My metronomes won't synchronize

Soon after Dutch scientist Christiaan Huygens invented the pendulum clock in the 17th century, he observed that pendulums in nearby clocks often synchronize such that eventually their phases are locked. This curious phenomenon is still being demonstrated today, and you can find many videos on *YouTube* that use mechanical metronomes instead of pendulum clocks. A particularly spectacular example of the phenomenon involves no less than 32 devices. So why, then, do my two metronomes not follow the herd and behave themselves? I have ended up almost swinging from the chandelier while trying, unsuccessfully, to persuade them to tick in phase.

At the heart of a metronome is a double-weighted pendulum that comprises a spring-steel strip carrying two weights, one that is sliding and one that is fixed. The strip oscillates symmetrically about its vertical position, being pivoted below its midpoint. The sliding weight, which lies above the pivot, can be adjusted to vary the oscillation period; while the fixed weight provides the counterbalance. The entire setup is driven by clockwork components that also emit audible ticks. A striking feature of the metronome is that long oscillation periods of nearly 3 s (40 ticks per minute) can be obtained from a compact pendulum, only about 18 cm long in my devices. An ordinary pendulum would be well over 2 m long at this frequency.

While it has been suggested that metronomes merely placed close together will sync – via the exchange of their ticks' acoustic energy – I have yet to see this done. It is unlikely to occur because the disparity in energies – the acoustic energy of the ticks, compared with the more substantial kinetic energy of the oscillating pendulums – is too great. Indeed, it is like expecting the roar of the crowd at a football match to deflect the trajectory of the ball.

So to allow the metronomes to interact, they are most often placed on a low-friction rocking platform, which is often propped up on a pair of empty beer cans – an arrangement that has the considerable merit of demanding that the experimentalist first quench their thirst! If more experiments were like this, perhaps there would be no shortage of physics students? My setup (see image above) dutifully rocks when the metronomes are set swinging. But, although energy is clearly being interchanged, they do not synchronize like everyone else's. Why not?

There is a range of theories to explain why synchronization occurs, with many academic papers penned on the subject. Some authors maintain that an oscillator must always be mathematically nonlinear – a large swing amplitude means that it is not isochronous (when an oscillator's frequency is independent of amplitude) – and this is the case with metronomes. But this does not explain why Huygens' pendulums synchronized, even though their angular displacements probably did not exceed a few degrees from vertical, and their oscillations were therefore almost linear and isochronous.

Others conclude that synchronization will always result in the metronomes swinging in phase, yet Huygens' pendulums ended up in antiphase. A common theme emerging from some papers is a desire for generality, to come up with a single theory that underpins ensembles of synchronized oscillators as disparate as pacemaker cells in the heart, hand-clapping in audiences and neutrino oscillations in the early universe; as well as metronomes for good measure. Recent papers tend to employ numerical simulations rather than deriving analytical solutions, but here I sometimes find a hint of "tuning" the solutions towards a particular experimental data set.


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Still, having scrutinized the literature I was none the wiser as to why my metronomes did not follow the trend. Other experimentalists seem to consider only an ensemble of identical oscillators, so the fact that my metronomes are not the same may be a factor. One is a fairly recent model still in production (a Wittner series 800), while the other is older and of uncertain pedigree. However, the two devices are virtually identical in terms of their oscillator parameters: the two moving weights have nearly the same masses; the scale lengths are the same, as are the placements of the scales relative to the pivots, the swinging rod lengths and the escapement phases (the angular positions at which the devices tick). Therefore, to all intents and purposes, the two oscillators are dynamically identical.

The only significant difference lies in the total mass of each metronome, at 425 g and 510 g, respectively. While the difference *per se* is probably inconsequential, the sum of these masses is important when one considers the source of the kinetic energy involved in oscillation. The adjustable sliding masses weigh less than 10 g in both cases, yet it is the limited energy from both the sliding and fixed masses that causes the platform to wobble to and fro. The platform and beer cans weigh an additional 250 g. So if the whole assembly is too massive to wobble strongly enough, then the energy being exchanged will be insufficient to cause the synchronization. It is therefore significant that the metronomes used in experiments where synchronization does occur weigh much less than mine – the Wittner series 880 weighs less than 100 g. So is this the source of the apparent anomaly? I leave you to judge, but do also consider whether this venerable issue of synchronized oscillators must rank as one of the oldest topics in physics still attracting interest today.

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