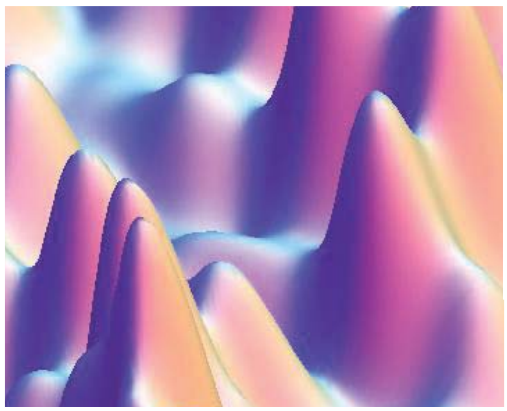
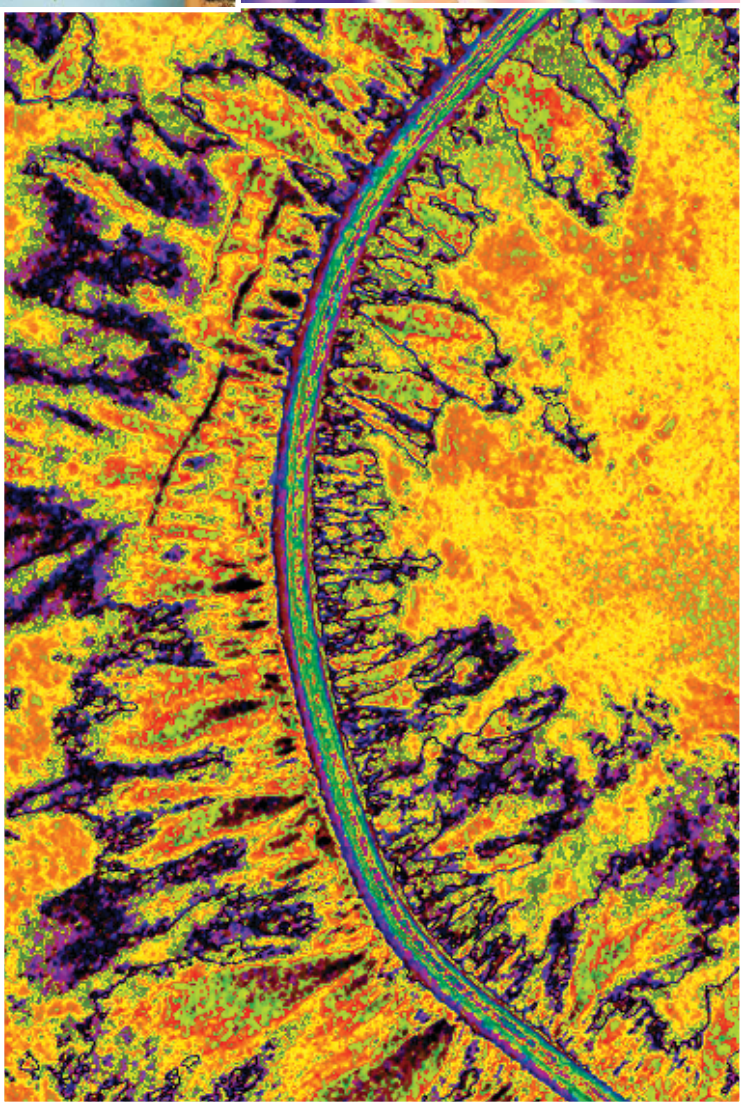
HWJS

HARVARD-WESTLAKE JOURNAL OF SCIENCE • ISSUE 3 • 2009





"WELCOME T

» » STUDIES IN SCIENTIFIC

20

08

TO A SCIENTIFIC PLAYGROUND," DR. ANTONIO NASSAR

C RESEARCH 2009

Editors-in-Chief

The Saga Continues: Letter from the editors

The year is 2009, the country is in a recession, and our country's position as the leaders of technological innovation is at risk of being overtaken by superpowers such as China and India. While very small compared to the grand scale of future progress, Harvard-Westlake's Studies in Scientific Research class is working hard to bring the minds of imaginative young students to practical application in the areas of engineering and general science.

As a culmination of the scientific research that has been completed throughout the last nine months, this year's Journal of Science strives to continue the tradition of high school student research that Allen Miller and Justin Chow brought to paper just two years ago.

With two full classes, SSR is stronger than ever. Not only are there more students to do physical work, there are more minds with the determination to carry out a successful continuation of what SSR is all about: bridging the gap between high school and college scientific research. However, the year has been quite unusual. Global issues have positively affected the span of projects that SSR students pursue. It seems the class has gone green – from a zero emissions race car to advanced research of biofuels. Of course there are many projects that deal with research in other areas, but we feel it is great that students are taking practical issues into mind when deciding what they want to learn about or innovate.

We hope you enjoy reading about these projects, and we feel it is an honor to compile what is really the imagination and knowledge of the future minds of America. Our goal is to have the reader become fascinated with what independent scientific research has to offer - an infinite possibility to make use of our brains for the future progress of our country and our world.

All the best,
Andrew Lee
Rory Handel
Rebecca Jacobs

Andrew Lee

Rory Handel

Rebecca Jacobs

DESIGNED IN THE US BUT ASSEMBLED ELSEWHERE

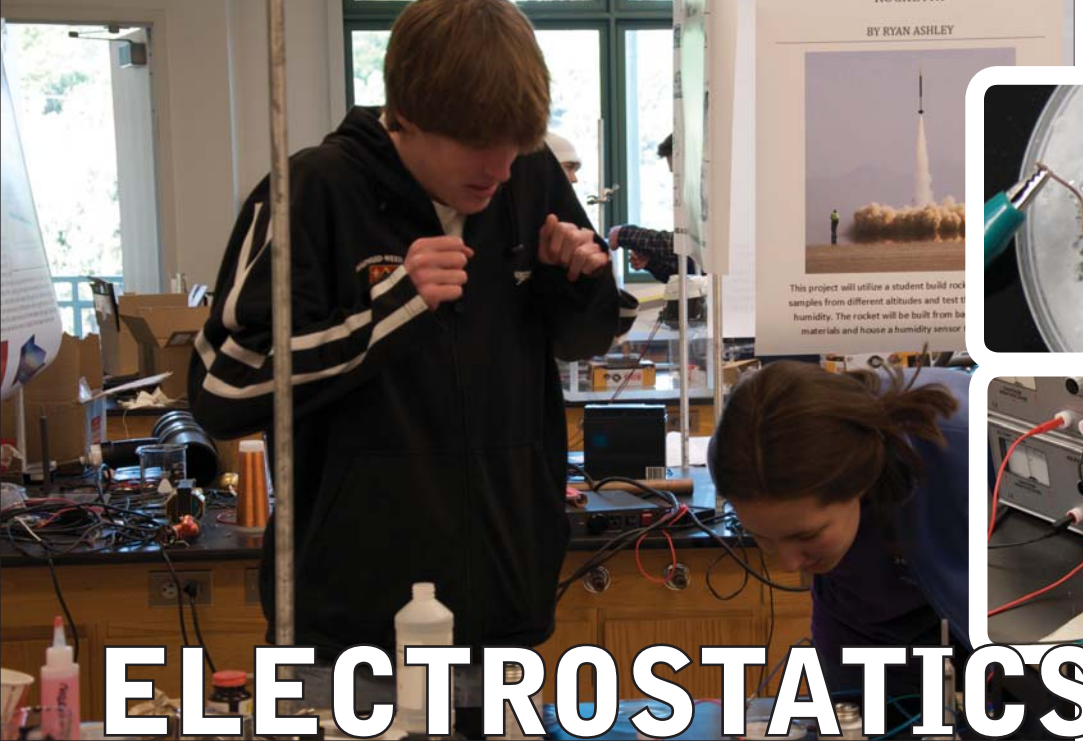
START RESEARCH EARLY, AND THINK BIG.

BY DR. ANTONIO NASSAR

The iPod is designed in California but manufactured in China. Like the iPod, almost all electronic devices are no longer manufactured in the US. Presently, we cannot compete with China, India, Indonesia, etc. on making shoes, clothes or assembling electronic devices because of their low-wage workers. However, since 50% of the world's top colleges and universities are in the US, we can still lead in practical research and patents by producing more high-income engineers. As long as our engineers keep coming up with new scientific and technological ideas, we will be fine. After all, one Boeing sold is equivalent to many millions of shoes and clothes altogether. We need to generate more intellectual capital in order to keep our technological edge. Today's global economy is technologically driven and innovations in engineering are extremely crucial for the economy of the nation.

A recent Duke University report concludes that we need to increase the enrollment rate within our engineering colleges in order for the nation to sustain its legacy as a preeminent technological innovator. There are many questions and problems, but a few concrete innovative solutions. The key challenge is how to encourage students to pursue careers in science and engineering. Especially, encouraging students at early age will definitely help colleges and universities. The gap between high school and college research discourages young students from pursuing scientific research. The economic crisis requires involvement of youngsters into research. Contrary to the establishment, every student should play a role in searching for new ways in the new economy. Besides scientists and engineers, we also need research-trained individuals to be tomorrow's politicians, entrepreneurs, lawyers and businesspeople. Unlike Donald Trump who says that …" every kid should start their entrepreneurial business at an early age," we should propose that ... "every kid should start their own research project at an early age." After a year of watching adults engage in devastating recklessness in the financial markets and depressing ineptitude in the global climate talks, it's important to gear up idealistic young people towards a new mentality in the world that desperately needs new ideas to change things, because the conventional way of thinking is simply not working anymore. That is what the Studies in Scientific Research (SSR) is trying to accomplish.

MUNGER 202: HOME OF THE RESEARCH CLASS.



ELECTROSTATICS & HIGH VOLTAGE CIRCUITS

BY REBECCA JACOBS AND ALEX DE SALAZAR

This project aims to provide a replicable demonstration of the relationship between electrostatic concepts, such as electric fields and charged particles, and concepts relating to circuits, such as voltage and current. In this demonstration, PTFE (Teflon) sealant and mineral oil are mixed, with a 12 kV potential differential set up between opposite ends of the mixture's container. This demonstration is more feasible than the traditional grass seed demonstration described by Jefimenko (1962) for this purpose.

Introduction

High school physics classes traditionally treat electrostatics and circuits as two completely separate, disunified topics. As a result, the electric forces and fields that move charges to produce current are poorly understood. Jefimenko (1962) is one of the few papers attempting to address this problem. Unfortunately, the method Jefimenko describes has been determined to be unfeasible as described. We propose a new method of demonstrating these electric fields, although methods to determine electric fields of high voltage circuits or demonstrate fields in complex circuits have yet to be achieved.

Former plan and materials

2 6kV Pasco power supplies, red and blue rapidograph ink, India ink, 5 glass plates, Redtop grass seed, mineral oil, Texso class 2 insulating gloves.

The power supplies and ink were used to construct the circuits: as described by Jefimenko, red ink diluted 1:1 with water was to be used for wires, and the better conducting India ink used for battery terminals. However, the red ink did not sufficiently conduct, so India ink was used instead. Several methods of aligning grass seed to the electric field were tried, including simply spreading the grass seed on the glass plate, using PTFE on the glass plate to reduce friction, and immersing the seeds in mineral oil in a tray underneath the glass plate. Unfortunately, in each of these methods, the grass seeds would move only when the electrodes of the power supplies were placed less than 1 cm away; they would not align to the electric field produced by a current running through the ink, or else no field was produced by the ink.

List of materials

2 6kV Pasco power supplies, Texso class 2 insulating gloves, PTFE (Teflon) sealant, mineral oil, a petri dish, aluminum foil, alligator clips.

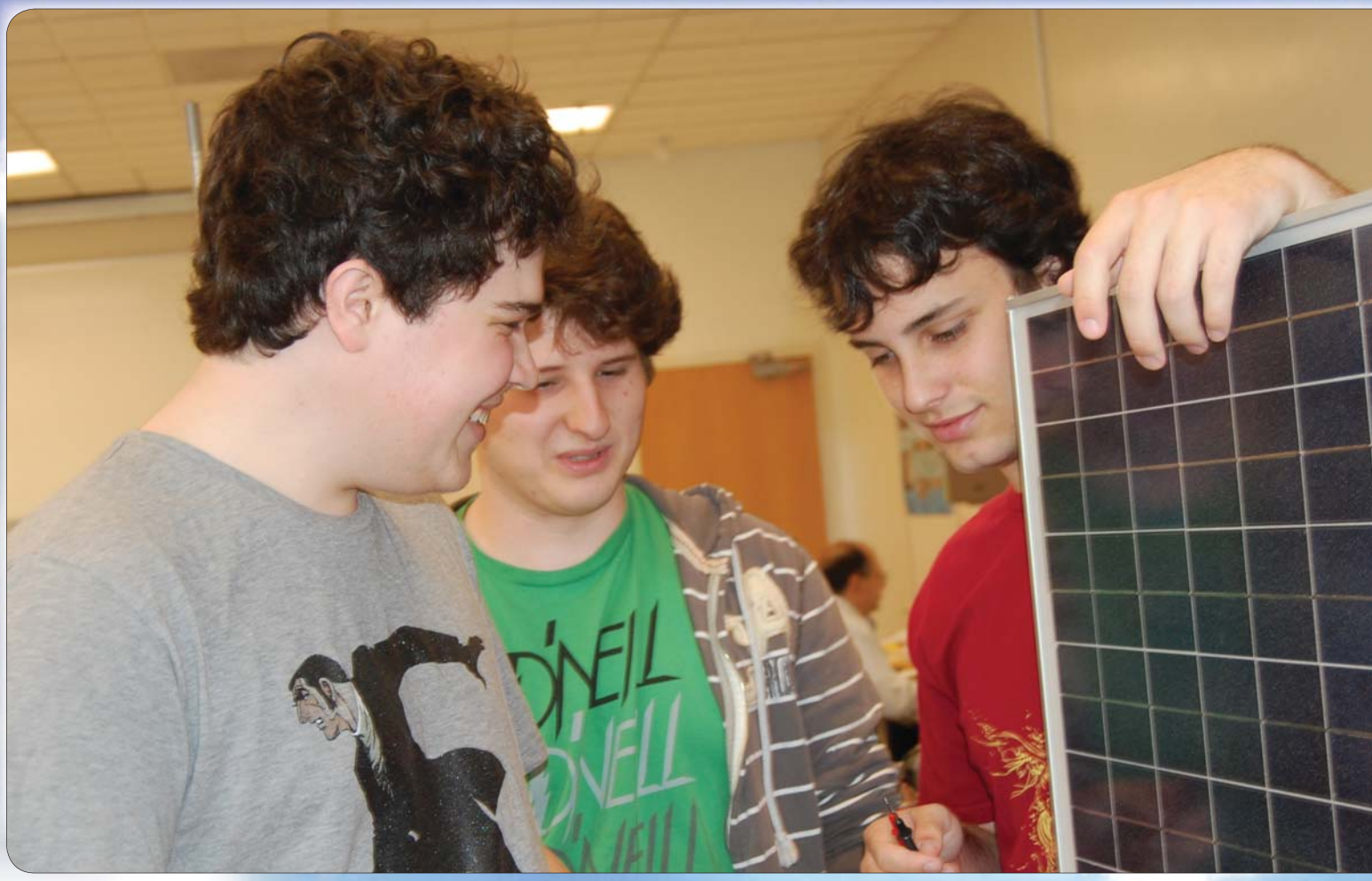
New method

Our new method is to mix PTFE sealant with mineral oil in a petri dish, clamp foil electrodes or alligator clips to opposite ends of a diameter of the dish, and attach the electrodes to the power supplies run at full voltage in series. This method has proved to show visible movement of PTFE strands in the mixture when the power supplies are turned on, already representing an improvement on Jefimenko's method. PTFE near the electrodes assembles into short threads, most of which deflect away from the electrodes. When the electrodes are bare alligator clips, this occurs primarily near the positive electrodes, whereas when the electrodes are clamped to aluminum foil this was found to occur near both electrodes.

Another method we have investigated is to place a copper wire in the dish and attach it to the terminals of the power supply. An 8 MΩ (mega-ohm) resistor is attached to the wire and the power supply is run at no more than 7 kV (to avoid burning out the resistor). The PTFE groups into strands or clumps which visibly align perpendicular to the wire.

Results

In order to make our demonstration better replicable by others, we have found an estimate of the optimal amounts of mineral oil and PTFE present in the mixture for maximum visibility—specifically, one square centimeter of PTFE paste and 7 cc of mineral oil. We have compared three brands of PTFE paste and found them to all have equal or near equal visibility, which implies that the movement and clumping is due to the PTFE rather than other chemicals present in the paste (which would likely differ from brand to brand). We have found that the minimum voltage at which movement is clearly visible is 5 kV.



HARNESSING SOLAR POWER

Ben Barad, Bobby Kazimiroff, and Adam Rothman want to cover the roof of Munger in solar panels. Here's how these guys are going to green up the Science Center and make an effort to cut down the school's energy bill.

BY ADAM ROTHMAN, BOBBY KAZIMIROFF AND BEN BARAD

Solar power technology is one of the most promising new ways of harvesting energy from the environment. Panels have no moving parts and burn no fuel; instead, they take power directly from the main source of energy, the sun, to the earth. Enough sunlight hits the earth to fulfill all of our energy needs many times over—solar has major potential as a power source. It is a source of reliable, renewable, clean energy. Solar panels use photons to knock electrons loose and use magnetic fields to force them to flow in one direction, all with a diode.

Diodes are based on the semi-conductive properties of silicon. By introducing chemical imperfections, a process called doping, conductivity can be achieved. A small amount of phosphorus can be added to a silicon sample, for instance. This type of doping creates negatively charged, N-type silicon. On the other hand, boron can be added to silicon to create the opposite effect. Boron creates a "hole" that an electron can fill that will move freely throughout the lattice. This too allows for conductivity. This type of doping

"SOLAR P
A PROMIS
OPPORTU
SCHOOL T
RISING C
FUELS."

Rothman, Kazimiroff, and Barad examine a solar panel (top left). The team surveys the roof of the Munger Science Center for potential panel locations (top right). Nanosolar's flexible new paneling provides an ideal solution for Munger's roof (bottom right).

creates positively charged, P-type silicon. Even a small amount of phosphorus or boron can change silicon from an insulator into a good conductor.

A diode is created by combining N-type and P-type silicon, layering one on top of the other. This setup forces charge to move in one direction and not the other. Electrons flow from the N-type to the P-type side, but not in the opposite direction. The holes and extra electrons are attracted to each other in the center of the diode, creating a charge barrier. Electrons combine with holes, closing the hole-electron pair. However, the lattice of the P-type silicon cannot maintain that extra electron, and so a new hole-electron group is created elsewhere in the silicon, and the electron is repelled out of the diode and the hole back into the center. However, the electron cannot cross the barrier from the P-type side since it is repelled by the electrons in the N-type silicon. Thus any new electron in the diode will flow in a single direction, creating a circuit.

Solar panels are simple diodes; the key improvement is that the energy created when photons strike the diode is used to knock electrons out of their place, leading to a hole-electron pair. As many photons strike the panel, more electrons are displaced and will flow through the circuit, doing work along the way.

Current fuel prices average at about $0.08 per kilowatt hour. This is subject to increase as coal and other resources decrease in availability.

The roof of the Munger Science Center is secluded from view, allowing for minimal aesthetic impact, and has a significant amount of area available for paneling. We expect about 7 hours of direct sun exposure per day. A 1 kW solar panel would generate 7 kWh per day or 2,556.75 kWh each year. Solar panels have a guaranteed lifespan of up to 30 years. Assuming the panels last this long, each 1 kW panel will generate 76,702.50 kWh over its lifetime. Purchasing an equivalent amoutn of power from the grid would cost $6,136.20. A 1kW panel not only costs less than $6,136.20, but the purchase price is paid up front - a responsible investment.

If the paneling costs $3,000 per kW, the school could expect a net return of $3,136.20 over the panel's lifetime. This amounts to a 104.5% increase over 30 years, or a yearly interest of ~2.4%. That's higher than the Federal Reserve's interest rate!

Through innovative new manufacturing methods, the San Jose, CA based firm Nanosolar is able to produce paneling for $1,000 per kW. Using these panels, the yearly return on investment jumps to more than 6%.

Solar panels will not only save the school money, but also demonstrate and solidify its stated commitment to going green--increasing the likelihood of future donations.

RORMaxx Formula AE: Technical Research

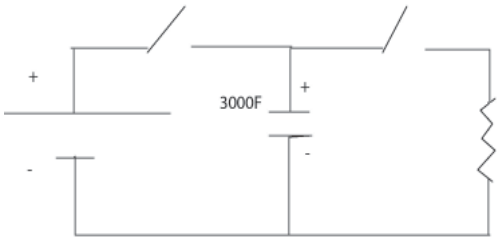
Four seniors attempt to build a racecar that uses alternative energy. Maxx Bricklin, Rory Handel, Carl Lawson endeavored to build a corporation and a working prototype before a loss of funding left the project in the design stage.

BY MAXX BRICKLIN, RORY HANDEL, CARL LAWSON AND SUNHO LEE

Ultracapacitor Circuit:

To address the issue of high acceleration demand in performance electric vehicles, a solution that avoids the voltage drop in normal chemical reaction batteries is necessary. Ultracapacitors can solve this problem. This technology is relatively new, and is just recently being seen as a viable solution for electric drives in modern alternative energy vehicles. For our specific application in Formula AE, we will use these Ultracapacitors to store charge from externally recovered energy lost under the friction of the air.

We have constructed a circuit which allows us to test the characterisitcs of this new technology. Below you can see a circuit comprised of our 3000 Farad ultracapcitor, 3.3V lithium-phosphate batteries, and a 1/6 Ohm resistor to allow for relatively quick discharge times:



Charging the ultracapcitor to 2.7V took very little time and presented only one problem. Our initial use of very fragile wires resulted in immediate overheating of the system before the UC was completely charged. To solve this, we replaced the thin wires with well insulated automotive grade cables. The next step was to record the discharge time of the UC and compare it to the experimental values below:

Charging (Voltage as a function of time)-

$$V(t) = \frac{1}{C}\int_0^t I(t)dt$$

Time to Charge Capacitor with Resitor to 63% of full charge or 37% discharge-

(τ) = RC
(τ) = (1/6Ω)*(3000F)
(τ) = 500 sec. or 8.33 Minutes

Recorded 2.7V-.73V Discharge Time: 9 Min. 54 Sec.

To lower this time we were originally using a 1000-watt light bulb to lower the resistance and thereby decrease the discharge time. This is represented below:

P = V2/R
R = V2/P
R = (3.3V)2 / 1000W
R = .011 Ω

This would allow for a very short discharge time, which is represented below:

(τ) = RC
(τ) = .011 Ω *3000F
(τ) = 33 seconds

The problem with using the light bulb was that in theory it would work flawlessly, except in reality, the voltage required for the light bulb to activate and lower its resistance to the one calculated above was significantly higher than the 3.3V available. We then assembled six 1-Ohm resistors in parallel to allow for the discharge time first shown. One other issue to note was the temperature of the 1/6-Ohm resistor throughout the discharge process. By using an infrared thermometer, temperatures approaching 200 degrees Fahrenheit were recorded posing heating problems for the circuit once installed in a vehicle.

Air Flow Recovery:

A major component of our alternative energy electric car is the wind energy recovery system. This system consists of air intakes that will channel air into a turbine fan, which turns an electric generator to create electricity. We currently have the fan set up in the lab and are using the fan from a miniature wind tunnel to simulate air at different driving speeds. Using an anemometer to measure windspeed, and a multimeter to measure voltage, we have been able to construct a graph of Voltage vs. Windspeed. From this graph we have

Professional automotive designers from the Pasadena Art Center College of Design worked with Rory Handel to create the above 3D rendering of Formula AE.

determined the equation that describes the relationship between the two. At the maximum operating speed of the windtunnel fan, approximately 42 mph, we are able to generate 46 V, a little over 10% of the estimated power needs of the car. Using a variable frequency strobe light, we have been able to measure the rotational frequency of the fan at each windspeed.

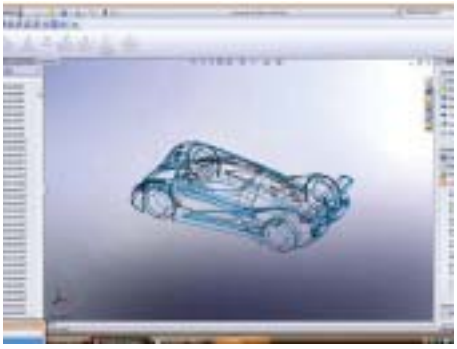
The circuit that harnesses this energy has been constructed as noted above, but we are facing a very unusual problem. When the Air Flow System is connected to the circuit in place of the 3.3V lithium-phosphate batteries, the resistance in the electric generator increases to a point that only allows for a minimal voltage gain. The problem with this could be one of the following and will be addressed in the next report:

1. Poor Quality Generator
2. Incorrect Circuit

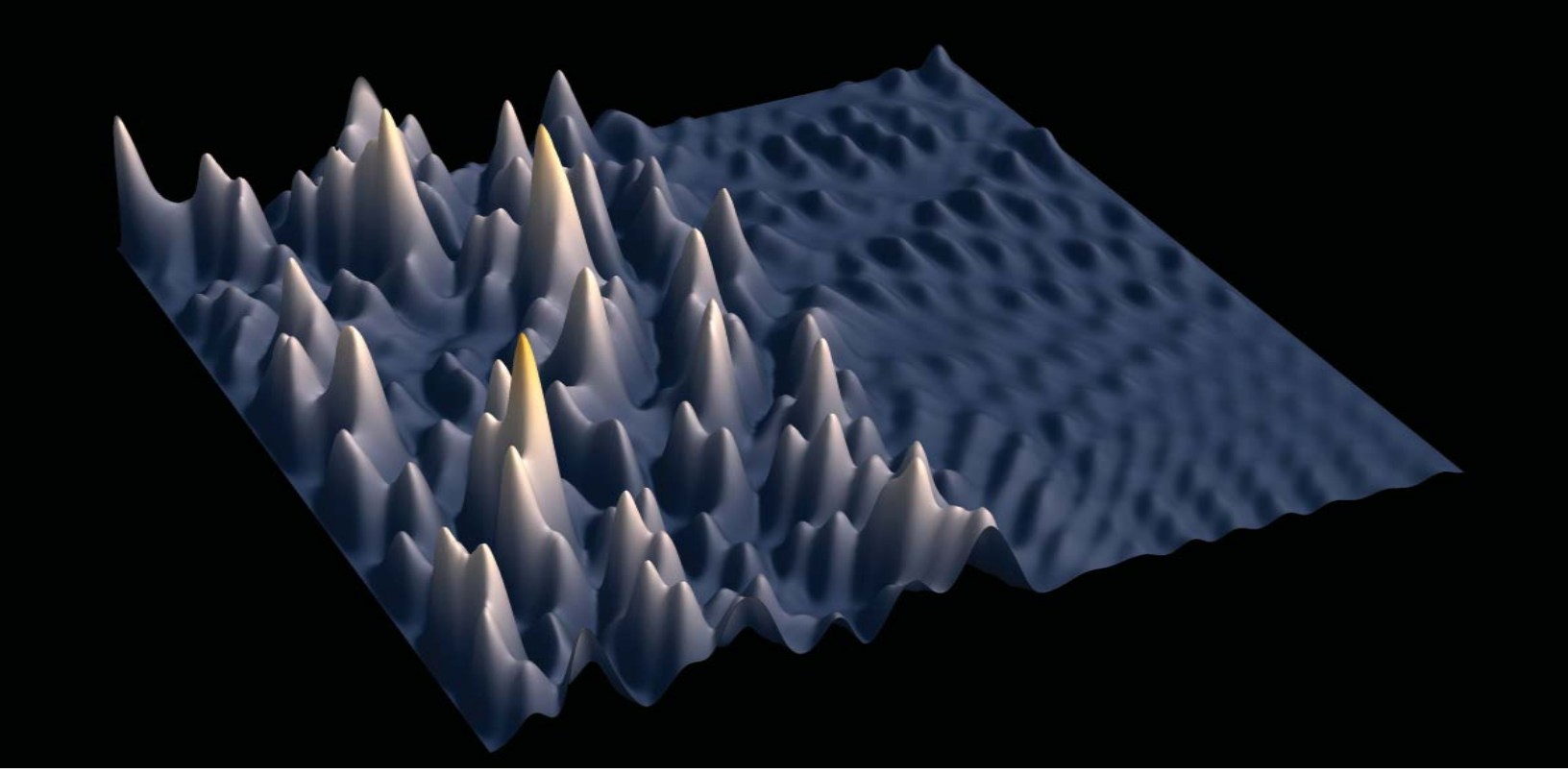
The next step in the Air Flow Fan design is to minimize the drag of the system using our Solidworks Computation Fluid Dynamics program. The system will be ineffective if the energy lost under the drag of the ducting is greater than the energy recovered from the system itself. One solution to this problem is to have a hydraulic flap close the entrances to the ducting at this energy-loss point as well as when the ultracapacitors are fully charged. With this implementation we can hopefully lower the overall coefficient of drag of the Air Flow System at high velocities where the aerodynamics play the most significant roll in energy losses.

Solar Panels:

Not only are we going to be using the wind recovery system and the ultra-capacitors to increase the efficiency of our electric race-car, we will be covering the exposed part of the car body with a newly developed flexible thin-film photovoltaic cells (Solar cells). Photovoltaic cells are made from crystalline silicon, which is able to convert the radiation from the sun into electricity that we can use. Most of the solar panels are made rigid because the thin-films needs to be protected from any minor damage, moisture, and also has to be insulated in case it rains. However, the newly developed flexible solar panels which use a flexible transparent colorless fluoropolymer to laminate the films to protect them from any damage have been commercialized since July 2008. With the new flexible thin-film photovoltaic cells, we will be able to incorporate the panels exactly in the shape of the body of our car which will make it more aerodynamic as well as increase the appeal to the human eye.



A 3-D design modeled on the computer.



QUANTUM STOCHASTIC RESONANCE

BY BISWAROOP MUKHERJEE

Introduction:

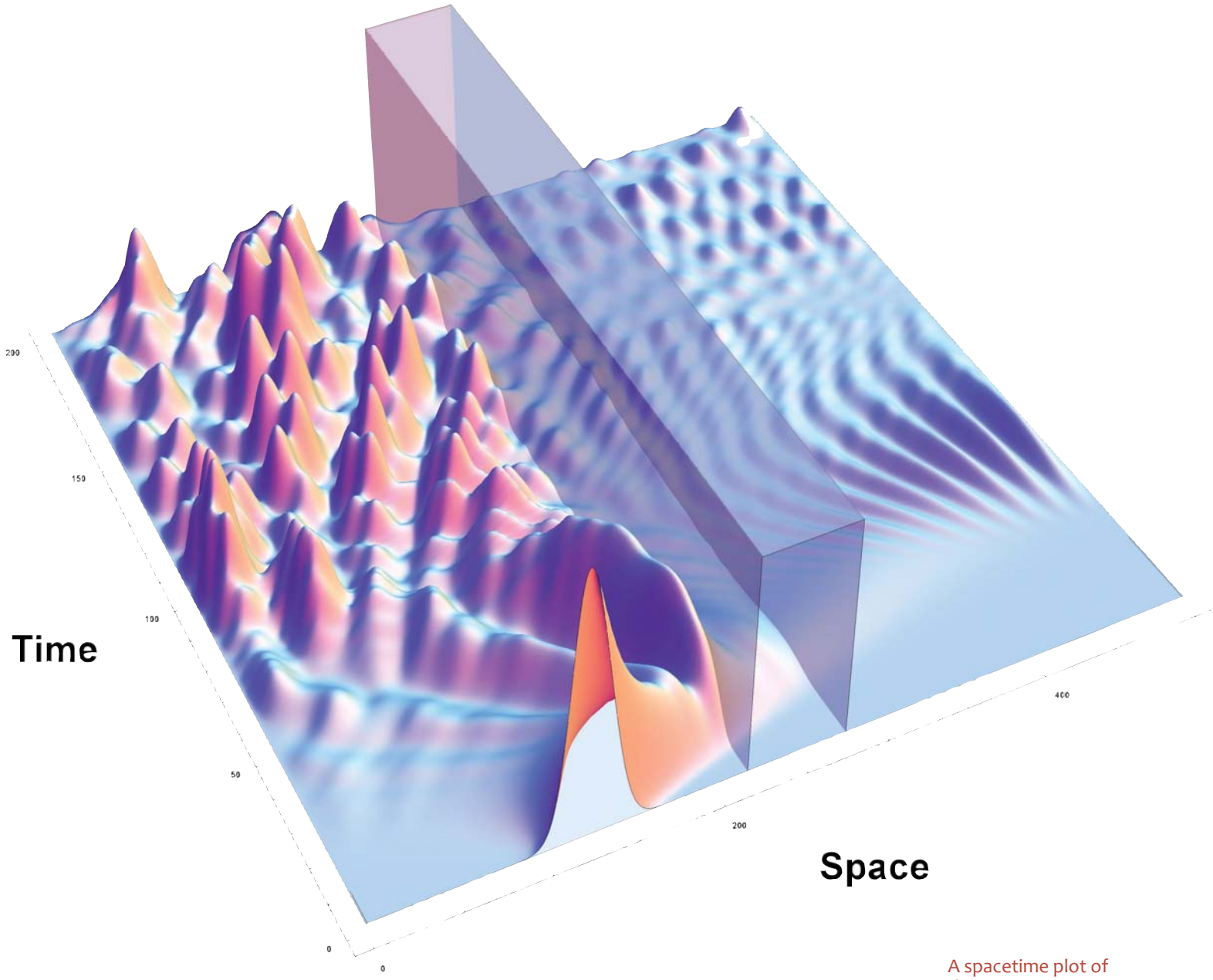
In recent years, researchers have explored numerous examples of dynamical systems influenced by a combination of deterministic forces (i.e. those determined by the particle's position or velocity) and stochastic (random) ones. An important class of such systems involve the escape of a particle from a partially stable potential well, over a potential barrier, into a more stable well. This situation occurs frequently in the natural world - in fields ranging from kinetics of chemical reactions, phase transitions, protein folding, and even ice age cycles. This system has been modeled with a classical particle in a bistable potential (such as that shown in Fig. 1), exhibiting a phenomenon termed *stochastic resonance* (SR). Depending on initial conditions, the particle will eventually sit at one of the two potential minima located at $x = \pm 1$. In response to a stochastic force $f(t)$, however, this particle will make small random transitions from one well ($x = -1$) to the other ($x = 1$). Instead, if a weak sinusoidal force is applied to the particle $F_{drive}(t) = A_0 \cos(wt)$, there will be no transitions from one well to the other. Remarkably, the combination of the stochastic and the weak periodic forces $f(t) + F_{drive}(t)$ generates an amplified oscillation across the wells.

This phenomenon is analogous to the more familiar mechanical resonance in a driven damped harmonic oscillator. The result suggests the counter-intuitive result that noise in a detector (the bistable system) can be used to enhance its sensitivity to weak signal (the sinusoidal drive). Such an effect has been observed in the detection of weak signals in optical devices and even in rat sensory neurons. To further explore the fundamental theory and its applications the reader is encouraged to refer to the excellent articles/reviews by Weisenfeld and Moss and Gammaitoni *et al*.

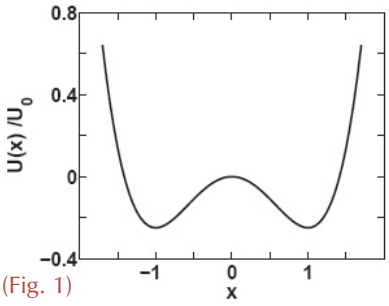
In this article we explore the possibility of extending this phenomenon into the quantum world, where instead of a classical particle, we send a gaussian wavefunction into a similarly oscilating well. So far, we have been able to show a clear oscillation between the wells without any driving forces. Although quantum stochastic resonance has been studied in great detail previously, this is the first time such an intensive calculation is being adapted on a classroom demonstration scale. It is clear that, with the advent of ubiquitous personal computers and software such as *Mathematica* that perform complex computations, new results in computational physics have become universally accessible to students. The interest in this field serves to stimulate a more thorough investigation of the mathematics and basic mechanics underlying this reserach. For the reader interested in writing his/her own code, we provide all of our simulation and analysis code in the HWScience website. We encourage the reader to use and modify this code for his/her own explorations, and suggest that this code can form the basis of lessons in Brownian motion, quantum mechanics, and, of course, in quantum stochastic resonance.

The remainder of this article is organized as follows: In section 2 we discuss the techniques used to solve the time-dependent Schrodinger equation, and further methods that will be used to enhance the power of the computation. In section 3 we demonstrate the time-propagation of a gaussian wavefunction in a number of potentials, with emphasis on the bistable situation. We conclude in section 4 by discussing further avenues that we are exploring such as an analysis into quantum stochastic resonance using an extended electron theory, as well as multidimensional situations.

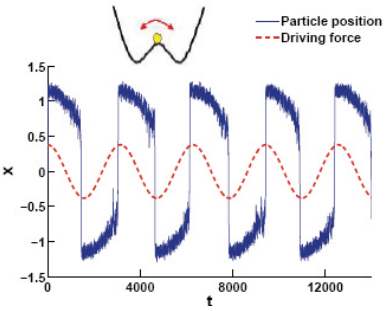
Continued on Page 12 ≫



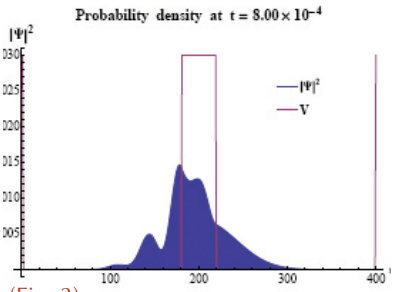
A spacetime plot of the quantum wave-function probability density , created in *Mathematica*



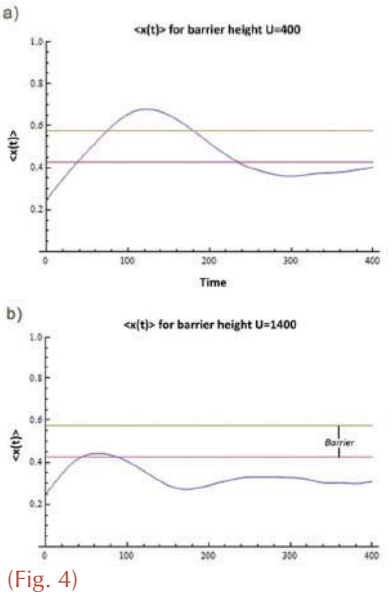
(Fig. 1)



(Fig. 2)



(Fig. 3)



(Fig. 4)

Methods:

2.1 Fundamental equations of classical stochastic resonance

We consider the motion of a particle of mass m moving with velocity v in one dimension in response to four forces: a conservative force field $F(x) = -dU/dx$ derived from the potential $U(x)$, a harmonic time-dependent force $F_{drive} = A_0 \cos(wt)$, a random force $z(t)$, and a drag force on the particle $F_{drag} = -gv$.

The second order in time equation of motion (Newton's second law) for the particle can be expressed in terms of two first-order differential equations for the position x and velocity $v = \dot{x}$, where the dot denotes differentiation with respect to time. These differential equations take the form

(1) $$\dot{x} = v$$

(2) $$m\dot{v} = -\frac{dU}{dx}(x) - \gamma v + A_0 \cos(\omega t + \phi) + \zeta(t)$$

Here, we choose the potential to be

(3) $$U(x) = \frac{1}{2}U_0\left(\frac{x^4}{2} - x^2\right),$$

These equations were integrated using C programming in a previous work [14], where we solved for the position of the particle as a function of time.

2.2 Quantum Mechanics

At very small scales, particles begin acting as waves. In order to explain phenomena such as diffraction patterns, physicists such as Werner Heisenberg found classical rules for postion and momentum no longer hold. Particle positions were only describable in terms of a probablility associated with it at each point in space. Most famously, Heisenberg [15] formulated the uncertainty principle, which states that we cannot know the position and momentum of a particle simultaneously:

(4) $$\sigma_x \sigma_p \geq \frac{\hbar}{2}$$

Moreover, this meant that in order to analyze the dymanics of a quantum particle, we look for a time-dependent continuous function ψ that determines the probability of finding the particle at any point in space. This *wavefunction* can be computed as a function of time by solving the time-dependent Schrodinger Wave Equation for ψ:

(5) $$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + V(\mathbf{r},t)\psi$$

The wave equation relates the time dependence of the wavefunction (denoted by the time-partial derivative on the left) with an energy operator on the right (the potential energy is V). In this study, however, we are only concerned with the single-dimensional case, where the Laplacian ∇^2 in the kinetic energy operator turns into a simple second-order partial derivative:

(6) $$i\hbar\frac{\partial\psi}{\partial t} = \left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(\mathbf{r},t)\right]\psi = \mathbf{H}\psi$$

where $\mathbf{H}$ is the *Hamiltonian* or energy operator.

Despite the abundance of neat methods of solving this equation, none so far have been implemented in *Mathematica*, and are thus unable to harness its computational and analytic power. Here, we use a standard tridiagonal matrix method elaborated by Kinzel and Reents in a easy-to-implement *Mathematica* program. First, as is usualy the case with differential equations, the solution to Eq. (6) can be expressed as:

(7) $$\psi(x, t + \mathrm{d}t) = e^{-iH\mathrm{d}t}\psi(x,t)$$

In order to conserve the total probability $\int |\psi|^2 \,\mathrm{d}x = 1$, we use an approximation derived from the taylor series for e^x:

(8) $$e^{-iH\mathrm{d}t} \approx \left(1 + \frac{i}{2}H\mathrm{d}t\right)^{-1}\left(1 - \frac{i}{2}H\mathrm{d}t\right)$$

Next, since computers work in discrete steps, ψ is discretized:

(9) $$\psi_n^j = \psi(j\mathrm{d}x, n\mathrm{d}t)$$

The corresponding discretized Hamiltonian operator is:

$$(H\psi)_n^j = -\frac{1}{(\mathrm{d}x)^2}\left(\psi_n^{j+1} - 2\psi_n^j + \psi_n^{j-1}\right) + V^j\psi_n^j$$

(10)

The first term of the right hand side is a spatial second derivative of ψ taken around $x = j\mathrm{d}x$, while the second term is simply the potential energy operator seen before in Eq. (6). Substituting this operator into Eq. (8), and using considerable manipulation, Kinzel and Reents arrive at an elaborate solution for ψ_{n+1}^j. Fortunately, this can be easily programmed in *Mathematica*, and the program can be adapted to simulate the dynamics of any wavefunction in practically any potential.

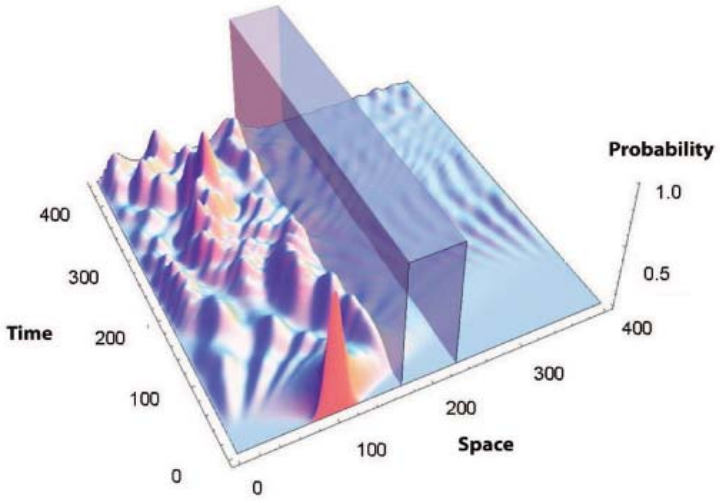


Fig 1: The bistable potential U(x) used in this work.

Fig 2: The solid blue curve shows the particle position, showing repeated transitions between potential wells in phase with an applied driving force (red dashed line).

Fig 3: The wavefunction as a function of space at a certain time. The quantum tunneling effect is quite evident here.

Fig 4: The expectation value as a function of time for two different barrier heights. While the particle is expected to pass through the smaller barrier (a), this no longer happens at higher barrier heights (b)

Fig 5 (To the left): The spacetime plot of the probability density function (see p 11 for detail).

Results

In Fig. 2 we show the position of a classical particle in the bistable system, moving in response to a periodic drive. Clearly, the periodic transitions of the particle between the left and right wells is in phase with the driving force (dashed red line).

This result demonstrates the basic phenomenon of stochastic resonance in the classical situation. In order to recreate this effect in the quantum world, we need to recreate some form of periodic ``force". Although it is possible to make the potential time-dependent, our program is currently unable to handle that. Although we are currently implementing newer simulation algorithms that will support such potentials, it is still possible to create interesting investigations and demonstrations using the original program. One clear application is the phenomenon of quantum tunneling. Since the wavefunction associates every point with a probability, it is possible that quantum particles encountering a barrier will have a probability of being *within* the barrier. Thus, although the energy of the particle may be lower than the barrier potential, part of the wavefunction will tunnel through the barrier - a region forbidden to classical particles. It is useful to note that this is not a mere theoretical speculation. Not only does this explain how alpha particles are able to escape the potential well of an atomic nucleus, this phenomenon enables scientists to probe very small scales using scanning tunneling microscopes. Time-independent considerations of tunneling result in the slightly unsatisfying result of a transmission probability approximation

$$T \approx \exp\left[\frac{-2L\sqrt{2m(U-E)}}{\hbar}\right] \quad (11)$$

Our time-dependent solution in Mathematica enables a neat demonstration of the actual tunneling effect, as we send a Gaussian wave packet described by:

$$\psi(x) = \exp\left[-\frac{x^2}{2\sigma^2} + ikx\right] \quad (12)$$

towards a potential barrier in a much larger well with infinite walls. As the simulations runs, it computes the wavefunction as a function of space for each time step. Each of these time frames can be compiled into a movie of the propagation of the probability density. One such frame is shown in Fig. 3.

Of course, the potential can be replaced with our old bistable system. In this case, the actual movie (the most recent upload athttp://www.youtube.com/user/SSRquantum) is more interesting than a single frame. We have observed an entire oscillation of the wavefunction, which starting in one well, shifts to the other, and back after some period T. However, these simulations are time-intensive, and further statistical analysis on the period of the oscillations will take days of runtime.

Another interesting mode of analysis is the plot of the expectation value a function of time. Although the wavefunction itself is complex-valued, its square modulus($|\psi|^2$) is literally the probability density function of the particle. The most expected position of the particle is thus:

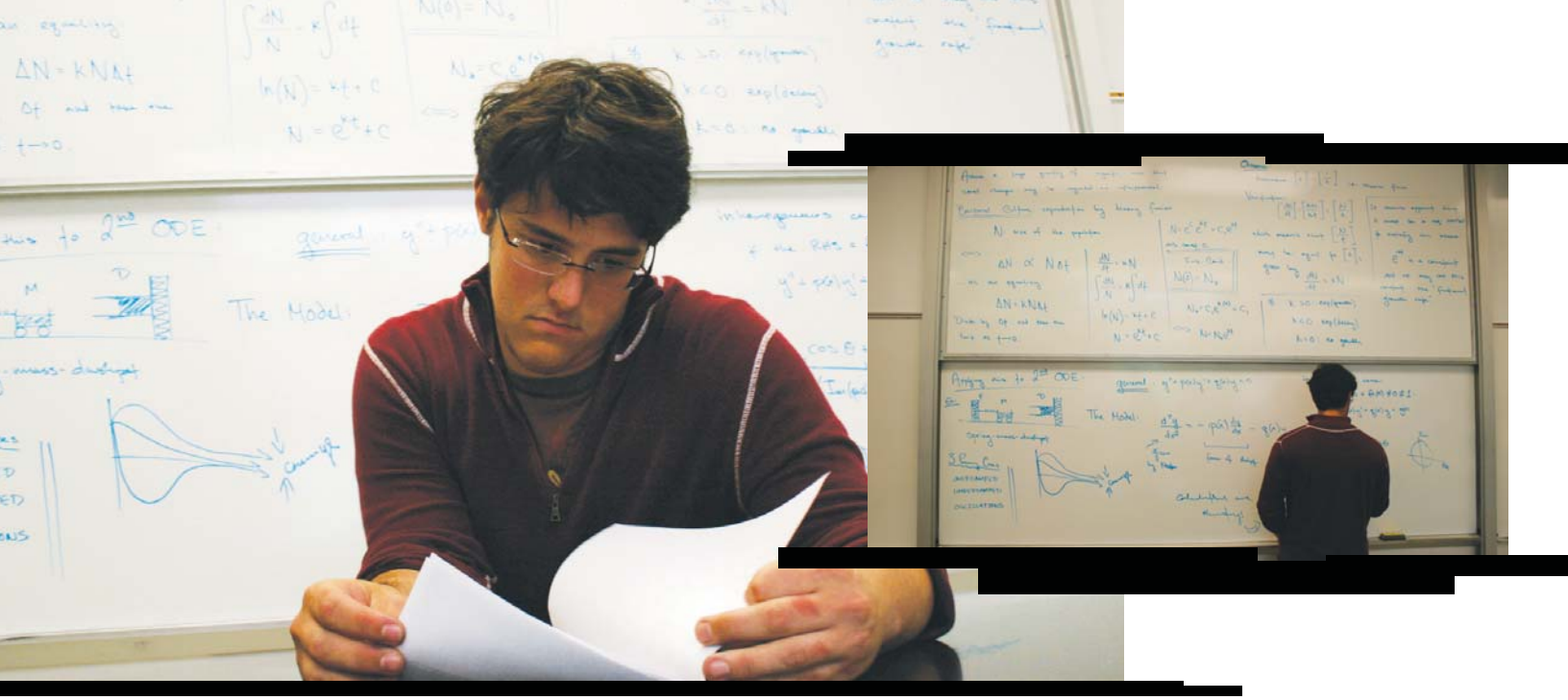
$$\langle x(t)\rangle = \int_{\infty}^{\infty} x|\psi(x,t)|^2 \mathrm{d}x \quad (13)$$

Lastly, we suggest a visual representation of the time-propagation of the wavefunction as a clear demonstration of both the quantum effects, as well as the simple fact that the wavefunction is usually dependent on space and time. In Fig. 5, we combine each consecutive frame of the tunneling movie described earlier as cross-sections of a space-time plot of the probability density function. Here, both the tunneling effect and the complicated interference patterns that ensue from reflection are apparent.

Conclusions:

Finally, we note that these simulations can be further developed for use in the classroom, and that the code can be easily modified to examine a variety of noise-induced dynamics in bistable systems. Furthermore, we are currently trying to simulate the motion of a quantum particle in two cases. In one, we plan to create a time-dependent potential that will allow us to simulate quantum stochastic resonance. In the other, we plan to take in to account the radius of the charged particle in question, and solve the time-dependent Schrodinger Equation under an extended electron theory.

I would like to thank Dr. Nassar for the support through the SSR class and his immense knowledge on quantum mechanics.



Looking for the big answers

Science strives to understand the components of the universe through the use of logic and quantitative analysis.

BY BENJ BELLON

Nature holds an inherent beauty, and science attempts to unravel and understand the chaotic order of the universe: studying the universe in an attempt to fully appreciate the art that surrounds us. However, despite the wonders of the universe, I endeavor to find an explanation of human consciousness and action.

The complexity of this problem presents a daunting challenge, but I believe that human nature is no more complex than the world we observe. Thus, in an attempt to convey insight into my research in a clear and concise manner, I will briefly introduce a few of the many challenges that I have undertaken in an attempt to discover the beauty of humanity. Although a more thorough paper of my research is available, the absence of any proofs are only due to the limited length of this article.

As I thought of ways to tackle the issue of human consciousness, I found myself thinking that observation and perception are key components of almost every "rigorous" proof that exists. Of course, basic assumptions are usually necessary to progress any idea; however, any such assumptions are ultimately limited by human logic. The inherent flaw in this is that human logic need not apply to the universe. In fact, the assumption that the universe follows any form of human logic is absurd.

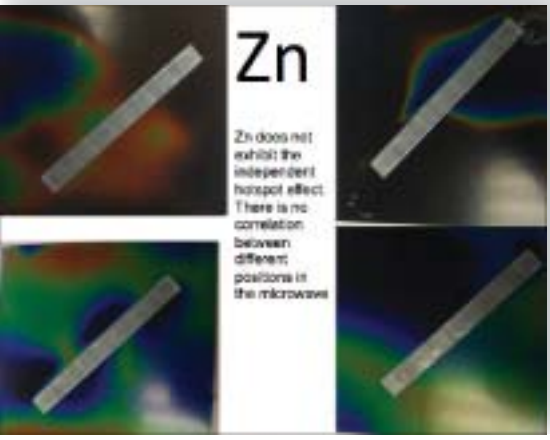
With this in mind, I began to break down the fundamental assumptions that humans have made in order to further scientific understanding. I arrived upon an assumption that exists in almost every scientific and mathematical discipline: the idea of time. Regardless of the way time is perceived: linear, a form of space-time, non-linear, or any abstraction of time as a measurement, the underlying assumption made is that time exists in some form or another.

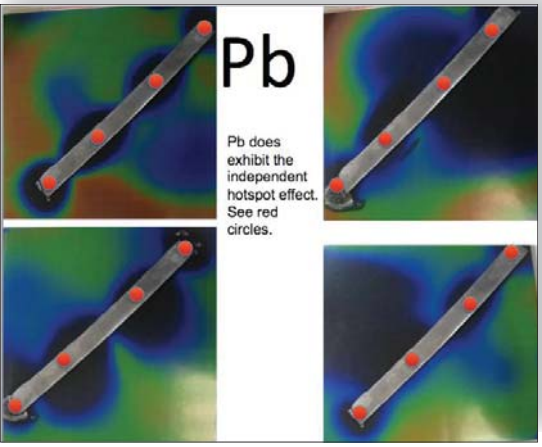
I have no belief that the concept of time is "wrong"; however, as I am attempting to delve within potential flaws I have taken a blunt and absolute stance that time may not exist. Essentially, time is an observation of external changes relative to the self-awareness of any group or individual. Thus, I proceeded to define time in terms of the various interactions between neural networks, which give rise to perception. The obvious dilemma is defining time using scientific methods that have all been based on the existence of time as a linear and constant truth. However, I eventually managed to describe a rough outline of time using a strictly geometric approach. This new perspective of time, albeit a rather poorly defined perspective, allowed me to approach human consciousness in an entirely different way.

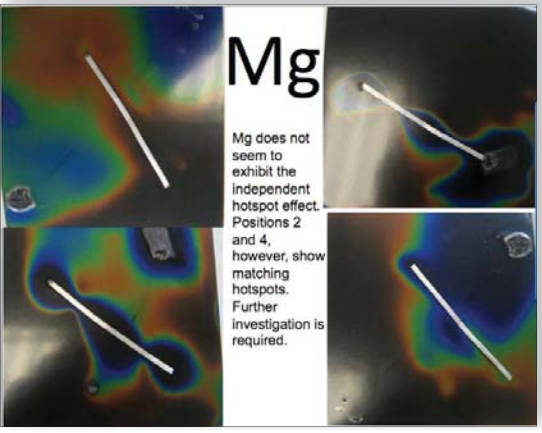
Human consciousness describes the ability to mentally manipulate external factors and visualize the "self" within that scenario. Decisions, feelings, thoughts, and every human action begins as a perceived outcome. The potential for something to occur in a particular way gives certain values to our possible actions. The change that a person experiences around them is constantly reconciled with the change that is expected. It is from that integration of information that humans are able to learn and grow.

Attempting to predict possible predictions is a challenge of infinite proportion, and I have successfully failed to produce any possible way of computing potential perception. At the most basic level what I have tried to create is a way to explain why, if a coin is tossed, one person may choose heads and the other may choose tails. Expanding that idea, what is the reason certain people choose to admit defeat while others will never concede? Are there any components of human nature truly beyond any explanation? Can irrationality be modeled? Even though I am eager for a solution to explain my questions, I consider that a potential answer may be that it is impossible to truly describe humanity. Either way, a solution exists.

OBSERVING STANDING WAVES IN MICROWAVE OVENS







BY IAN CINNAMON AND AVA KOFMAN

Background:

Interested in the effects of microwaves, we originally set out to determine whether microwaves had damaging effects on DNA in cells. The first two weeks of our project were spent both combing through literature and talking to faculty about the means necessary for carrying out such a project. However, upon further review, we determined that the transportation of viable non-senescent cells would prove difficult if not impossible with Harvard-Westlake's current non-existent tissue culture facilities. Our attention was then focused upon an altogether different project, albeit one also involving substantial usage of microwaves.

Intrigued by the interesting effects copper produced when microwaved, as discovered last year by Will Baskin-Gerwitz ('08) and Matthew Edwards ('08), we set out this month to confirm as well as further their discoveries

Abstract:

A standing wave remains constant in a standing position as a result of a specific interference. Standing waves have been observed in microwaves due to the presence of specific cold spots (or nodes.) The distance between the nodes can be measured and yields the distance of the wavelength. (Distance between nodes = wavelength/2.)

With these effects observed, we can attempt to effectively map the microwave using heat-sensitive paper (different brands for confirmation) and a fast-shutter speed camera. The variables we are taking into account are wire (length, gauge, composition (what kind of metal), placement relative to magnetron, mark with paper), microwave (light on/off, internal temperature) and the heat sensitive paper (size, brand, placement, initial temperature.)

Research and knowledge thus far:

During first quarter, we worked on calibrating the microwave. The first step in this was ordering heat-sensitive paper on which to place the metals and hopefully later antennas as well as other objects. We are mapping the microwave's cold spots (nodes) as well as measuring the heat capacity, or maximum temperature reached, of the heat sensitive paper. We successfully mapped the lower horizontal level of the microwave by using liquid crystal paper.

During second quarter, we began testing various metals on the heat sensitive paper. We tested lead, magnesium, copper, and zinc. Lead and copper clearly demonstrated the standing heat wave effect. Magnesium weakly exhibited it, but more testing is required to confirm. We decided to go with lead to use as a basis for the project because it is soft, easily shaped, and has a low melting point. After selecting lead, we began testing different lengths of lead strips at different positions in the microwave. Both 10mm and 15mm long strips appeared to exhibit standing waves the same distance apart from one another, proving that the lead is not acting as an antenna. The hotspots were 5mm apart. Since the eventual goal is to make more efficient cookware, we tested circular pieces of lead cut from a length of lead sheet.

During the third quarter, we continued to focus solely on lead. Lead is easy to shape and mold. We placed different lengths of lead wire in the microwave at different orientations and positions. The lead heated up consistently every 5mm. We then tried connecting the ends of the wire to form a circle. We found the same hotspots appeared. We also tried turning the lead into a spiral and once again found the same consistent results. We finally determined that the shape, length and placement of lead wire in the microwave is irrelevant to the location of the hotspots: the lead heats up consistently at set spots.

MAGNETIC DECELERATION

As today's global energy crisis continues to multiply in scale, our societies and communities have become increasingly reliant on mass public transit as a cost-effective means of daily transportation. This massive influx into the transportation niche offers opportunities for a wealth of innovations of special interest regarding this project. The magnetic decelerator and generator is a system of consecutive electromagnets designed to decelerate a subway train as it approaches an upcoming station while harnessing the train's kinetic energy into electricity. Electricity is obtained via a resistance-based generator configured to obtain maximum yield from the train's speed. In this project, numerous experiments were conducted to discover the most efficient configuration of the system, both energy-yields based and cost-wise. Ultimately, an ideal model of the system was constructed and various formulas were found to correlate energy efficiency to mass, strength, surface area, and relative distance of the magnets. Plans for a full-sized prototype were developed

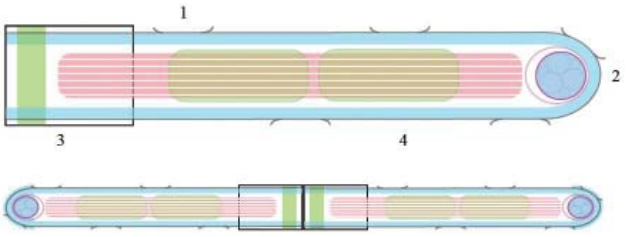
Energy

GENERATION

BY RICHARD LIU

Permanent Magnets and electromagnets have traditionally been used for a variety of different purposes, employed in both experimental and scientific arenas. The most recent development, the maglev train, relies on a continuous track of charge-shifting electromagnets that propel the train at incredible speeds. Powerful superconducting magnets suspend the train several inches above the track, while other exterior magnets thrust the vehicle forward via magnetic induction. This project, however, focuses on a different application of magnetic force: magnetic deceleration and electrical generation and its varying effects on weight, speed, and surface area of the vehicle it is designed to decelerate. Because of the gradual long-term increase in mass public transportation due to the global energy crisis, many different concepts of product development have been centered on the field of public transit. The deceleration system is designed specifically for subway trains to efficiently and effectively decrease speed as they approach their upcoming destination, while at the same time harnessing the train's kinetic energy into electrical energy through an underground generator. The system is designed to accomplish four major goals: achieve a significant increase in safety due to the lack of human interference and error, generate sufficient electricity to power the entire subway station and even possibly the train itself, reduce operating costs to pay for itself in less than five years, and most importantly, discover a new and possibly more proficient means of high-speed braking. The system could eventually be installed in all major subway systems in the future for a new generation of mass public transportation, one that is more safe, efficient, cost-effective, and smart.

1/4 Scale models are currently being constructed and will be completed by September 2009



PLAYING MUSIC TO PLANTS

BY JAMIE SHAUM

Will playing music to plants for twenty-five minutes every day really increase plant growth? In my experiment, I am going to test upper frequencies using a super-tweeter similar speaker. By hooking the speaker up to a frequency generator, the speaker could be set to play a very broad sine-wave to encompass as many frequencies as feasible to make sure the resonant range is played at some point in the test. High frequency tones have been known to force surfaces with sub-micrometer distances to spontaneously attract each other, defined as the Casimir Interaction. The width of the smaller capillaries in the leaf systems of the average plant should be about that size. The leaves of plants, besides serving as the main photosynthesis site, also produce a hormone called Auxin, which among many things help to curb plant growth. A careful ratio of auxins and cytokinin at the apical meristems keep plant growth in check. So with the leaf capillaries slightly constricted, fewer auxins reach growth buds, and the ratio is thrown in favour of cytokinin, and cell division is initiated. Constriction of leaf capillaries would, thus, constrict the flow of auxin, which is a rather large macromolecule, but not affect the flow of smaller and more necessary molecules, such as water or G3P.

MAPPING THE GROWTH OF CANCER STEM CELLS

BY JEFF YU

Recent discoveries have identified a malignant stem cell type, called cancer stem cells, present in various tumors, including breast, colon, and brain cancer. Creating an effective computer model of cancer that takes into account cancer stem cells could better predict the growth of cancers and clarify the role of stem cells in cancer initiation and progression. In this project, I will construct a computer model based on biological evidence and data. The program will simulate cancer growth based on various factors, including stem cell concentrations.

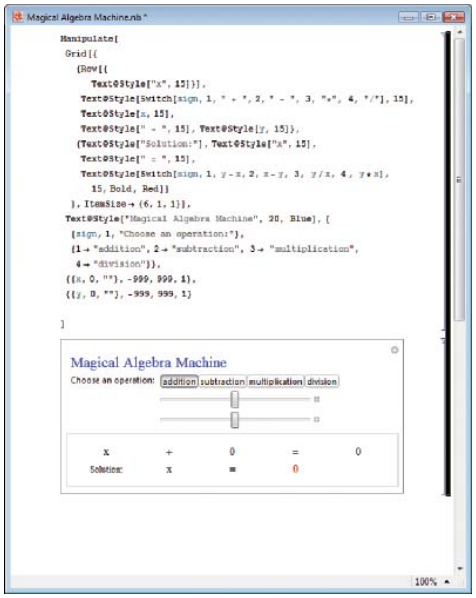
Cancer may arise in any tissue that contains a stem cell population. Cancer-causing mutations can accumulate in these stem cell populations. Although research in this area is ongoing, it is highly possible that these mutations are at least one of the origins of the cancer stem cell, a cell that generates tumor cells through the stem cell processes of self-renewal and differentiation. Current cancer stem cell theory suggests that conventional chemotherapies target differentiated or differentiating cells. However, by targeting undifferentiated cancer stem cells specifically, tumor growth could be stopped at its origin, resulting in a more effective cancer therapy. In "Computer Modeling Implicates Stem Cell Overproduction in Colon Cancer Initiation," Boman *et al.* assert that computer modeling has implicated that an increase in crypt stem cell number alone causes tumor initiation in the colon. By creating a mathematical model of cancer growth that takes into account cancer stem cells, we can strengthen our understanding of the extent of the role of cancer stem cells in tumor growth.

Throughout the year, I have been using the Mathematica documentation as well as the Wolfram Demonstration Project in order to learn the Mathematica programming language. I have used the knowledge I have gained about the Mathematica syntax in order to create a program that solves simple algebraic equations using either addition, subtraction, multiplication, or division. A screenshot of this program is shown in Figure 1.

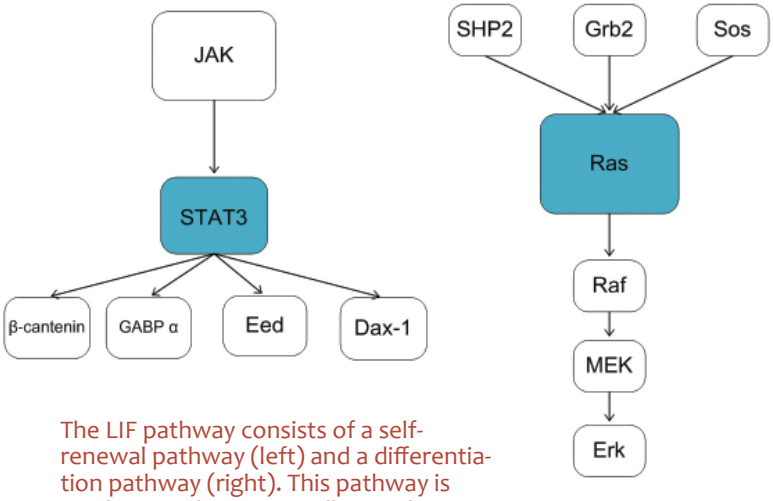
I have also utilized a Mathematica add-on application package called PathwayLab for my project. PathwayLab is designed to visualize, analyze, and document biochemical pathways. In my project, PathwayLab has allowed me to simulate the signaling pathways involved in tumor growth.

Figure 2 below shows the pathway diagram I have created to simulate the LIF pathway, a pathway involved in the proliferation and differentiation of stem cells. The pathway on the left represents the pathway to self-renewal, while the one on the right represents the differentiation pathway. The blue boxes, STAT3 and Ras, represent genes which encode for proteins that promote cell growth. This diagram represents a simplified version of the pathway. When results accurately simulate tumor growth, more detailed versions of the model will be produced.

By utilizing the computational power of Mathematica, we can simulate the growth of cancer stem cells and shed light on the role of cancer stem cells in tumor growth.



This program, created with Mathematica, solves simple algebraic equations.

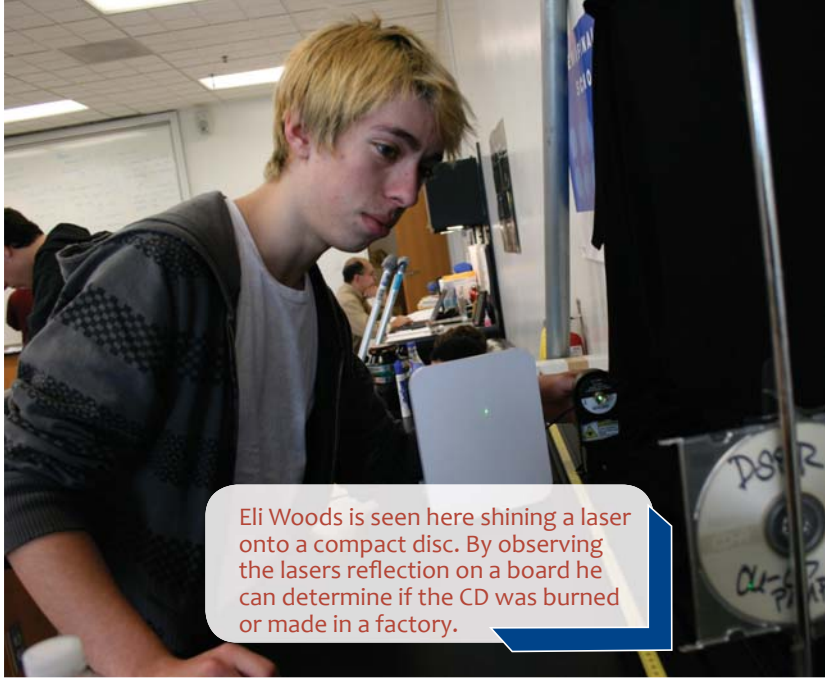


The LIF pathway consists of a self-renewal pathway (left) and a differentiation pathway (right). This pathway is used to simulate stem cell growth.

DETECTING BOOTLEG CDs

BY ELI WOODS

Although the invention of the compact disc made the cassette tape obsolete, its suffered many of the same problems. Like the cassette tape, the data from a CD could be easily copied onto a blank CD, enabling bootleggers to continue their deceitful craft. However, because of the difference between the structures within a burnable disc and a pressed disc (i.e. one you would buy from a music store) there is an easy way to tell if a disc is a bootleg or legitimate copy. CD's are essentially structured like a vinyl record in that they have a continuous spiral imprinted on one side where all of the information is stored. By shining a laser that has a wavelength less than the width of the spiral groove and observing the resulting reflective pattern, you can tell if a CD is burned or pressed. Pressed CD's do not have a uniform groove all the way around the CD because of the process that they must undergo to be pressed, so the reflective pattern will look like a single slit diffraction pattern. The burned discs also produce a reflective pattern similar to a single slit diffraction pattern but also have two horizontal lines of light on each side of the pattern. This difference is due to the presence of an actual groove throughout the burned disc, while the pressed disc simply has its information arranged in a spiral formation to be compatible with all CD players. I attempted to perform the experiment on DVDs as well but could not conclude if this method worked because of the many different types of DVDs. With the continued use of discs as storage devices comes the continued creation of bootlegged copies, but as the world moves towards fully embracing electronic data storage these concerns will become as trivial as the cassette tape.



Eli Woods is seen here shining a laser onto a compact disc. By observing the lasers reflection on a board he can determine if the CD was burned or made in a factory.

LEVITATING OBJECTS WITH SOUND

BY GAVIN MCCOURT AND JASON MOW

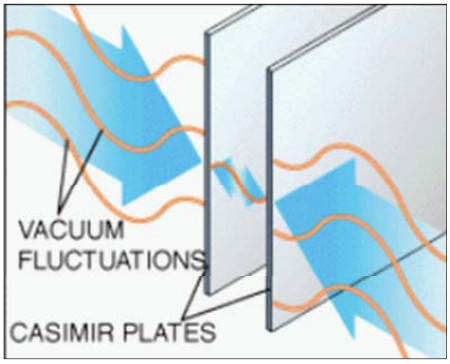
Invented in the 1940s, acoustic levitation is the means for suspending matter in a fluid, whether it is a heavy gas or liquid, by using the acoustic radiation pressure from intense sound waves to balance the force of gravity. When sound waves are intense enough they become nonlinear and in this state are powerful enough to counteract gravity. The effect of levitating something with sound is possible because of three basic properties of sound waves: they are longitudinal, adhere to the law of reflection, and the interaction between their rarefactions and compressions causes interference.

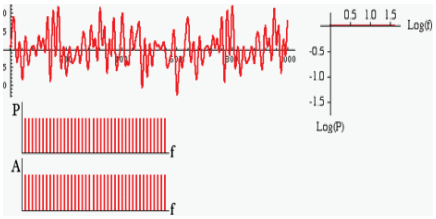
Other than the awe-inspiring effect, there are certain practical applications of acoustic levitation like container-less processing, which has become important in modern times as a result of the small size of microchips. Materials that are corrosive or otherwise react with containers during chemical analysis can be suspended in an acoustic field in order to prevent contamination. Another application is NASA using acoustic levitation to simulate anti-gravity.

The simplest acoustic levitator has two parts: a transducer, which is a vibrating surface that makes sound, and a reflector. These two are often shaped concavely to focus the sound waves. This is the model that we will attempt to construct. On Earth, the high-pressure areas just below the nodes must be large enough to support the floating object. One interesting question about acoustic levitation is the effect that putting a live animal into the field would have. Scientists have suspended ants, beetles, spiders, ladybugs, bees, tadpoles, and fish. Below is a picture of a fish and spider being levitated:

Our experimentation has consisted of various setups utilizing lower powered speakers. Using low mass Styrofoam balls, we hope to produce a similar effect. By placing the apparatus horizontally rather than vertically, we find that there is a significant response to certain resonant frequencies. In addition, we hope to be able to create a visual representation of the standing wave purely from the vibrations caused by the speaker to suspend the lightweight masses in the tube. Because the speaker being used currently is not of a significant, nonlinear amplitude (150 db +), vertical acoustic levitation does not seem plausible, but we are still testing different environments in which it may be possible to achieve acoustic levitation. The results of our research will hopefully result in a more cost-effective way to create a small scale acoustic levitator which could pave the way for more widespread development of applications for this promising technology.

Jason mow demonstrates acoustic levitation in the research classroom.





Leland Cox (right) preparing the aluminum Casimir Plates and acoustic chamber.

THE CASIMIR EFFECT & ACOUSTIC ANALOGUES

BY LELAND COX

Purpose:

To analyze the source of the Casimir effect in terms of quantum fluctuations by establishing an analogue for the force using high frequency oscillations in air pressure.

Background:

Discovered in 1948 by Dutch physicist Hendrik B. G. Casimir, the Casimir Effect is a force caused by perturbations of Zero Point fluctuations of the electromagnetic field between conducting surfaces.

Method:

In order to recreate a field of air pressure fluctuations, two high frequency transducers are installed in a plexi-glass box (6″x16″x16″ internal volume). Inside the box is a plate of area "A" suspended by a spring. This plate is held directly above a parallel surface, the distance between which is "d." These parallel plates acta as a bounding region, defining the maximum wavelength that can resonate between the plates.

These two regions perturb the field of high frequency sound by creating areas of resonance and recreating a pressure force on the outside of the plates. The 322″ area between the plates selects out only higher frequency sounds allowing all generated frequencies to exist outside of the plates while limiting the frequencies inside. This functions as an analog of the zero point fluctuations of the electromagnetic. By only selecting out certain frequencies it lowers the effective pressure energy of the cavity cause the larger pressure of the space in the box to force the plates together.

I will test several wave functions to examine the nature of the electromagnetic fluctuations that exist in vacuum. I will test sine waves, saw waves, triangle waves, white noise, pink noise and Brownian noise.

The noise type that most closely resembles the fluctuations in the electromagnetic field should echo the formula:

$$F(r)/A = \frac{\pi^2}{240}\frac{\hbar c}{r^4} = 0.013\frac{1}{r^4}\,\mathrm{dyn}(\mu\mathrm{m})^4/\mathrm{cm}^2.$$

The constants must be substituted for constants that are relevant to waves traveling through air i.e. the speed of sound.

The unique sound fields will be created by running a six channel sound processor at a series of frequencies and noise types. This will allow for more intricate and complicated interference patterns to be tested, and for each frequency to be adjusted easily.

The force between the plates will be attained by measuring the degree with which the spring expands following Hook's law. (F = kx where is a known constant and x is the spring displacement.)

There have been some recent problems in replicating sounds accurately at high frequencies. It appears that there is a certain amount of interference that takes place when the speakers are driven to the necessary volume. I hope to resolve this problem by changing signal generators and possibly replacing the currently used transducers with more robust tweeters.

CREATING A STUDY-AID BE

THREE STUDENTS DEVELOPED AN ENERGY DRINK TO HELP STUDY. THE STUDY AID BEVERAGE PROMOTES FOCUS, ALERTNESS AND MEMORY.

BY ANDREW LEE, MICHAEL LEE AND JASON MOW

Michael Lee, Andrew Lee, and Jason Mow have designed a product called Brainade, a powdered formula that can be added to any refreshing drink and serve as an agent that promotes enhanced concentration. This formula blends well with virtually any drink, from fruit juices to soft drinks to simple drinking water, and its subtle hint of agave nectar will enhance the taste of any beverage. Aside from its taste, Brainade vastly improves alertness and concentration skills, and unlike other competing energy drinks, it has no unhealthy or irregular side effects. This is because it is created only with natural ingredients and includes no synthetic vitamins or extracted amino acids that might damage the body and mind.

The inspiration for Brainade was rooted in personal experience, or more specifically, it derived from a late night group study session that all of us participated in. We had studied to the point of exhaustion, and although we considered consuming some kind of energy drink to promote concentration, we were suspicious of their synthetic ingredients and possible detrimental side effects. We were curious why no natural energy drinks were available on the market, and we considered the possibility of creating one ourselves. Our next step was to begin researching online the best natural products that enhanced techniques of attention and alertness.

A specific analysis of Brainade's formula reveals how each ingredient meets the objective of taste and enhanced concentration. The central ingredient is organic agave nectar, chosen because it acts as a sweetener without producing a spike or crash in the human body. Because we were motivated to include natural ingredients that avoided energy or mood swings, our recipe excluded sugar and caffeine. Another important ingredient is rhodiola root powder, a natural herb that enhances energy production. Rhodiola has been used in traditional medicine for centuries and is one of the best herbs for enhancing mitochondrial energy production. Serious consideration was given to our formula's agents of concentration and focus, and we finally selected ginkgo and ginseng as our final products to include in our mixture. When choosing to add ginkgo, we studied the effectiveness this leaf had at memory and concentration enhancement and concluded it would be essential to add in our product. Similarly, ginseng is a traditional ingredient used regularly for many other medicinal purposes for its promotion as an adaptogen, a product that increases the body's resistance to stress. Our unique approach is to blend these ingredients at a level that will maximize their potential to boost alertness.

Having secured our initial compound, we began testing our product on subjects to measure product satisfaction. Twenty Harvard-Westlake students agreed to sample our product and provide feedback on the drink's taste and effectiveness as a concentration agent. The first ten students were given the formula and asked to complete a ten minute IQ test. The next group was given a placebo and asked to perform the same task.

"WE WERE CURIOUS WHY NO NATURAL ENERGY DRINKS WERE AVAILABLE ON THE MARKET, AND WE CONSIDERED THE POSSIBILITY OF MAKING ONE OURSELVES."

EVERAGE

After the first round of testing, our drink, unfortunately, seemed to have no significant results on the average IQ score between the groups. We decided to stop further testing and go back to our formula.

We began to question our method of testing, for after talking to statistics teachers, we concluded the IQ tests were inherently flawed. Since our drink is promoting alertness and concentration, an IQ test seemed irrelevant in testing the effectiveness of our drink. Mr. Thill, a statistician at our school, gave us alternative way of testing, which involved a memory test among the volunteers. Rather than randomly assigning people to each group, we decided that a matched pairs design would be the most efficient way to see significant results. Each student was to perform the memory test before they consumed the drink and then once more after, and we would then take the difference among their scores and compare the results. We are hoping that this method of testing would be more sufficient in making our claim and closer to our ultimate goal.

We are in the final stages of our project, and we maintain a positive outlook as to the advantages of our drink in terms of taste and as a means of increased concentration. By the end of the month, we hope to conduct our third round of testing for this incredible project.

Mike Lee and Andrew Lee create a mixture of Brainade to test on students (top). A collection of energy drinks on the market is shown (bottom left). The ingredients for the energy drink sit on a lab table (bottom right).

MAKING BIODIESEL OUT OF VEGETABLE WASTE OIL

BY ALEX STEINER

Background:

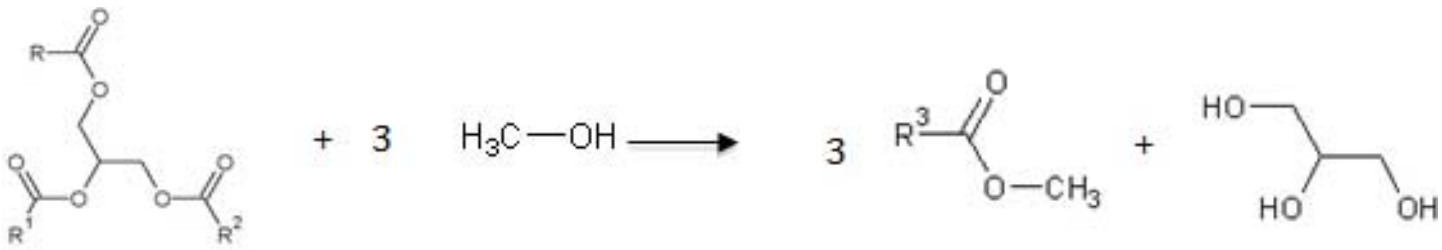
Biodiesel refers to fuels made from the transesterification of vegetable oils or other natural oils so that these oils can be burned in a diesel engine. In the transesterification process, an ester, a type of organic molecule, is converted to another ester by reacting with an alcohol. In the case of making biodiesel, triglycerides, which make up vegetable and animal oils, are reacted with methanol in the presence of a hydroxide catalyst to produce methyl esters.

Biodiesel results in significant reductions in net carbon dioxide emissions because its carbon dioxide emissions are offset by the carbon dioxide consumed by the plants used to make it. It also offers little to no nitrous oxide and sulfur oxide emissions, major causes of smog and acid rain, compared to petroleum diesel. The major drawback for biodiesel is that most of its source crops are food crops so increasing the production of biodiesel decreases the food supply. However, biodiesel can also be made from waste vegetable oil (WVO), oil that has been used to cook other food such as French fries or popcorn, reducing emissions without reducing our food supply. Enough waste vegetable oil is made in the US each year to power at least 1% of our vehicles, and far more could be supplied from other potential non-food crop biodiesel sources such as algae.

> "BIODIESEL RESULTS IN SIGNICANT REDUCTIONS IN NET CARBON DIOXIDE EMISSIONS."

Project Overview:

In the project I'm exploring the feasibility of using waste vegetable oil (WVO), or grease, as an alternative energy source for biodiesel and potentially heating oil. The first phase of the project will be making biodiesel from WVO and using those results to create my own recipe for biodiesel from



WVO. The second experimental phase will be using the glycerol waste product to attempt to synthesize the glycerin acetates, which some researchers claim improve the cold flow performance of biodiesel when used as an additive, specifically lowering the cloudpoint, the temperature at which a fuel begins to gel or solidify.

then waiting for the biodiesel and water phases to separate.

I also tested for the cloud point of the biodiesel, the temperature where the fuel becomes cloudy and below which fuel performance is reduced. Four rounds of cloudpoint testing on batch three showed its cloudpoint to be approximately 5-7˚C.

With that in mind, I began exploring ways to reduce the cloudpoint. Since a solute depresses the freezing point of a liquid, I tried adding table salt to my biodiesel to see if the same held true for the cloudpoint. After a couple of trials, I observed that the cloudpoint of the biodiesel with salt added was about 2-3˚C lower than the cloudpoint of the biodiesel with nothing added. However, adding table salt to a fuel would be impractical for combustion in an engine so looked at making an organic additive, one of which being glycerin acetates.

After refining my biodiesel recipe and producing a sufficient quantity of glycerol waste, I began experimenting with trying to conduct a Fischer esterification of the glycerol by-product with acetic acid to produce glycerin acetates. I have added the byproduct of this reaction to my biodiesel sample and tested the cloudpoint. The first sample actually raised the cloudpoint of the biodiesel, but I noticed a precipitate formed in the biodiesel that did not form with the two subsequent reflux products which I attribute to the sample I added containing some unreacted acetic acid that formed acetate precipitates. The cloudpoint was unchanged with the third sample. I observed that the second sample I got from refluxing lowered the cloudpoint by 2-3˚C compared with my pure biodiesel. This data was clearly inconclusive, and what was problematic was I did not know if I had indeed made glycerin acetates.

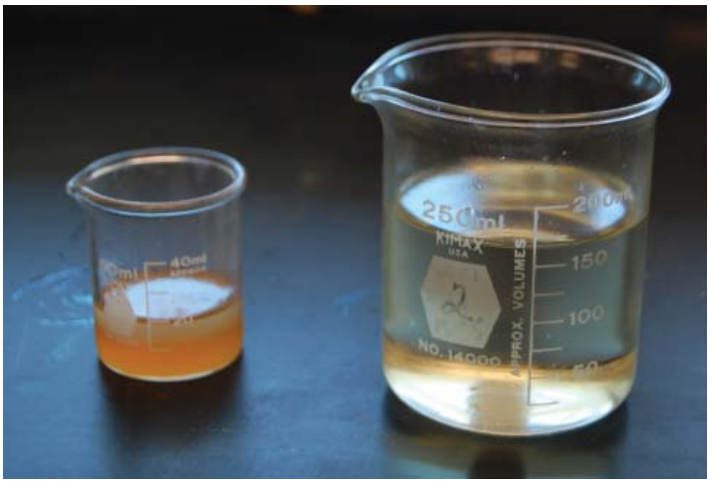
Since it was unclear whether I had synthesized glycerin acetates, I purchased a sample of triacetin, one of the glycerin acetates I was attempting to make, to see if it would reduce the cloudpoint. For a biodiesel mixture with 1% triacetin, the cloudpoint seemed relatively unchanged. The same result occurred with a 2% triacetin mix, so I suspended testing as triacetin did not appear to be a cost effective additive for biodiesel.

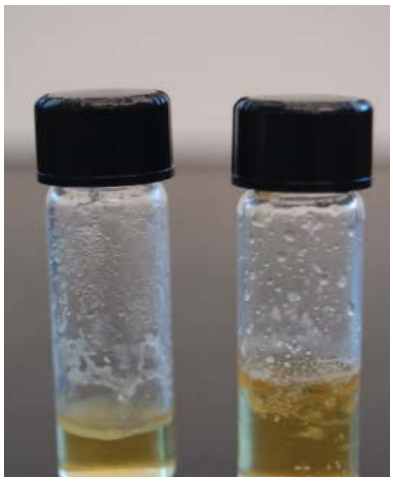
Steiner searches for a way to improve coldflow properties of biodiesel.

Results:

In my first couple of batches, I made biodiesel from bacon grease, but found that the resulting biodiesel was far too viscous to be of practical use in an engine. With used peanut oil, I made six quality biodiesel samples, gradually increasing them in size from a 5mL batch to a 300mL batch.

The recipe I used for making biodiesel consisted of first heating the WVO for about five minutes to boil off water vapor trapped in the oil. I then added three parts methanol for every 20 parts WVO and 1 part 3.5 M KOH per 4 parts methanol. After mixing, I stirred the reaction for 20 minutes and then let it sit overnight for the biodiesel and glycerol to separate. I then washed the sample twice by adding water and stirring,





Glycerin, Biodiesel and waste vegetable oil (left). Sample from attempted synthesis of triacetin (right).

POTATO CANNONS AND EXPLOSIONS

Kayvon Raphael tests his potato cannon on a target.

BY KAYVON RAPHAEL

I have been working on building and testing a "potato cannon" in SSR this semester. A potato cannon (or spud gun) is a pipe-based cannon which uses air pressure, or combustion of a gaseous fuel, or both, to launch large projectiles. I have built a combustion-powered cannon that can use any aerosol or combustible gas as the propellant. Combustion powered spud guns typically have the least complex designs, the four basic elements of which are:

A fuel system
A combustion chamber
An ignition source
A barrel

To operate, you first load a potato into the barrel and push it down the barrel to create an airtight seal. The next step is to add fuel to the combustion chamber (I have been using Axe body spray and a generic hair spray, both excellent combustible aerosols) and screw the end-cap on to seal the chamber. Then simply aim and hit the BBQ sparker. The fuel then ignites, creating hot expanding gases, and forces the projectile out of the barrel. Distances vary greatly depending on many factors, including the type of fuel used, the efficiency of the fuel/air ratio, and the combustion chamber/barrel ratio. In my tests so far I have been able to achieve ranges of ~220 yards and hope to be able to increase that with different propellants (propane or oxygen for example). I am also going to measure the muzzle velocity of the cannon by suspending it in a pendulum-like manner and recording test firings. Using the height the barrel recoils, I will be able to calculate the muzzle velocity.

USING THE SUN TO COOK FOOD

BY MATT BAGNARD AND COREY VANN

Matt Bagnard and Corey Vann put together their solar oven.

Given the opportunity to create something, we knew we wanted to create a solar oven. We wanted to create an opportunity for people to not have to buy microwaves or ovens to get warm, tasty food. We wanted to make a portable oven so people can create good food on outdoors trips where microwaves or ovens aren't accessible. Overall, we want the solar oven to make the world a better place through environmental and economic means.

In order to create a solar oven, a lot of different things are needed to get an effective and productive working apparatus. First, an efficient way of harnessing the heat from the suns energy is need for an oven to work. Secondly, a well insulated oven chamber is needed to harness that energy from the sun and create an environmentally sound solar oven. We decided to start from the bottom and work our way up in our journey to create the perfect solar oven. After purchasing some wood, we cut it into even pieces to create the wooden frame of the solar oven chamber that looks like something below:

Once the frame was built we basically had ourselves a wooden box and nothing more. To make sure the heat stays in there during cooking we needed to line the edges of the box with some sort of sealant to prevent the heat from leaking. So we used some foam and rubber strips to line the edges of the frame thus creating a sealed chamber. Next, we took some fiber glass insulin and started filling the chamber with it. This will create and even better and more effective hot oven chamber.

Our next step for this project is to create an effective way to mount the mirrors on box. The mirrors need to be adjustable to be able to take in the suns energy at different point in the day at different angles.

Our goal going into this project was to create something that would be beneficial to the environment and at the same time be very useful. This project has allowed us to feel like we are building something for a greater good than for just a science class.

USING ROCKETS TO COLLECT AIR SAMPLES

BY RYAN ASHLEY

My project is to construct a small model rocket out of materials bought from hobby shops that can safely house an air trapping apparatus able to bring high altitude air down to ground level uncompromised. These projects usually utilize weather balloons, and air is tested for humidity, pressure, and temperature. Instead of doing testing at those high altitudes, as weather balloons do, my plan will be to trap the air with the rocket at high altitude, then bring the air back to ground level, without changing the composition of the air transported back. These meteorological projects are very ambitious in nature, and most student projects I found failed in their goal to keep high altitude air in a container without contaminating the sample, thus nullifying any data taken from the experiment. The rocket that I will be using is a basic kit rocket that uses E-grade Estes rocket engines that can propel a rocket to altitudes upwards of 2000 feet. The rocket is approximately 1.5 feet long and 1.5 inches wide, meaning that any air trapping apparatus will have to be housed in a very thin, small area. This apparatus is planned to be a "trap door" style container, which will close trapping air inside it when the ejection charge from the rocket engine ignites. This apparatus however will have to be made out of lightweight materials, which would usually not be fire resistant enough to be housed inside a rocket, especially one that will be operated utilizing a combustion charge. I plan to launch this rocket out of the Simi Valley area, as Ventura County has easier regulations on launching projectiles.

VORTEX TUBE

BY CARL LAWSON

Intro:

The Vortex tube was first invented by Georges Ranque in 1933, but went relatively unnoticed until Hilsch published the results of his study in 1946. The Ranque-Hilsch Vortex tube is a device with no moving parts that causes an input of compressed air to split into a stream of hot and cold air. The shape of the tube causes the input stream to spin at nearly one million RPM as it flows along the tube. The air on the outside of this spinning column has a much greater velocity and becomes much hotter. The opposite effect occurs for the slower moving air in the middle of the column, which becomes very cold. The Ranque-Hilsch Vortex tube is fascinating because it requires no additional energy to produce its heating and cooling effects; it simply redistributes the energy already present in the compressed air. The energy free nature of the device leads to many beneficial applications.

Experiments:

Before I could explore potential applications of the vortex tube, I had to understand the relationship between input pressure and the temperature change created. To do this I connected a pressure regulator to the air compressor that allowed me to control the input pressure. Using a digital thermometer, I measured the temperature at each end of the tube for input pressures increasing in small increments. These data points yielded three graphs, which show a linear relationship between input pressure and temperature difference.

I was also able to record maximum temperature differences for my vortex tube and air compressor set up. The maximum temperature change at the cold end was -32.6°C, and 18.5°C at the hot end.

Demonstrations:

The Ranque-Hilsch vortex tube can easily be used to demonstrate the First Law of Thermodynamics: energy conservation. Since the vortex tube only redistributes the energy already present in the input stream, the sum of the energy of the air at both ends will equal the energy of the input stream of air.

Applications:

The Ranque-Hilsch vortex tube has several practical applications. It is used in industrial factories for low cost air conditioning. Vortex tubes are also being used with gasoline powered air compressors to make ice in 3rd world countries where electricity is not available to power refrigerators. Vortex tubes can also be cascaded together to achieve cryogenic temperatures at a fairly low cost. I would like to explore the possibility of using a Ranque-Hilsch vortex tube to combat the problem of overheating that limits the effectiveness of turbochargers in cars. A turbocharger compresses air and forces it into the engine. The greater amount of oxygen present in the engine creates a more complete combustion of gasoline and greater fuel efficiency. However, the air becomes very hot when it is compressed and can cause the engine to "knock", a phenomenon that occurs when the heat and pressure in the engine cause gasoline to combust before the spark plug detonates. Knocking throws off the timing of the engine, and limits its power. Turbochargers must be set to compress air well short of their capabilities in order to avoid this problem. I would like to use a vortex tube to cool the air from a turbocharger before it enters the engine. Cooling the air before it enters the engine would allow turbochargers to compress the air much more before it would reach the temperature where the engine would knock.

Experimental setup showing the air compressor, digital thermometer, digital pressure regulator, and the vortex tube.

Charlie Grosslight tries to freeze water by boiling it first using powerful vacuums.

FREEZING BY BOILING

BY CHARLIE GROSSLIGHT

Grosslight investigates a new way to freeze water, by boiling it first.

In order to understand "Freezing a water wave by boiling" one must be familiar with two concepts. One refers to the process of freezing water via energy loss from induced boiling. A liquid in a vacuum will boil when the atmospheric pressure is reduced, causing some water molecules to become water vapor as they steal energy from the remaining water. The second concept is much easier to comprehend, that water will freeze when it reaches 0 degrees Celsius. As the induced boiling continues, the more energy will be taken from the liquid water, reducing its temperature. As this process is prolonged, the lower the temperature of the water will become until it reaches its freezing point. These are the concepts behind freezing by boiling.

During this process however, it was discovered that the freezing of the water could be hastened by introducing a sudden jolt of kinetic energy to the system. This created a transverse wave in the water that would soon after cause the water to freeze, freezing the wave itself.

As the atmospheric pressure is decreased, water phase changes from a liquid state to a gaseous state, taking energy from molecules that remain in a liquid state. So, the longer the boiling is maintained, the more heat is lost. Eventually, the temperature of the liquid drops enough that it freezes. After measuring the time it takes for the water to freeze, kinetic jolts of energy are then introduced and differing time intervals during the boiling process to find the earliest moment in which the water will freeze.

A beaker with a measured volume of water is placed in a chamber connected to a vacuum pump. In order to measure the volume of water, water is poured from a graduated cylinder with 10 mL of water. A small stone (made of aluminum) is placed in the water to disrupt its symmetry and allow the water to boil and then freeze more readily. The vacuum pump is turned on, the time for the water to begin freezing is recorded and this process is repeated several times until an average final time with sufficient accuracy is found. Then once every trial a jolt of kinetic energy is sent through the system at different time intervals for each trial, starting with 30 seconds before the final freezing time. If the jolt does not freeze the water, the experiment is void because the energy created by the jolt is transferred to the water, slightly increasing its temperature (this is the reason that the system cannot be placed on an oscillation table because the water will not freeze for a vastly large amount of time).

After doing many trials, it seems that there are many unknown factors that can influence the freezing time that were not taken into account, making it difficult to pinpoint the optimum point in time to make the kinetic energy jolt. However, it wasn't unsuccessful in determining the effectiveness of the jolt. Freezing time was shortened up to 3 minutes earlier than normal for 10 mL and 1 minute for 5 mL. In the figures, the frozen water wave can be seen as the result of the kinetic jolt freezing the system.

MAKING A GREENER CLEAN

BY RICHARD LIU AND ALEX STEINER

With our planet's fate resting in the hands of our conservation efforts, everything – regardless of its size or relative importance – must be done to restore and replenish the environment. Even small matters, such as cleaning agents, disinfectants, and household cleaners that surprisingly contribute to serious worldwide pollution are of upmost importance. In the industry of household cleaners, Hypochlorous acid – a well-known but little used chemical – demonstrates tremendous potential in the future of cleaning. It not only serves as a powerful, clean and natural alternative to many of today's harmful cleaners, but is also significantly cheaper and easier to maintain than bleach, detergent, Butyl cellosolve, and other common cleaning agents.

Hypochlorous acid (HOCl), with a pH of 2.5, closely resembles bleach (generally in the form of NaOCl) in both cleaning power and antibacterial strength. With a concentration of about 30-40 ppm, HOCl is mild enough to drink yet concentrated enough to disinfect. Recently, twenty-five clinical studies have shown HOCl as an agent of inhibiting DNA replication both safely and effectively. When bacteria are exposed to HOCl, there is precipitous decline in DNA synthesis as the acid inactivates the victim bacteria and causes them to lose their viability. It quickly eradicates a broad range of pathogens, including antibiotic-resistant bacteria (MRSA and VRE), viruses, fungi, and spores, as well as accelerating wound healing processes by reducing inflammation and increasing nutrient-rich blood and oxygen flow to the wound area. Such properties make HOCl an excellent multi-purpose household cleaner and disinfectant for numerous materials.

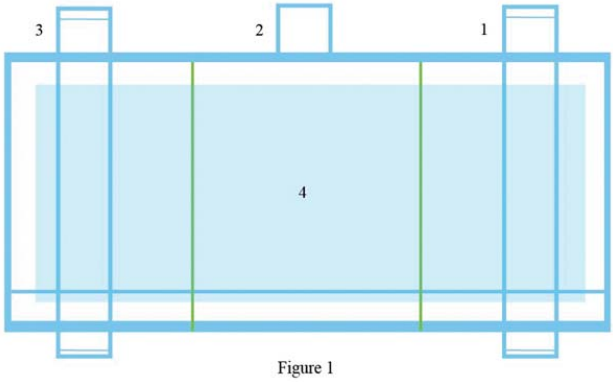


Figure 1

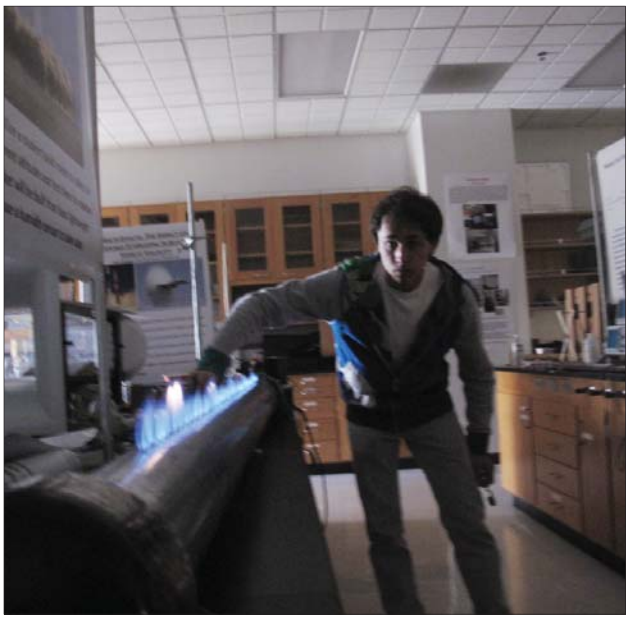
Sodium Hydroxide, on the other hand, is used for a wide variety of different applications, including: paint stripping, Alumina production, use in chemical analysis, soap production, paper manufacturing, Aluminum etching, food preparation, animal tissue digestion and more. It is frequently used in the home as a drain cleaning agent due to its degreasing properties. NaOH decomposes complex molecules, and has been known to absorb and convert carbon dioxide to lower atmospheric pollution.

Traditionally, there have been many methods to producing HOCl, but one of the most effective relies on the electrolysis of NaCl solution. In such a system, there are several reactions taking place:

$2\ H_2O\ (l) + 2\ e^- \rightarrow H_2\ (g) + 2\ OH^-$
$2\ NaCl\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2(g) + Cl_2\ (g)$
$2\ Cl^-\ (aq) \rightarrow Cl_2\ (g) + 2\ e^-$
$Cl_2\ (g) + H_2O\ (l) \rightarrow HOCl\ (aq) + HCl\ (aq)$

Direct current is first passed through a salt mixture to separate the components of NaCl into Na^+ and Cl ions at a pH of 7 to produce chlorine gas. Next, electrolyzed water reacts with the sodium cations to produce sodium hydroxide, while chlorine anions react with water to produce Hypochlorous Acid (4). A permeable membrane is used to separate charge, as the two different products of the reactions are produced at two different sides of the reaction system. In this experiment, a fiberglass casing was divided into three components: one for recyclable tap water (2), one for producing NaOH (3), and one for producing HOCl (1). Soon after starting electrolysis, both products are produced on the opposite sides and allowed to flow into graduated beakers.

Interestingly, it was discovered in several experiments that Cobalt compounds can dramatically reduce the activation energy for the electrolysis reactions, thus revealing realistic possibilities for using solar power to supply the reaction system. Solar panels connected to a catalyzed system provide plentiful and steady energy for the reaction to constantly take place (given an infinite supply of sodium chloride and cobalt catalyst). Because tap water is recycled in the system, only minimal amounts are necessary to refill the machine each hour. The produced HOCl and NaOH can be directly bottled and used from the system for up to four hours before Hypochlorous acid decomposes due to its relatively short half-life. Ultimately, this experiment opens up new doors for making a greener clean, from a simple hundred dollar device built in this project to handheld HOCl producing machines towards a cleaner, more beautiful tomorrow.



THE RUBEN'S TUBE

BY ERIC ARZOIAN

The Ruben's Tube, or flame tube, is a physics experiment that is used to visualize sound waves and show the relationship between sound waves and air pressure. To build the tube, I purchased a long steel tube. Then, I drilled holes along the tube leaving a small space between each hole. From one side of the tube, a gas source is attached and from the other, a speaker is attached to a rubber membrane. When a frequency is played, sound waves form in the tube and create high and low pressure points at certain points in the tube. At low pressure points, more gas is allowed to escape, creating a peak. At high pressure points, and where gas cannot escape, the flame is not as high and a crest forms. I was also able to measure wavelengths of standing waves produced by certain frequencies. As the frequency changes, the nodes and anti-nodes of the sound wave move along the tube, and form different flame representations of the wave produced. As I played around with the tube, I saw that with higher frequencies, more standing waves are produced, and vice versa.

alternative energy

science

inventions

technology

team work

innovation

think tank

»scientific research

research papers

collaboration

playground

presentations

discussions

programming

computers

patents