, the core idea of coupling feedback and emergent properties is a common thread connecting these complex electromagnetic phenomena with common and intuitive metronomes.