PHYSICS AND TECHNOLOGY
CAVITATION

by Bryce Bolin

SNAPP! BAAMM! POW!! BIFF!!! This is not an episode of classic Batman but rather the sound of the ocean floor off the coast of Jacksonville in 1943. Worrying about German undersea interdiction, US Navy undersea telemetrists were alarmed at the amount of this clamoring clacking which by far surpassed any known man made method of this sort.

Now giving 'das boot' to the 1943 Germans and Tom 'We Have to Kill Adolf Hitler' Cruise, I'll go ahead and tell you that the undersea tumult was a result of the alpheid's (or pistol shrimp's) claw clicking. Competing with the likes of the sperm and beluga whales for being the noisiest animal in the ocean, the pistol shrimp is capable of generating acoustic pressures up to 80 KPa with a cavitating bubble a few centimeters from its claw. Those are some hardcore Pascals. And the shrimp are more than capable of stunning and killing the small fish on which it preys.

Cavitation bubbles are formed when the pressure of a flowing liquid falls below the pressure in vapor bubbles – think of a whirring propeller. As the liquid slows in the bubbles' medium, the bubbles collapse, and in the case of the pistol shrimp's cavitating bubble, produces sonoluminescence (short-bursts of light from imploding bubbles in a liquid medium). The collapsing bubble can reach temperatures over 5,000K, though the light is of low intensity and can't be visually observed over the 1 millisecond duration of the claw's click.

Cavitating bubbles are thought to have application in cold fusion technology, such as in the case where they can produce extremely high temperatures necessary to produce fusion. Cavitation technology is also being developed for undersea torpedoes, which have rocket motors and fly underwater in a super-cavitating bubble produced by emitting gases at their tip.

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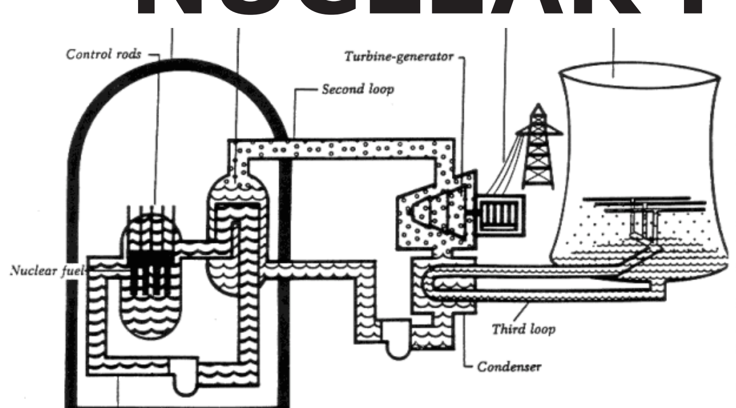
CALL FOR WRITERS

UPNews is always looking for undergraduates who want to contribute. If you'd like to get involved, e-mail us at upnews@phys.ufl.edu

THE PHYSICS OF NUCLEAR POWER

By Alicia Swift

Nuclear power is becoming an ever-popular and increasingly viable solution to many diverse, yet difficult, problems facing the world today. Uncertain energy prices and global warming, as well as mounting political tension over gas and oil supplies, have brought nuclear power back to the forefront of political discussions after it lost popularity in the 1980s and 1990s.



Due to its unpopularity for over twenty years, many people today are unaware of how nuclear power is generated. The concept of nuclear power stems directly from nuclear physics. An atom is held together by a form of potential energy, called binding energy. This vast amount of energy is released from certain atomic or molecular interactions, which can then be used to generate power.

Most nuclear power plants have a pressurized water reactor (PWR). A PWR is composed of both a primary loop and a secondary loop. The primary loop consists of a nuclear reactor, where uranium (or some other radioactive material) is immersed in water. The hydrogen atoms in the water act as catalysts, beginning nuclear fission which releases a lot of heat. This heat is then transferred to the water, which is pumped through the primary loop. A heat exchanger is used to transmit energy from the primary to the secondary loop while keeping the radioactive material contained in case of an accident. This transmitted energy causes the water in the secondary loop to boil, which is passed through turbines to generate electricity. In this way, nuclear physics and thermodynamics are employed to generate power for millions around the world.

The diagram is from the Nuclear Regulatory Commission website. It shows the primary loop and secondary loop of a PWR (here labeled as a first and second loop).

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This Month's Professor Spotlight
SERGEI SHABANOV

by Victor Albert

Dr. Shabanov is an Associate Professor of Mathematics and an Affiliate Professor of Physics at UF.

UP: What is your background?

SS: I graduated from the Kolmogorov High School of Physics and Mathematics (#18) at the Moscow State University, a specialized technical school whose acceptance rate is about 1 in 600. I listened to the last course that Kolmogorov taught. The courses taught there advanced me to my junior year in college on the Soviet scale. The courses in Analysis that I had in 9th grade I now teach to graduate students. After high school and college, I obtained my Ph.D. in Leningrad (now Saint Petersburg) in theoretical and mathematical physics and later became a staff scientist at the Joint Institute for Nuclear Research in Dubna, Russia.

How did you move?

I left Russia in the beginning of 1992, soon after the collapse of the Soviet Union, working first in Switzerland, then Italy, France, Germany, Spain. I received the Humboldt fellowship in Germany and I was an invited professor in Spain. In 1999, I finally moved to UF where I became an adjunct professor of mathematics and an Institute for Fundamental Theory (IFT) research fellow. At present, I am an associate professor of math and an affiliate professor of physics. Being an affiliate faculty member of the physics department helps me do research with other physics faculty and graduate students.

What is your field of study?

In the past years, I did many works on gauge theories, path (Feynman) integrals. At present, my research interests have also included nanophotonics and laser-induced plasmas. In nanophotonics I study resonant scattering of light on periodic structures as well as develop novel spectral numerical methods for solving electromagnetic scattering problems.

What were you interested in first, math or physics, and how did you become interested in either?

As far as I remember, since childhood, I've always been interested in math, physics, how the world works. High energy theory gave me an opportunity to learn how the four fundamental forces of nature work as well as to understand their mathematical structure and their key physical principles.

Why do you think high energy theory is the most fundamental?

The high energy theory deals with the fundamental laws of nature, every other law of physics follows from them. Our understanding of a complex physical phenomenon (which, in principle, can be derived from the fundamental laws of nature, provided we can solve them for that many degrees of freedom) is based on identifying the most significant degrees of freedom whose dynamics explain most of the phenomenon. The rest is treated by perturbation theory.

For example, collective motions of atoms (phonons), described just by a few degrees of freedom, turns out to be much more useful than studying dynamics of individual atoms of a solid, which is not feasible for any modern computer. In my studies of the interaction of EM waves with periodic structures, I also try to identify such key degrees of freedom whose dynamics gives a nearly complete solution to the problem.

CONTINUED ON INSIDE

who we are

UP is a monthly undergraduate physics newsletter sponsored by the University of Florida's chapter of the Society of Physics Students, for students, by students. We seek to strengthen the undergraduate physics community at the University of Florida by providing a forum for undergraduates to share their views and experiences with each other and to act as a source of information for opportunities and events in physics.

Visit Department
Coffee Time
Tuesdays & Thursdays 3-4pm In NPB 2205
Professors, staff, and students are all invited!
Coffee, tea, hot cocoa, and cookies only 50 cents

what's UP
in this issue

Spotlight on Science

UNDERGRADUATE RESEARCH

by James Stankowicz

The best way to rise to the top of the physics ranks is to contribute to the general body of human knowledge as soon and as often as possible. Fortunately, UF is one of the top universities in the country when it comes to opportunities for undergrads to do research, and, of course, the physics department is no exception. The writers at UP News urge any and all undergrads to get up as soon as they finish reading this issue (and assuming their professors won't get too mad at them) and find a professor who will teach them the ways of research.

To give you a small taste of the sorts of things even undergrads can sink their fangs into around the department, we've collected some testimonies:

In the past, I have been modifying a (classical) molecular dynamics code that models the behavior of fullerenes. This semester I am investigating the quantum mechanics of the three- and four- body problem (Helium and Lithium atoms).

-Third year undergrad working in the Quantum Theory Project

I modeled a two band structure of the newly discovered pnictide superconductors, and studied the local properties of impurity states.

-Third year undergrad working in condensed matter theory

(Note: pnictide superconductors are those superconductors containing nitrogen.)

I am working in mathematical and computational physics, particularly on quantum field theory. I am studying a mathematical method that may allow for the study of field theories that are currently impossible to study. To do this, I am updating a computer program which tests the new method on a gird approximation of the field.

-Third year undergrad doing individual research with a professor

Current research in general relativity is focused on the detection of gravitational waves through the LIGO and LISA projects. There is laboratory work being done here at UF in support of LIGO and LISA. Theoretical work such as perturbation theory, is also being done. Relativity theory now requires a hybrid of analytical and numerical methods. This semester I am using computer algorithms to model potential gravitational waves in noisy backgrounds, and working on methods to be used for confirming detection by LIGO or LISA.

-Fifth year undergrad contributing to the LIGO project

Don't let the years of the testifiers fool you - there are professors (particularly who do experimental work) who will take on even first-semester students. Browse around the physics department website, particularly the 'research' section, find a few professors whose work looks interesting, and send out a few e-mails asking if they have any projects or openings for undergrads. Then sit back and relax (which actually means "work your butt off") as the prizes, accolades, and glory come pouring in!

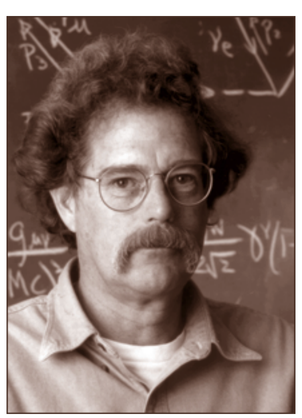
Aside from the obvious satisfaction of contributing to the general knowledge, there is no better way to scream "PICK ME! PICK ME!" to physics graduate schools or classy scholarship committees than to spend four years working for a professor, and to get your name on a few published papers. So take our advice to heart, and get to work!!

YOUR PHYSIC TEXTBOOK AUTHOR

DAVID GRIFFITHS

by Daniel Bannoura

Many of us are well familiar with the name David Griffiths since two of the textbooks that the physics department uses are written by him. Comments on his books range between "Griffiths makes everything as simple as possible, and sometimes simpler," to "Griffiths doesn't make any sense. I better buy another textbook to help me understand the material, or just change my major to History or Economics." This article sheds some light on David J. Griffiths - the horseshoe-moustached, Einstein-haired legend.



Griffiths was born in 1942 and prepped at the Putney School in Southern Vermont. He graduated from Harvard University magna cum laude and Phi Beta Kappa in 1964. He continued studying Physics there and received his Ph.D. in 1970. His doctoral dissertation on theoretical Particle Physics "Covariant Approach to Massless Field Theory in the Radiation Gauge" was supervised by the eminent theoretical Physicist Sidney Coleman. After graduating from Harvard, he had two post-doctoral positions at the University of Utah and the University of Massachusetts, Amherst. Soon afterwards, he worked at Mt. Holyoke College, Amherst, MA, and Trinity College, Hartford, CT, before joining Reed College in Portland, OR, where he is currently the Howard Vollum Professor of Science.

David Griffiths is principally known to us as the author of three textbooks for undergraduate physics courses: Introduction to Electrodynamics, Introduction to Quantum Mechanics, Introduction to Elementary Particles (not used in our department), and numerous articles and papers. He is the recipient of many awards, including a Sears-Roebuck Foundation Teaching Excellence and Campus Leadership Award in 1991, chosen by his colleagues on the basis of his excellence in teaching and outstanding leadership. He was also the recipient of the 1997 Robert A. Millikan award reserved for "those who have made outstanding scholarly contributions to physics education."

There's Still PLENTY of Room at the BOTTOM

by Arthur Ianuzzi

When I was in grade school, I learned that atoms were too small to ever be "seen." Thankfully, though, this limitation, like many that I learned about years ago, has not held up. It is now possible to perform surface scans of materials with atomic resolution. Currently, there are two techniques for performing these scans.

The first is scanning tunneling election microscopy (STM). In this method, a conducting tip is held just above the surface of the material, and a potential is applied across the gap between the tip and the sample. In this configuration, electrons will tunnel quantum-mechanically across the gap. Since the tunneling current is a function of the distance from the tip to the sample, the elevation of the surface at that point can be determined.

Piezo electric elements are then used to position the tip in the two dimensions that are orthogonal to the gap. Piezo elements are crystals that convert electrical voltages into physical displacement, so just like an ink jet printer uses motors and gears to scan across a page, the STM uses piezos to move the tip around on the sample to gather an image.

The second method is atomic force microscopy (AFM). In this method, a tip is dragged across the surface, and its elevation is measured by some means. The most common method of measuring the tip elevation is to shine a laser on a cantilever that holds the tip and watch the change in angle of the cantilever by watching the laser's reflection move.

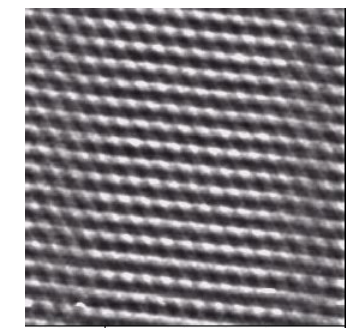


Image of graphite obtained by STM

Since dragging the tip across the surface tends to dull the end of the tip, some devices use a method in which the tip is tapped on the surface, rather than constantly pushed against it. Alternatively, the force acting between the tip and the surface due to van der Waals or other forces can be measured by watching shifts in a resonant system.

In order for the tip to have pin-point accuracy, and for the device to have atomic-scale resolution, the tip must be very sharp. The best tip would be one atom wide at the point, but this is not essential, since the electrons will tend to tunnel from whichever atom is closest to the surface. This level of sharpness, as amazing as it sounds, is surprisingly simple to achieve.

There are several methods of making tips, one of which is to stretch a wire until it breaks. The resulting end will sometimes be sharp enough. Another method is to cut a fine wire at a sharp angle with a pair of scissors; this is similar to the way the sharp end of a nail is cut. Finally, there are some more exotic methods, which use cutting edge technology such as carbon nanotubes as a tip.

These techniques can also be adapted to measure other characteristics of the surface, such as magnetic field, and it is also possible to move atoms around on a surface of a material. So whether you need to see an image of the crystalline structure on a surface, or you just want to spell out your name in gold atoms, STM and AFM are the tool to use.

SHABANOV CONTINUED FROM FRONT

What are some of the major differences between the US and other countries in terms of education?

I've taught in Germany and Spain and the level of preparedness of students in the US is significantly less. In my teaching career here at UF, the average level of students has fallen the last 6 or 7 years. I can no longer give the same tests as I did back then because they won't pass them.

How hard is it to get grants in different areas of physics?

Applied disciplines which have an outlook to different technologies usually have much better financing. For instance, my interest in photonics came out of sponsored work for the US Air Force and some consulting work for industry on EM scattering applications to radars, which is a pure applied math problem.

Advice to students?

Get a good undergraduate education in math and physics and apply to a good graduate school. The courses are not most important to a student, it's important for students to learn themselves and do individual study. The main job of an advisor is to guide a student, but not to spoon-feed him; after all, the student has to read the books himself. When I was a graduate student, I felt embarrassed when talking to my advisor if I didn't know any particular math or physics result that was related to my research project and was already in textbooks. So, I read as much as I could, and certainly every textbook suggested by my advisor. The courses and meetings with the advisor were more like the guide lines, directions. The actual knowledge came from my own studies and, most crucial, problem solving on every subject studied.