NEWSLETTER

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AAPT Winter Meeting

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by Peter Scovil, Section Representative

New Orleans is a very interesting city, due to early French and Spanish colonizations. The historic French Quarter is a fascinating blend of history, jazz, good eating and good shopping. But physics dominated for six busy days. Naturally, there is a lot going on on the World Wide Web. There were workshops on how to access and use the web, how to create web pages. In one, by Wolfgang Christian (wochristian@davidson.edu) has created Java applets for physics, calling them physlets. These can be accessed at webphysics.davidson.edu. They consist of interactive single-concept programs which may be animated. My computer doesn't have much in the way of internet support apart from Microsoft Explorer 3.0, but I was able to access at least half of them. If your school has internet access for students, check this out. You may find you can modify these or create your own. In a similar vein, Andrew Gavrin (agavrin@iupui.edu) uses actively uses the web in his lectures, for example, to ask questions based on reading assignments. The answers are due before the lecture with enough time for him to analyse the responses and see where students are having difficulties. He calls it Just-In-Time teaching. This has led him to change his lectures when he discovered that a concept he assumed was well understood was not clear at all to the students. This makes the students feel directly involved in their learning process. Rolf Enger (engerrc.dpf@usafa.af.mil) uses the JIT idea as well at an air force academy. Larry Martin (martin@northpark.edu) uses the web to deliver assignments, collect and automatically grade responses. See www.northpark.edu/~martin/WWWAssign or www.assign.physics.ncsu.edu/demo for a free version. Francis Hart (fhart@sewanee.edu) has students present term papers in astronomy as e-mail attachments. Edward Wright (wright@astro.ucla.edu) has cosmology and relativity tutorials on line at www.astro.ucla.edu/~wright/cosmolog/htm. Maria Dworzecka (dmaria@vms1.gmu.edu) has multiple choice questions on the web at http://physics.gmu.edu/~wmillis/MAPPS/. Cathy Colwell (colwell@freenet.tlh.fl.us) is using the web for high school (see www.mainland.volusia.k12.us/physicslab). Neil Fleishon (nfleisho@calpoly.edu) is part of the Connected Curriculum Project, a storehouse of course materials in physics, math and engineering on the web (see http://prisma.foe.calpoly.edu/conncurr/).

If you are involved with Wonderland, some possible activities presented by Randolph Peterson (rpeterso@seraph1.sewanee.edu) suggests students ride a Ferris Wheel or swing ship type ride sitting on a set of bathroom scales. Would we be able to do that at Wonderland, Al? Try rolling a tennis ball on a rotating merry-go-round to see frame-of-reference effects.

The Exploratorium Science Snackbook 2 is a wealth of great science ideas, especially for younger children. It encourages inquiry-based, co-operative, concrete, conceptual learning. Check out their web site: www.exploratroium.edu. Videotapes of toys done on the Space Shuttle missions show the effects of microgravity. These are available from NASA.

There were a lot of other very interesting talks, but I have touched on a few that I felt I could share most easily. Future AAPT conferences are August 3-8 in Lincoln, Nebraska and Jan. 9-14 in Anaheim, California...and Guelph July 29 - August 3 in 2000! The AAPT half price offer yielded 108 new members world wide - and 13 of those were from Ontario alone. We Ontarians know a good deal when we see it! The special price is good to the end of August in case you missed it.

OAPT Web Site

Guleph University is now the host of an OAPT web site. Get info on executive members (including a great picture of me, your humble newsletter editor), the upcoming OAPT Conference, links to other physics web sites, and much, much more!
The URL is:
http://www.physics. uoguelph.ca/OAPT/index.html

A Detailed Investigation of the Standard Rounding Rule for Multiplication and Division

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(Editor's Note: This "lay paper" is one of several from the A.P.S. meeting held in April. These papers and other physics news can be found at the A.P.S. Virtual Press Room at http://www.aps.org/BAPSAPR98/vpr/index.html. This paper caught my eye because I have the students spend several days investigating experimental error: which they always complain about.)

Introduction

The use of rounding rules and significant figures is taught to students in virtually all high school and introductory college-level science courses. Despite its widespread use in the education of science students, there is still much confusion about the origin, accuracy, and safety-of-use of these "rules". In a recent note to *The Physics Teacher*, R. H. Good [1] raises serious questions about the validity and safety of standard rounding rules by pointing out a division problem where the rule causes valuable information to be lost in the calculation. In his note, Good describes a fictional situation where a physicist receives a large grant to determine an important physical constant more precisely than previously known. After much work, the data are given to a technician who, using the standard rounding rules, proceeds to throw away some of the hard-earned information in the calculation of the constant. This situation is clearly unacceptable!

The purpose of this work is to test the accuracy and safety of the standard rounding rule for multiplication and division. While it has been shown that this rounding rule can be inaccurate (Schwartz [2]), this work is the first to quantify its accuracy in a reliable way. Our investigation will show that the standard rounding rule in highly inaccurate, predicting the correct number of significant figures in the result less than 50% of the time! When the rule does fails, it almost always predicts 1 less significant figure in the result than is warranted. Thus, the use of the standard rule often causes valuable information to be discarded in calculations.

Background Information

The concept of a rounding rule is closely related to that of significant figures. When a number is written in significant figures, as they often are in the physical sciences, each digit is considered to be certain and the number has an implied uncertainty of ± 1/2 in the last decimal place. Because of this implied error, there is an approximate relationship between the number of significant figures and the precision (percent uncertainty) in the quantity. A number written with 1, 2, and 3 significant figures has a precision of approximately 10%, 1%, and 0.1% respectively. This approximate relationship is the justification for the standard rounding rule for multiplication and division.

The standard rounding rule states that the result from a multiplication or division should be written with the same number of significant digits as the least precisely known number used in the computation. For example, the product of a 2-significant-figure number and a 3-significant-figure number should be written with 2 significant figures according to the standard rule.

Testing the Rounding Rule

A statistical method was used to investigate the accuracy of the standard rounding rule. This method involved the random generation of millions of multiplication and division problems. For each randomly generated problem, the result was calculated and the predictions of the standard rounding rule were applied to the result. If the standard rule predicted the minimum number of significant figures needed to contain all of the valuable information in the result, the rule was said to "work". If the standard rule predicted more or less than this number of digits, then the rule was said to "fail". This method was applied to 1 million multiplication and 1 million division problems and statistics were computed.

Besides the standard rounding rule, there is an often used alternate rounding rule. This alternate rule states that one should always use one more significant figure than suggested by the standard rule. In the division problem discussed by R. H. Good [1], this alternate rule would have protected against the loss of valuable information. In order to investigate this alternate rounding rule, for comparison to the standard rule, it was subjected to the same statistical method described above.

Results

The application of the standard rule was found to work only 46.4% of the time. The standard rule is, indeed, highly inaccurate. The standard rule was found to predict 1 less significant digit than warranted 53.5% of the time. The standard rule is very dangerous to data, causing valuable information to be lost over half of the time. On very rare occasions (0.05% of the time), the

(continued at the top of page 3)

standard rule was found to predict 1 digit too many. The fact that the standard rule can fail is due to its approximate nature, but this is the first work to quantify the accuracy of the standard rounding rule in a reliable way.

The accuracy of the alternate rule was found to be 58.9%, about 13% more accurate than the standard rule. The most important aspect of the alternate rule is, however, the fact that it never discards valuable information. This is supported by a mathematical analysis (not described in this presentation) that shows that the standard rule can, at its worst, be wrong by only ± 1 significant figure. The "extra" significant digit that the alternate rule calls for ensures that it never discards valuable information. Thus, the alternate rule is more accurate and completely safe for data.

Conclusion

It is shown that the standard rounding rule is highly inaccurate, causing valuable information to be lost over 50% of the time. The alternate rounding rule is shown to be more accurate than the standard rule and completely safe. With no perfect rounding rule possible, the best rounding rule is the simplest rule that is relatively accurate and safe. The alternate rule is superior to the standard rule and should be adopted as the new standard.

References

[1] R. H. Good, "Wrong Rounding Rule", The Physics Teacher, 34(3), p.192 (1996)

[2] L. M. Schwartz, "Propagation of Significant Figures", Journal of Chemical Education, 62, p.693 (1985)

Physics Simulations Web Site

Edouard Tcherner (tcherner@interlynx.net) a teacher at Northern Secondary School, http://www.krev.com/ed/index.html, Toronto, has posted Interactive Physics simulations developed and designed by 1998 OAC Physics students. All the necessary links and instructions are provided.

The computer experiments are designed to run on the IBM computers at 1024 by 768 pixel resolution. Clipart has been attached to the object to make simulations more attractive and meaningful for students.

Physics News Update

The A. I. P. Bulletin of Physics News
by Phillip F. Schewe and Ben Stein

THE FIRST SNAPSHOT OF AN EXTRASOLAR PLANET? The existence of extrasolar planets around several stars has been inferred from the wobble in the stars' emissions, but the planets themselves have not been seen amid the glare of the parent stars. Now, the Hubble Space Telescope has taken a picture of an object (named TMR-1C) that might, depending on how the data is interpreted, be either a brown dwarf star or a protoplanet (perhaps with a mass several times that of Jupiter).

The object, about 450 light years away and glowing in infrared light, was glimpsed at all because it has apparently been ejected from a nearby binary-star system, and therefore stands apart from any stellar brilliance. This and the object's youth (it might be only 100,000 years old) might redirect thinking on how gas giant planets form. According to NASA scientist Edward Weiler, "If the planet interpretation stands up to the careful scrutiny of future observations, it could turn out to be the most important discovery by Hubble in its 8-year history." (NASA press release, 28 May 1998.)

TUMBLE AND FLUTTER: how paper falls to the ground is impossible to describe exactly with the laws of physics because of the mathematically intractable equations governing the fluid flow of air. To gain at least some understanding, scientists beginning in the 19th century, have modeled this problem in 2 dimensions. Now, experiments at the Weizmann Institute in Israel (Andrew Belmonte, University of Pittsburgh, 412-624-9385) have provided the first quantitative tests of these 2-D theories. In the experiment, researchers dropped thin strips of metal, plastic, and brass into a thin fluid-filled tank, which forced the strips to move in a two-dimensional plane. What determined whether the falling strips predominantly oscillated from side to side (flutter) or rotated end over end (tumble) was the Froude number, the ratio of the time it takes for the strip to fall its own length to the time it takes for the strip to move from side to side. Longer or lighter strips, which have a low Froude number (like an 8.5 x 11" page) flutter while smaller or heavier strips (e.g., a business card) tend to tumble. (Try it yourself.) The study of vorticies set up by the falling slips may be relevant to the question of how airplanes stall, and may be exploited by insects to enable them to fly with great efficiency.

THE EARTH VIBRATES CONTINUOUSLY even without help from earthquakes. A collaboration of scientists from UC Santa Barbara and Tokyo Institute of Technology has analyzed gravimeter data from 1983 to 1994 and found 61 days to be seismically "quiet" enough for the purpose of searching out Earth's natural oscillation modes. They identify several such modes in the 2 to 7 milli-Hz range (that is, vibrations with periods of hundreds of seconds). The acceleration of material in the solid Earth produced by these spheroidal waves is tiny, on the order of nano-gals, or 10^{-9} cm/s^2. The researchers suspect that the cause of the vibrations is atmospheric turbulence. (Tanimoto et al., Geophysical Research Lett., May 15; contact Toshiro Tanimoto, UC Santa Barbara, toshiro@magic.geol.ucsb.edu.)

THE DEMONSTRATION CORNER

Lenz's Law with Plumbing Pipes

by

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In the January 1997 issue of *The Physics Teacher*, two articles appeared detailing the use of rare earth magnets to demonstrate Lenz's Law in the classroom. The principle involved is that a permanent magnet falling through a tubular conductor will induce a current in the conductor and hence a magnetic field which will oppose the magnetic field of the permanent magnet and thus slow its rate of fall. This article gives variations of the methods discussed in those papers.

Arbor Scientific (1-800-367-6695) sells two rare earth magnets. The smaller magnets (P8-1123) are 0.5 inch in diameter and 0.25 inch in length and are sold in pairs for $20 U.S. The larger "Giant Neodymium" magnet (P8-1124), which is sold individually, is 2.2 cm in diameter and 2.5 cm in length and costs $35 U.S. We have tried dropping the smaller magnets, individually and in pairs, through .75-inch copper plumbing pipe and also dropping the larger magnet through 1-inch pipe. Although both illustrate Lenz's Law dramatically, unless cost is a limiting factor there is no doubt that the larger magnet provides a much more spectacular demonstration.

We start the demonstration by dropping a non-magnetic "dummy" of the same size as the magnet through a 1-inch Type L copper pipe which is available through local plumbing supply centres. The time to fall through our 1.73 metre long tube is 0.6 s. We use stainless steel because it looks just like the magnet and when the dummy and magnet are held together there is no mutual attraction, and with some verbal distraction, you can convince students that you have two identical pieces of iron (that is, if you want to fool the students and make the demonstration seem even more amazing). The time for the large magnet to fall through the pipe is 15 s. Students are surprised to the point of disbelief!

Be aware that the most common commercial copper pipe is Type M which is thinner walled than Type L and the time taken to fall through a 1.73 meter Type M tube is only 9.2 s. The factor in time of $15/9.2 = 1.6$ is to be expected because the wall thickness of Type L is greater than that of Type M by a factor of 1.4 (not equal to 1.6 but close) and the resistance to current should be inversely proportional to wall thickness.

We next use a 0.58-metre section of Type L (one third of the original length) and the time of fall is now 4.6 s, which is only slightly less that one third of the original 15 s. This illustrates that terminal velocity is reached very quickly. We created another variation which allows the students to actually see the magnet falling. A 3/16 inch bit was used to mill a slot along the length of a 0.58 metre length of Type L pipe. The time to fall is only reduced from 4.6 to 3.5 s. This surprises most students because they think that eddy currents must go all the way around the pipe and they expect the magnet will fall through the slotted pipe in much less time.

The fact that terminal velocity is reached very quickly allowed us to create another spectacular variation of this demonstration. Clear plastic pipe of the same inside diameter as the 1 inch copper pipe was used to make a composite tube of alternating lengths of plastic and copper. Our tube has two sections of plastic, each about 30 cm, and two of copper, each of about 40 cm (lengths are not critical). The sections are held together with brass sleeves. The demonstration is most dramatic when the magnet falls through the sections in the order plastic-copper-plastic-copper. The time to fall through the plastic sections is a fraction of a second whereas the total time for the whole tube is between 5 and 6 s. It's the alternation between speeding up and slowing down which the students find most interesting.

ANYBODY OUT THERE?

Don't forget that I'm always interested in hearing your comments, criticisms, etc.

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Submissions describing demonstrations will be gladly received by the column editor.