

## AROUND THE CLOCK

**Dan Kleppner** – In design curves, you have a lot of latitude on how to make it. The bookcases I make use superellipses, at the top of the columns, and the cradle that I built, each of those tabs is in a form of superellipse. It's a wonderful curve, I recommend it. But I enjoy woodworking, I enjoy designing! The same instincts for making things, work in experimental physics! I enjoy building apparatus, it's lovely to make a piece of apparatus which starts functioning. But even if an experiment doesn't do what you want it to do, if the apparatus functions, that's a great source of satisfaction! And in a laboratory, there is always a lot of jubilation when the apparatus is first turned on and first works!

My physics, it's generally classified as atomic physics. I got off to a wonderful start, I share good luck, I graduated from college in this country and I went to Cambridge University on a Fulbright Fellowship, and I had a tutor there in physics, and he told me about his research, a new subject called molecular beam magnetic resonance, and about a proposal by I. I. Rabi, who invented that technique, that it might be possible to use this technique to make an atomic clock. And the atomic clock might be so precise that you could see the effect of gravity on time, that Einstein predicted. And I found that utterly astonishing, the thought that gravity affects time, I had a hard time, just in visualizing that. Well, the next year I went to Harvard University to start graduate work, and I had the good luck to join the research group of Norman Ramsey, he was a student of Rabi, he was a great physicist also and he had an idea for a new type of atomic clock, and asked whether I would like to try to do it! And the idea did make sense, so we went on and built this clock, it's called the hydrogen maser! And at the time it was among the most precise atomic clocks in the world. And in fact eventually an experiment was done using the maser that did show the effect of gravity on time.

But I've always had a soft spot for time, it's a very unusual concept in physics... But whatever time is, we're able to measure it better and better, for many decades the clocks gradually improve more and more. Out of this growth of these clocks of course came the Global Positioning System, and to me it's very startling that that technology grew out of a test on the most useless thing you can think of namely, Einstein's theory of general relativity, and it makes a very good argument for why it's worth investing in basic science! I mean, without these advances in clock metrology, the Internet would not work, for one thing! Metrology sounds to many people like a rather dull subject. But it really isn't. That when you measure things better, you see more! And now, the door has been opened to clocks, these new clocks are good enough to see the gravitational redshift for a few centimeters in height! So, that's quite

extraordinary, and it's had an extraordinary result, we gotta rethink just what we mean by time! You can't really separate time from gravity at this point.

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