The following is a contribution to the JREF's ongoing blog series on skepticism and education. If you are an educator and would like to contribute to this series, please contact Bob Blaskiewicz.

All university-level physics instructors, at some point in their careers, will receive an unsolicited letter or email from a member of the public detailing a novel, unorthodox, and potentially revolutionary theory. Most of these theories are ignored or swiftly discarded. At my previous teaching position (Cal Poly in San Luis Obispo, California), the physics department has been maintaining an archive, affectionately known as "The Box", of all the crackpot theories that have been mailed in since the early 1990's. A few years ago I borrowed The Box over the summer and read through its contents, and found that some of these theories can be repurposed for classroom discussion or for homework problems. When students can identify errors and misconceptions, they gain familiarity with the critical analysis of claims about the natural world.

An example of such a theory involves the "Principle of Equivalence" from general relativity, which states that a frame of reference experiencing a gravitational force is identical to an accelerating frame of reference. Astronauts on board a spaceship which is accelerating in a straight line through outer space at 9.8 m/s^2 feel the same sensations of "weight" as they would just standing on the surface of the Earth. The crackpot theory is that our sensation of gravity on the Earth's surface is actually caused by the Earth
expanding
at 9.8 m/s
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, producing the "fictitious force" that we interpret as gravity. I propose this theory to my introductory physics students, and they always laugh, but I then ask that they
specifically
identify its weaknesses. They can even propose experiments to test the theory, such as comparing the timetables for international flights; if the Earth were indeed expanding, the flight times should be increasing with time. One can also analyze this theory using the laws of kinematics, usually taught in the first few weeks of an introductory physics course—if the Earth were expanding, that means in the past it was smaller than it is now, and the smallest it could possibly be is a single point, so if it started from a single point at rest and expanded outward at 9.8 m/s
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, how long would it take to achieve its current radius of 6400 km? (Answer at the end of this article.)

This teaching method can be extended to bad science generally, including topics which are

familiar to scientific skeptics. In particular, a critical analysis of homeopathy is well-suited to an introductory physics or chemistry class when the atomic model of matter is first mentioned, since the origin of homeopathy predates this model. Surprisingly, I have found that very few of my students had ever heard of homeopathy, and those that had thought that it was identical to herbal medicine. By having students actually calculate the number of molecules of the substance in each step of the dilution process, they gain not only a familiarity with dealing with powers of ten, but also the discreteness of matter when they calculate the ultimate number of molecules being much less than one. After one such class discussion, a student asked, “So if there aren’t any molecules left, then how does it work?” “They believe the water remembers,” I replied, and the class responded with laughter.

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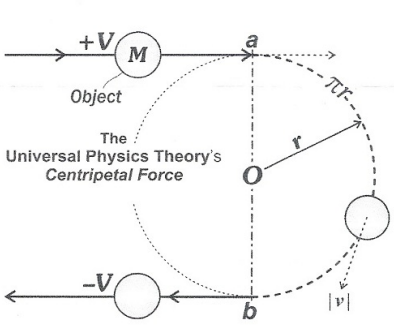
Dear physics professor,

I could have written pages upon pages expressing the virtues of ***The Universal Physics Theory***, but no words seem to justify. Instead, I feel that it can best be described by an example:

The classical Centripetal force, deduced by Isaac Newton, has been time-honored to be $F = \frac{mv^2}{r}$.



Since $F = mA$, and $A = \frac{dv}{dt}$, then $F = m \cdot \frac{dv}{dt}$.

In the present illustration, a force (centripetal) compels object M to follow a circular path of fixed radius, yet without altering its absolute velocity $|v|$. While the object travels from point *a* to point *b*, it undergoes a complete reversal of its *directional momentum*. The object's differential velocity dv goes from $+V$ to $-V$, thus $\mathbf{2}v$, during the time t_{ab} that it takes to travel the distance πr from point *a* to point *b*. Given that the object's absolute velocity never changes, the only force accountable for changing its directional momentum is the centripetal force F_c; and it takes the form of:

$$F_c = m \cdot \frac{2v}{t_{ab}}$$

Since $t = \frac{s}{v}$, then $t_{ab} = \frac{\pi r}{v}$. This means that the true ***Centripetal Force*** equation becomes

$$F_c = m \cdot \frac{2v}{\left(\frac{\pi r}{v}\right)} \quad \text{or} \quad F_c = \frac{2mv^2}{\pi r}.$$

In other words, Newton's Centripetal force errs by a factor of $\frac{2mv^2}{\pi r} \neq \frac{mv^2}{r} \rightarrow \frac{2}{\pi}$.

Since Newton's gravity is based upon his centripetal force, and that the Coulomb electrostatic attraction and Einstein's gravity are both based upon Newton's gravity, as a consequence, all known astronomical and atomic, orbital and rotary parameters (masses, velocities, radial distances, energies, etc.) as well as all related equations need to be re-evaluated. And this is only the tip of the iceberg! In his treatise, ***"The Universal Physics Theory"***, the author reveals many other conceptual and mathematical blunders which are even more disturbing. The repercussions of his discoveries are so extensive, that the restructuring of the entire edifice is inevitable.

Have an enjoyable read,
Chief editor (France Liberté)

Not all pseudoscientific theories provide teachable moments like these—many of the theories

lack internal logic or testable claims—but the ones that do can serve as a sort of vaccination against bad ideas. The term is deliberately chosen; vaccination is the introduction of a weakened form of a disease so that the body's immune system can "learn" how to protect itself against a stronger version later. Crackpot theories and pseudoscience have weak scientific arguments at their foundation, and so the process of picking apart these arguments can strengthen students' analytical abilities and hopefully make them more resistant to their own misconceptions. As science educators, one of our charges is to promote scientific literacy among the general population. Dissection of crackpot science is a legitimate and often very entertaining way to achieve this goal.

Another possibility for showing the difference between science and pseudoscience is to have students note the differences in writing style. Whereas scientific papers are generally formal, dispassionate, detailed and carefully stated, crackpot papers are informal, self-aggrandizing, vague, and flippant. This speaks to their lack of training and rigor and can be used as a point of discussion, especially among students who are embarking on their own research projects.

So if you're a science teacher and you receive an email from a crank, don't just throw it away! (Don't reply to the crank either, by the way—they are usually unshakably devoted to their theories, so it will be frustrating and fruitless for both of you.) Try instead to locate the flaws in their arguments and make pedagogical lemonade out of pseudoscientific lemons.

(The answer to the expanding Earth problem is about 19 minutes.)

Dr. David Dixon was born and raised in southeastern Wisconsin and received his Ph.D. in physics at the University of California at Berkeley, specializing in experimental mesoscopic electronic transport. He began his professional physics teaching career at Marquette University in 2000, and has taught at Carroll University and California Polytechnic State University. He is currently an assistant professor of physics at Saddleback College in Mission Viejo, California. A public lecture on this subject, "Pathological Physics: Tales from The Box," can be found at http://bitly.com/TaAukz .
"Teaching Science with Pseudoscience"