letters

London bridge's wobble and sway

Such dramatic events as the collapse of the Tacoma Narrows Bridge in Washington State in 1940 and the assassination of President John F. Kennedy in 1963 have become iconic examples for physics teachers. Unfortunately, sometimes an incorrect physics explanation has attached itself to such events; the bridge collapse, for example, has been wrongly attributed to forced harmonic oscillations.[1] I wonder if the same thing is happening in regard to the wobble of the London Millennium Footbridge.

On 10 June 2000, the footbridge across the Thames River opened for public use and immediately experienced an unexpectedly large lateral oscillation—a "wobble"—that forced its closing and eventual retrofitting. (See http://www.youtube.com/watch?v= eAXVa__XWZ8 for an excellent video.) Synchronous lateral excitation is the explanation commonly given for the wobble by several physicists in the field of nonlinear systems.[2,3] Wikipedia's entry on the Millennium Bridge also reports, "The natural sway motion of people walking caused small sideways oscillations in the bridge, which in turn caused people on the bridge to sway in step, increasing the amplitude of the bridge oscillations and continually reinforcing the effect."

Unfortunately, that explanation is at best partial and at worst completely incorrect. Let's start with an observation by John Macdonald involving the Clifton Suspension Bridge in Bristol, UK.[4] The dominant lateral vibration of the Clifton bridge was at 0.5 Hz. The middle span of the London bridge also had its first lateral mode at 0.5 Hz, with a second lateral mode of approximately equal amplitude at 1.0 Hz.[2] In contrast, average walking frequency is about 1 Hz.[5] In other words, the average walker took four steps, two with the right foot and two with the left, for every left–right cycle of the first lateral mode of the Millennium Bridge. So even if the walkers were in phase with the bridge's motion, that would not have amplified the bridge's first lateral mode unless a nonlinear mechanism was at work.

An explanation that has nothing to do with synchronous lateral excitation has been suggested first by Chris Barker and in more detail by Macdonald[4]—namely, that the walkers adjusted neither their frequency nor their phase but their balance due to the bridge's lateral motion. Macdonald suggested that as a balance strategy walkers adjusted the width of their steps in response to the lateral motion of the bridge. And as the bridge's lateral motion increased in amplitude, in some instances, the walkers' lateral adjustment increased, thus providing the necessary driving term proportional to the bridge's lateral motion. That balance response can either amplify or dampen the bridge's motion, depending on the natural frequency of the bridge and the frequency of the walkers' steps.[4]

Observations of walkers on the London Millennium Footbridge and other lateral swaying bridges, and laboratory experiments on walkers on swaying platforms, are contradictory.[4] The wobble is a wonderful example of an unresolved problem, and I hope it is presented as such in future physics classes and lectures.

References

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Frame dragging on flybys

The Quick Study on Earth flyby anomalies (PHYSICS TODAY, October 2009, page 76) teases the reader who is unfamiliar with the subject. We're told of a microscopic, nonconserving change in the speed of a satellite as it flies by Earth. The slight change in kinetic energy may be increasing or decreasing, as if Earth's rotation were being weakly added to the velocity of the satellite. Up to an altitude of 2000 km, an empirical fit of the data depends on a constant of proportionality equal to twice the product of Earth's radius and angular velocity divided by the speed of light. What jumps immediately to mind is frame drag—the idea, according to general relativity, that spacetime in the vicinity of a rotating mass will be dragged around as the mass spins. Yet this point is absent from several proposed and seemingly far-fetched explanations. Even if frame drag fails quantitatively or in some omitted detail, it seems intuitive to the uninitiated and should have been addressed, given PHYSICS TODAY's diverse readership.

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Nieto and Anderson reply: The magnitude of the frame-dragging effect would be impossible to detect for satellites that fly by Earth. But Jupiter is another story. Indeed, NASA's Juno mission, scheduled for launch in 2011, will place a polar orbiter about Jupiter in 2016. The orbiter will approach Jupiter at altitudes ranging from about 4000 to 6000 km every 11 days over about 31 orbital revolutions. The very real possibility that frame dragging will have a measurable effect should be addressed