[How Much Pi Do You Need?](http://blogs.scientificamerican.com/observations/2012/07/21/how-much-pi-do-you-need/)

\_\_\_\_LT: can annotate mathematical text.

CS#1, Day 04, HW#4: Annotate

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By Evelyn Lamb | July 21, 2012|

I hope you’re ready for your big Pi Approximation Day party tomorrow. You might have observed Pi Day on March 14. It gets its name from 3.14, the first three digits of the ratio of a circle’s circumference to its diameter. Always on the lookout for excuses to eat pie, some geeky math types also celebrate the number on July 22. The fraction 22⁄7 has a value of 3.142857, so it has the same first three digits as pi.

Both 3.14 and 22⁄7 are approximations of pi, so the two days deserve the same title. In fact, 22⁄7 is closer to pi than 3.14 is. So if you’re an aspiring pedant, you can choose to celebrate July 22 as Pi Day and March 14 as Not Quite as Close to Pi Day. (Either way, you’ll enjoy more pie.) But what does it mean to be an approximation of pi—and why does it matter?

Pi is irrational. That is, the decimal expansion never ends and never repeats, so any number of decimal places we write out is an approximation. (Of course, we can write the number exactly using just one symbol: π.)

Each decimal digit we know makes any computation involving pi more precise. But how many of them do we actually need for sufficient accuracy? Of course it depends on the application. When we round pi to the integer 3, we are about 4.51 percent off from the correct value. If we use it to estimate the circumference of an object with a diameter of 100 feet, we will be off by a little over 14 feet.\* When we add the tenths place, and use the approximation 3.1 for pi, our error is only about 1.3 percent. The approximation 3.14 is about ½ percent off from the true value, and the fairly well known 3.14159 is within 0.000084 percent.

If you were building a fence around a giant circular swimming pool with a radius of 100 meters and used that approximation to estimate the amount of fencing you would need, you would be half a millimeter short. Half a millimeter is tiny compared with the total fence length, 628.3185 meters. Being within half a millimeter is surely sufficient, and the tools you are using to make the fence probably introduce more uncertainty into your structure than your approximation of pi.

What about something with higher precision standards over much larger distances? I asked a NASA scientist how many digits of pi the agency uses for its calculations. Susan Gomez, manager of the International Space Station Guidance Navigation and Control (GNC) subsystem for NASA, said that calculations involving pi use 15 digits for GNC code and 16 for the Space Integrated Global Positioning System/Inertial Navigation System (SIGI). SIGI is the program that controls and stabilizes spacecraft during missions.

Pi appears most often in formulas involving circles or periodic motion, and it infiltrates some fundamental physical constants. These constants appear all over physics: masses of elementary particles, the number of molecules in a volume of a gas, the forces holding matter together, and so on. (Pi itself is not considered a fundamental physical constant.) The fine-structure constant, or “coupling constant,” which measures the strength of the electromagnetic force that governs how electrons and muons interact with photons, involves pi, and the permeability of free space, which describes how a magnetic field forms in a vacuum, is 4π×10-7. It is important to know highly accurate values of the fundamental constants to make good predictions of phenomena involving physics, and the experimental determination of the constants can even help improve our understanding of the physical laws that govern the universe.

Believe it or not, there is a committee that makes recommendations about the values of these fundamental constants. The Committee on Data for Science and Technology, or CODATA, an interdisciplinary group from the International Council for Science, periodically publishes a set of accepted values of the fundamental physical constants. The most recent version, [2010CODATA](http://physics.nist.gov/cuu/Constants/index.html), was published in June 2011.

Peter Mohr, a physicist who works for the Fundamental Constants Data Center at the [National Institute for Standards and Technology](http://www.nist.gov/index.html), which is involved in [calculating](http://www.scientificamerican.com/podcast/episode.cfm?id=researchers-weigh-benefits-of-a-new-11-01-24) and [disseminating](http://www.scientificamerican.com/article.cfm?id=patrick-gallagher-nist) the accepted CODATA values, says that the institute uses 32 significant digits of pi in their computations. (For programming geeks, this is called “quadruple precision.”)

So NASA scientists keep the space station operational with only 15 or 16 significant digits of pi, and the fundamental constants of the universe only require 32. Yet in 2006 [Akira Haraguchi](http://www.japantimes.co.jp/text/fl20061217x1.html#.UAbEeXFuS_U) of Japan recited 100,000 digits of pi from memory in 16 ½ hours, stopping for five minutes every hour to replenish his strength with onigiri rice balls. And the world record for number of digits of pi computed is [10 trillion](http://www.numberworld.org/misc_runs/pi-10t/details.html), at least as of October 2011. Pi computation can be used to test computer precision, but I think this is a symptom of pi-mania rather than a legitimate need for pi. Other numbers could be used just as meaningfully, but we choose to use pi.

It seems that we know, and strive to discover, many, many more digits of pi than we need for any practical application on Earth, or even in the part of space we can hope to get to right now. I guess the endlessness of the decimal representation just fascinates people. Haraguchi, the pi reciter, told The Japan Times that his memorization of pi is part of his quest for eternal truth. For some, it is probably a challenge: How far can I go? We want to push our limits, and memorizing pages of numbers seems pointless until we give it the halo of pi.