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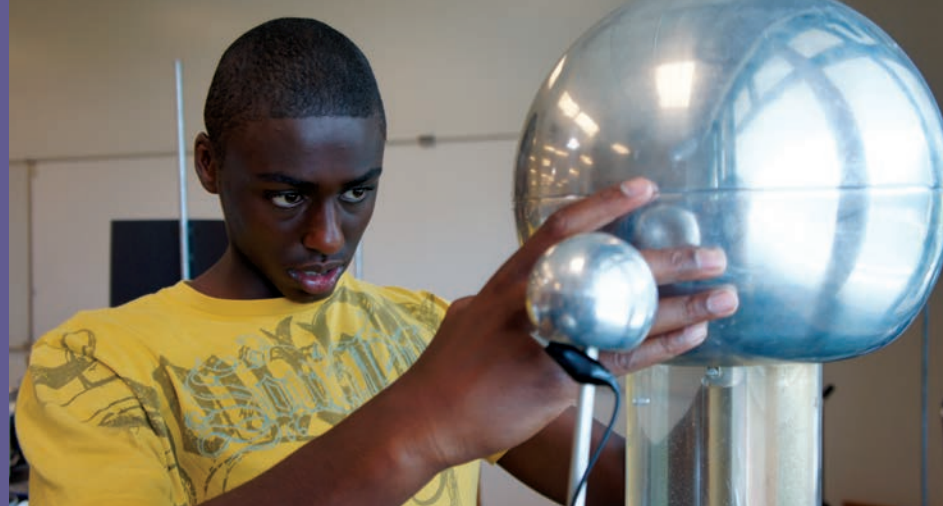
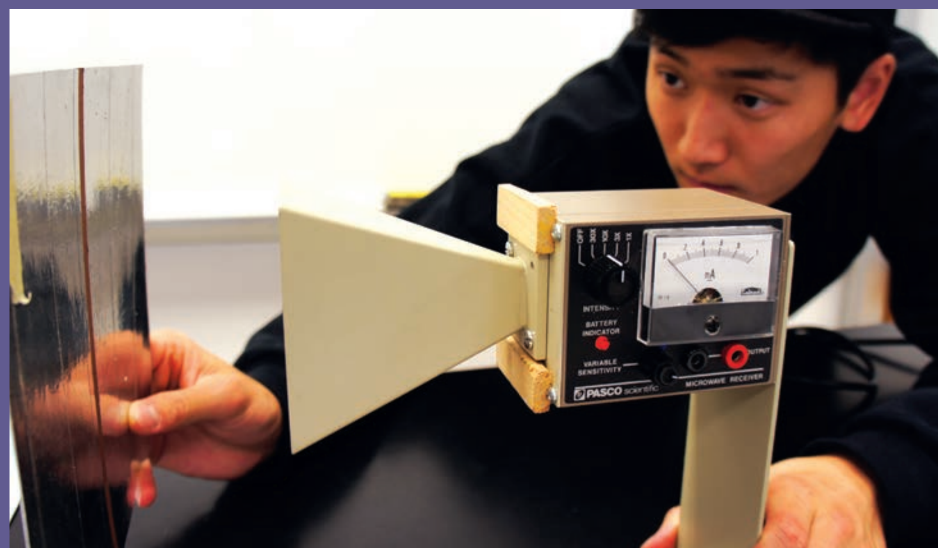
A STUDY OF UNDERWATER HERMAPHRODITISM

TRANSMISSION OF ELECTRICITY THROUGH THE HUMAN BODY

USING A KELVIN WATER DROPPER AS A GENERATOR

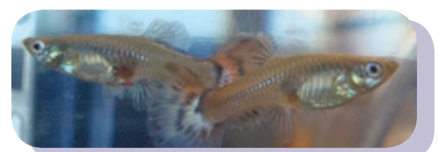
Harvard Westlake Journal of Science 2011

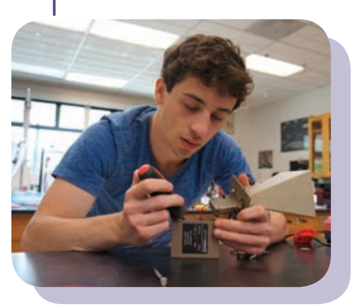




» studies in scientific research

The Papers





Letter from the Editors

The students of Studies in Scientific Research form a diverse microcosm of Harvard-Westlake's student body. Athletes and musicians, physicists and biologists, iPhone users and Android users, and most other dynamic oppositions are represented in full force. Yet despite the varied interests of this disparate bunch, one uniting trait characterizes the entire group: a passion for scientific inquiry, for exploration, and for challenging preconceptions.

SSR is as much a class for investigation of current topics in science as it is an introduction to self-motivated engineering projects. Few other classes at Harvard-Westlake are as student-driven: projects are planned, executed, and analyzed all according to each student's respective designs, and it is personal motivation instead of grades or tests that is the life-blood of the course. Unsurprisingly, such a class attracts people who thrive on debate and discussion of current events in science and new theories. Such topics as the Large Hadron Collider, the soon-to-be-retired Space Shuttle, and the quantum eraser experiment were but a few sources of the conversations that filled the SSR room this year.

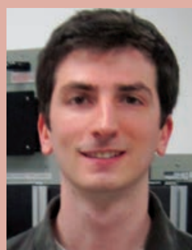
This year's Journal is filled with the products of inventive minds. Compressing a year's worth of exploration in to 28 pages can be difficult, but we hope you find the reports that follow to be lucid in explanation, entertaining in content, and most of all, enlightening in substance.

— Ben Kogan and Mary Rose Fissinger
Editors in Chief

INTERVIEW
with Michael Jura '99

After graduating from Harvard-Westlake, Michael Jura '99 completed B.S. degrees in Physics and Electrical Engineering/Computer Science at MIT and then a Ph.D. in Applied Physics at Stanford. He currently works as a Device Scientist at Bandgap Engineering, a solar cell start-up company in the Boston area.

What was your college experience like?



Michael Jura '99

I arrived at college thinking I might major in either physics or biology. In contrast to some of my college classmates from other high schools, I felt extremely well prepared by Harvard-Westlake for the pretty intense MIT science classes. I really enjoyed the classes and the friends I made. I ended up becoming really interested in the physics of nanoscale electronics. For most semiconductors that run your computer and other consumer electronics, it's ok to approximate electrons as classical particles that move around like a fluid. However, when semiconductor devices, like a transistor (basically a switch, the basic building block of modern electronics), become very small (on the order of 10's of nanometers), the quantum wave-like nature of electronics becomes crucially important to understanding how the device works. This consideration is central as electronic devices become smaller, faster and cheaper.

What was your graduate school experience like?

Grad school was a great experience for me. One splendid aspect was that I met my wife there. In contrast to the structured classwork environment of college, graduate school allows one to be much more independent; I loved focusing on research questions I found intellectually interesting while working in a very free-form, flexible environment. Dr. Nassar's class at Harvard-Westlake is exciting because it gives students a taste for the graduate school experience of conducting independent, creative research while still in high school.

My thesis work involved imaging electron transport through clean semiconductors (elaborate gallium arsenide structures) at low-temperature (0.35 K); an example is shown below. We worked with this special, well-controlled system in order to understand the basic physics—it is not fully representative of how electrons move through standard room-temperature semiconductors. In these images, electrons act as quantum-mechanical waves, and in many ways, they behave like light: they interfere causing the fringe patterns (seen at the bottom of the image), and they can be focused into narrow branches (like the 2 strong branches seen in the image).

As I got closer to finishing my Ph.D., I began thinking about how I could apply my background in semiconductor physics to something that can improve the world. The issue of climate change makes it clear that it is critical to develop clean sources of energy. Furthermore, solar power has the most potential for reinventing the world's energy infrastructure. Along with many other physicists I know, I ended up moving into solar cells.

What do you do now?

I'm now a device scientist at Bandgap Engineering, a venture-backed clean tech start-up in Massachusetts focusing on solar cells. The biggest hurdle to the widespread adoption of solar energy is its cost compared to conventional fossil fuel power. We've developed an inexpensive process to make silicon nanowires that can improve the efficiency of standard silicon solar cells. A nanowire is pretty much what it sounds like: a thin rod of silicon with a diameter in the 1-1000 nm range. Silicon is great because it's non-toxic, has a long history in the semiconductor industry, and is abundant – one can imagine making enough solar cells to power the world from silicon. One problem with silicon is that it doesn't absorb light well. You wouldn't know by looking at piece of silicon though because the light it has trouble absorbing is infrared. That's where Bandgap's silicon nanowires come in: our nanowire-enabled cells can more efficiently absorb light.

I really enjoy working in the small start-up company environment. The work culture is flexible and informal. Our over-riding goal is to improve and commercialize our technology. Most of our company works in development or engineering, and everyone on the technical team has a Ph.D. or extensive industry R&D experience. I mainly design, measure, and analyze our cells. Others in the group focus on the actual fabrication of the cells, but because the company is small, we all play many roles and help each other out—much like graduate school. Most importantly, I'm passionate about the company's mission: to develop low-cost clean energy that can displace current carbon-emitting sources. My job is a great balance between science and engineering. We're trying to build a product that will improve (save!) the world, but it still requires answering questions about a new physical structure.

*This article is based on an interview originally conducted by Mike's MIT classmate Aileen Wu and posted on their class blog (mit2003classnotes.blogspot.com). Mike can be reached at mike.jura@gmail.com.

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A Study of Underwater Hermaphroditism

Hanna Huang and Sue Won Lee

Introduction:

Sequential hermaphroditism, also known as dichogomy, is the phenomenon in which an organism has the ability to undergo sex change in order to sustain the population when necessary. The subcategories of dichogomy are protandry, where the organism is born male and changes to female, and protogyny, where the organism is born female and changes to male. Although this characteristic is most common in angiosperms (flowering plants), it is also exhibited in gastropods, crustaceans, and some fish.

Poecilia reticulata, more commonly known as the guppy, is one species of fish that has been thought to display this trait. They are born as females and may be able to change to males later in life. Normally, in a dichogomic population, there is a dominant male, a dominant female, and a group of smaller females. The dominant male and female are responsible for procreating for the entire population. In the event that the dominant male dies, the dominant female transforms into a male and replaces the deceased dominant male. One of the smaller females then takes the place of the former dominant female.

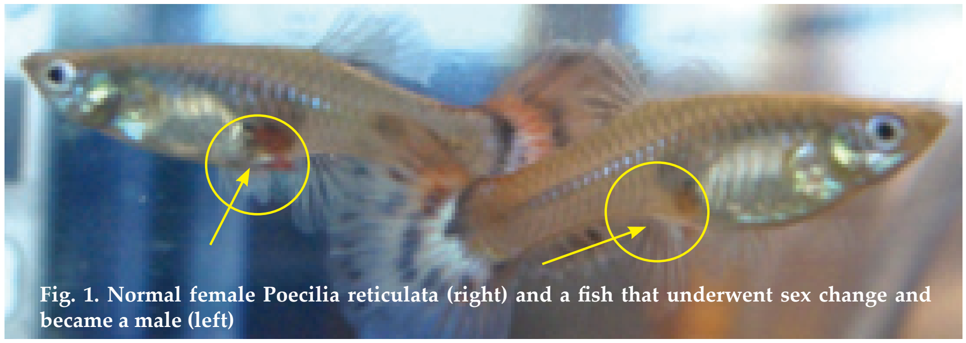


Fig. 1. Normal female Poecilia reticulata (right) and a fish that underwent sex change and became a male (left)

Experiment:

Originally, we were planning to test the rate of sex change in a species of fish that was known to display dichogomy, *Dicrossus filamentosa*. A few proposed factors that could affect the rate of sex change were the acidity of the water, the quality of light, and the temperature of the water.

Unfortunately, we were not able to acquire the species of fish in mind for this experiment, so we decided to find another species of fish and test it for dichogomy. We chose *Poecilia reticulata*, as it was more readily available. Upon further research, we found contradicting reports on whether the guppy is hermaphroditic. We set about to test this.

There is a structure on the underside of the guppy's abdomen called the gonopodium that signifies the sex of the fish: males have a gonopodium while females do not.

Results:

We had one population of female *Poecilia reticulata*, and one population of male fish. Because there was no information available on how long sex change takes, our first test was to time the rate of dichogamy. We separated the males and females, and changed the conditions based on how the fish reacted. Both tanks were filled with de-chlorinated tap water and kept at room temperature.

At first, we thought that they did not change because they were in sight of each other: although we had separated them, their tanks were side by side. We fixed this by placing sheets of paper in between the two tanks.

After no change for about a month, we installed a 50-watt light bulb above the two tanks in order to heat the water to resemble the temperature of tropical water. However, we noticed that under these conditions, the fish ate less and spent most of the day hiding under the plastic plants in the corners. Only after we turned off the light bulb and the water temperature returned to around 20º Celsius did the fish revert back to their original behavior.

After sixty-four days (about two months), baby fish were found in the tank that previously contained only females.

Conclusion:

Some of the fish had structures that resembled gonopodiums, which signaled sex change from female to male had occurred. Of the four females, three displayed this change. The sex change was confirmed upon the arrival of baby fish, since the female fish could not have mated with other female fish to produce offspring.

We confirmed that *Poecilia reticulata* is, in fact, a species of fish that displays dichogamy. Because of the lack of time, we are unable to carry out the rest of our experiment involving factors that can affect the rate of sex change.

We hope that next year, some students in this course will take over and continue the experiment.

Acknowledgments:

We would like to express our appreciation towards the teachers who generously aided us this year in this experiment: Mr. Larry Axelrod, Mr. Blaise Eitner, Ms. Krista McClain, Mr. Antonio Nassar, and Mr. Walt Werner.

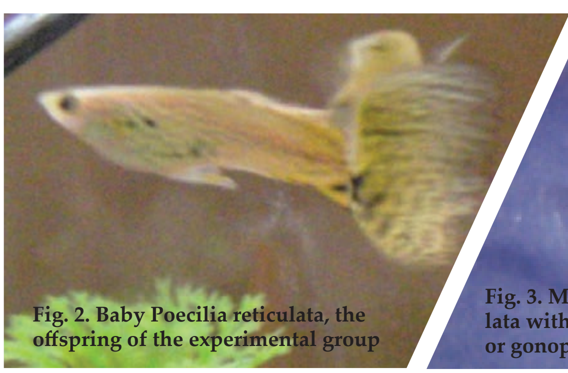


Fig. 2. Baby Poecilia reticulata, the offspring of the experimental group

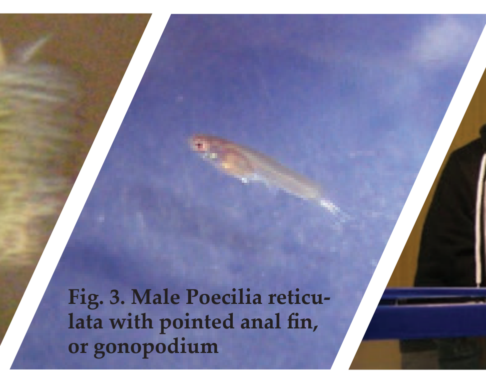


Fig. 3. Male Poecilia reticulata with pointed anal fin, or gonopodium

An Acoustic Refrigeration Experiment

Ethan Kudrow and Charlie Stigler

Conventional refrigeration, though effective, involves the use of several environment-damaging chemicals, such as Freon, a chlorofluorocarbon. Though there are alternative methods of refrigeration, they are often far too expensive for practical uses. We investigated the possibilities available with acoustic refrigeration. Because acoustic refrigeration consumes primarily electricity, it is considerably more environmentally friendly than conventional refrigerants. Our goal is to create an acoustic refrigerator that is not only cost-effective, but that is also utilitarian.

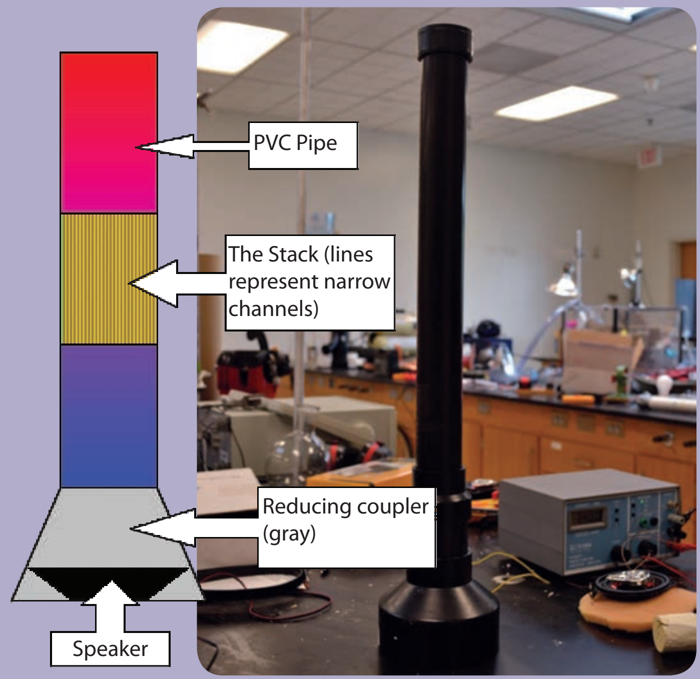
A thermoacoustic engine operates by creating either a sound or heat gradient which can result in another gradient (of either sound or heat) if positioned properly. This occurs as a result of the properties of a standing wave.

Standing waves create regions of nodes and antinodes, or areas with different pressure concentrations; nodes are areas with low-pressure concentrations and antinodes are areas with high-pressure concentrations. Because temperature is a function of pressure, high and low pressure areas can produce high and low temperature areas. The reason a noticeable temperature gradient is not created every time there is a standing wave is that there is a relatively free movement of atmospheric gas.

To create a temperature gradient, we first need to find a way to stop the back and forth movement of gas, thus creating a sound gradient. In theory, if we are able to construct a device that separates the flow of gas between the node and antinode of a standing wave, we will be able to create a temperature gradient.

We constructed our refrigerator using a (length) of PVC piping, a PVC cap, a reducing coupler, a speaker, honeycomb composite, and some foam padding. Because the diameter of the speaker (6 cm) did not match the diameter of the piping (2.5 cm), we connected the two using a reducing coupler. The diameter of the coupler at its largest was 10 cm, and at its smallest was 2 cm. we padded the inside of the coupler to prevent unwanted reflection and loss of sound energy and put the speaker inside it, connecting the other (2 cm) end to the pipe. We then cut a cylinder out of honeycomb composite and attached this to string, then slid it into the pipe. Lastly, we capped the pipe (to reflect sound). This is depicted in the diagram at on the next page.

To execute the experiment, we first determined the ideal frequency for the standing wave based on the length of the pipe.



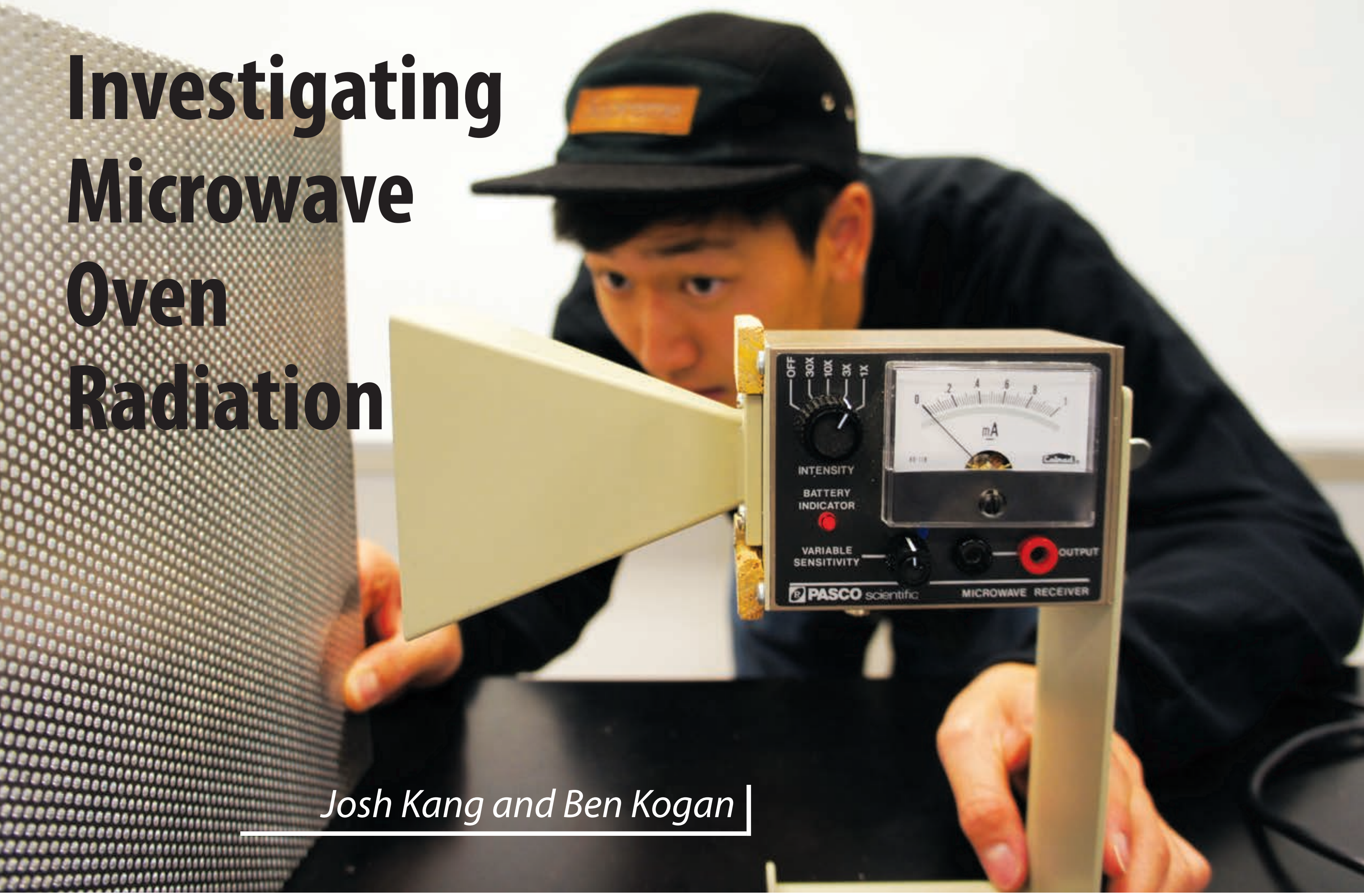
Given that wavelength is equal to the speed of sound divided by frequency, we were able to determine an ideal frequency of about 300 Hz for our pipe of length 56 cm. We then pushed the stack (the term used to describe the honeycomb cylinder) close to halfway down the pipe.

Then, with two thermometer probes inside the pipe on opposite sides of the stack, we capped the pipe and began to play the standing wave. Though we attempted to run the experiment for as long as possible, we were limited by the time constraints of a forty-five minute class period. While initial temperatures were a tenth of a degree apart, for both of our trials at full volume we recorded a temperature gradient of one degree, occasionally reaching a degree and tenth for brief periods of time (though on one occasion, due to misplacement of the stack, the temperature of the entire system increased by about a half of a degree).

The consistent performance of the prototype suggests that the concept of acoustic refrigeration is feasible, and can be practical. The relatively small change in temperature is most likely the result of our inexperience with acoustic refrigeration. A much more significant change in temperature may be possible if we perfect the model we already have, through ironing out small problems in execution. Some examples of errors to correct include the short trials (less than forty-five minutes), the strength of the speaker, the precision of the placement of the stack, and the level of insulation, all of which could contribute to making a significant temperature difference.

Measurements taken outside of the PVC pipe suggest that thermometer is not accurate. However we have noticed a temperature gradient being produced within the pipe when the speaker is not on, suggesting that the speaker is passively producing some sort of temperature gradient. It is possible that this is the result of a natural resonance occurring due to ambient kinetic energy in the air. Our immediate plans are to replace the possibly problematic leads on the thermometer and investigate the passively created temperature gradient.

Investigating Microwave Oven Radiation



Josh Kang and Ben Kogan

Abstract:

The purpose of our experiment is to evaluate the safety of microwave ovens. We set up a microwave transmitter and receiver on a track that allows us to adjust the distance between both components and measure the effect on transmission of harmful microwaves while maintaining their alignment. We then test and analyze the polarization of our microwave transmitter. Finally, we use this setup to measure the change in microwave transmission for a series of simulated microwave gratings of various hole sizes (representing the metal screens found in microwave oven doors). Using our data, we assess the efficiency and safety of conventional microwave ovens.

Introduction:

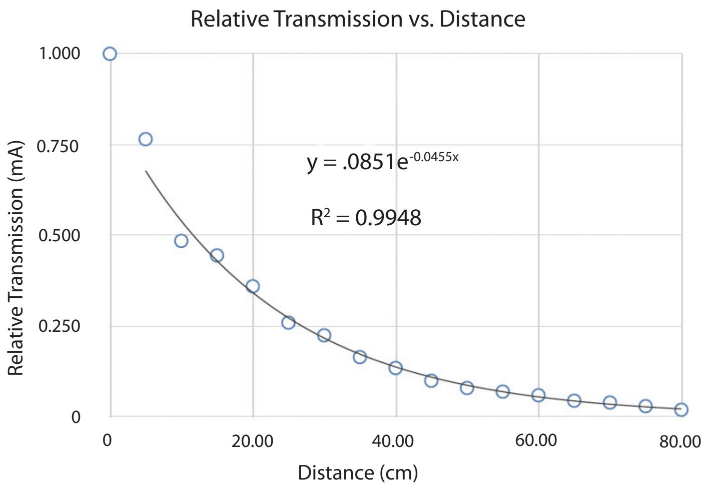
Microwave ovens are used in countless kitchens around the world for their ability to cook food quickly and evenly. While conventional ovens cook food from the outside and allow heat to gradually migrate inward, microwave ovens directly excite the atoms of fat- and water-based compounds within food. However, the 2.5 GHz waves generated by a microwave oven are hazardous to any living organism directly exposed to such radiation.

Understanding Microwaves, Microwave Ovens, & Our Equipment

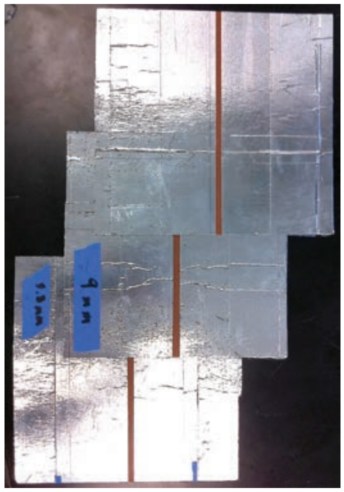
Using a magnetron—a heated cathode that interacts with a magnetic field to produce high-frequency radio-waves—a microwave oven generates the microwave radiation that cooks food. These microwaves are reflected on five sides by the metal walls of the oven and absorbed entirely by the food inside. However, the front cover of a microwave oven is a metal screen with a matrix of round holes instead of a solid metal wall. This metal grating cover allows visibility of the food cooked inside while simultaneously preventing the escape of radiation through a Faraday Cage effect that results from the small size and proximity of the holes.

In this experiment, we will use a low-power 15 mW microwave transmitter with a frequency of 10.5 GHz. Because the frequency is significantly higher than that of a microwave oven—and the power output is far lower than the 700-1000 W of a microwave oven—there is no risk of significant radiation while using our microwave transmitter/receiver set.

Using the formula $\lambda = v/f$, with the speed v = 3.0*10^8 m/s (the speed of a microwave) and the frequency f = 2.5*10^9 Hz, the wavelength of a microwave oven λ_1 is calculated to be 0.120 m. In this experiment, our transmitter of frequency f = 10.5*10^9 Hz



has a calculated wavelength $\lambda_2 \approx 0.0286$. Because $\lambda_2 < \lambda_1$, whichever grating hole height is experimentally determined to block all radiation from our transmitter will more than certainly have the same effect on a full-powered microwave oven. Thus, by proving a certain grating size to be safe within our experiment, we will have demonstrated that the cutoff size for a safe microwave oven cover has holes of at least the same—and likely even smaller—size.

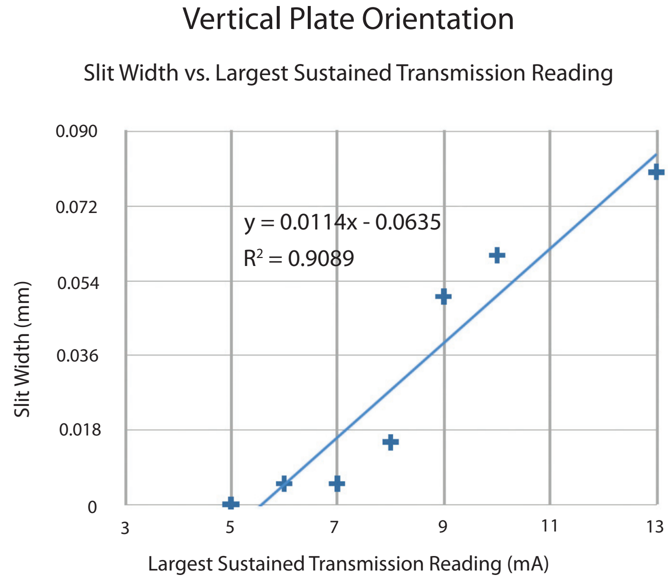


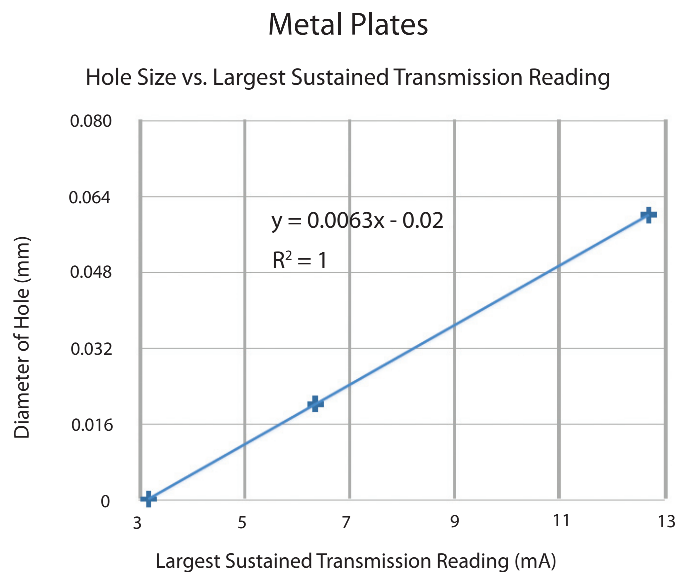
Simulated plates

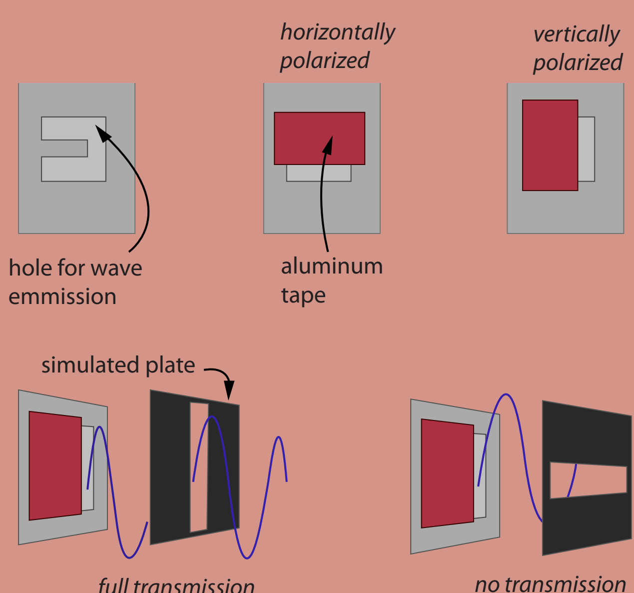
Procedure:

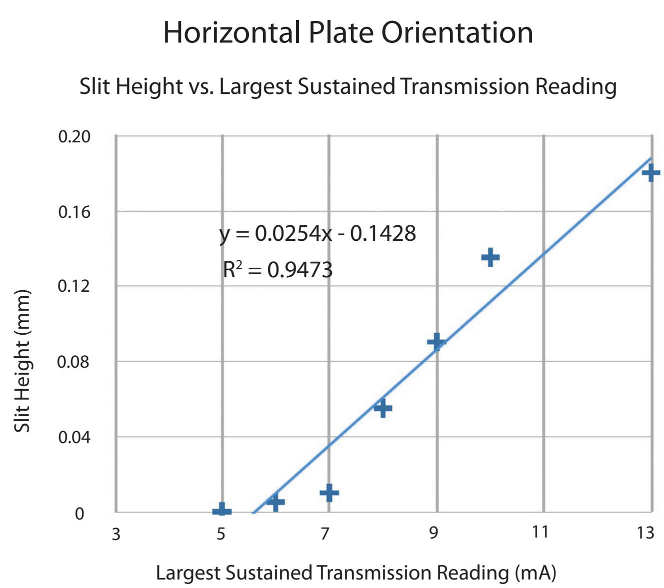
We first prepared to analyze the effect of distance on microwave transmission. To improve the accuracy of the distance trials, a track was constructed from two parallel metal rails to maintain the horizontal alignment between the receiver and the transmitter while allowing the distance between both elements to be easily adjusted. The receiver was then switched to the 30x setting, and the variable sensitivity was adjusted so that with no distance between the transmitter and receiver, the transmission value was at the exact maximum value on the mA meter. With these settings, two trials were conducted, and the relative transmission was observed and recorded at 5.00 cm increments as the receiver was moved farther away from the transmitter. We averaged the measurements for both trials and then graphed the results, as shown below:

To test the effect of hole sizes on microwave transmission, a series of 12” x 12” perforated metal sheets were purchased, as these sheets effectively mimic the construction of a microwave oven door grating. We also constructed five simulated microwave screens from aluminum tape and construction paper, as these materials allow for quick prototyping and adjustment of various hole widths without any additional financial cost. To determine which hole widths to construct, we tested which of our six metal sheets would allow microwave transmission though the perforated holes. The only metal plates that allowed microwave transmission were those with 12.7 mm and 6.35 mm diameter hole sizes, but there was no









transmission at the next smallest hole size of 3.175 mm. We then constructed three simulated plates by placing aluminum foil tape over construction paper while leaving a slit of uncovered construction paper in the middle. To simulate the holes in our metal gratings, we designed five plates with slit widths of 13 mm, 10 mm, 9 mm, 8 mm and 7 mm, respectively, to replicate the results from the two initial plates that allowed transmission. After testing these three plates, we decided to build two more with silt sizes of 6 mm and 5 mm to more precisely determine the range of slit widths in which transmission would drop to zero.

Horizonally polarized emitter

To assess the polarization pattern of our microwave transmitter, we attempted to polarize it using aluminum tape and then tested the effect using one of our simulated grating plates. Were the transmitter perfectly polarized—either horizontally or vertically—there would theoretically be very nearly full transmission with the tape aligned parallel to the direction of polarization, and close to no transmission with the tape aligned counter to the direction of polarization. Similarly, with the simulated microwave plate aligned in the same direction as polarization, there would be full transmission, whereas there would be no transmission with the plate counter to the direction of polarization. However, we found that the microwave generator exhibited nearly full transmission in the horizontal direction with the tape polarizer aligner either horizontally or vertically and the simulated plate slit aligned horizontally. However, by aligning the tape-polarizer horizontally, we were able to significantly reduce transmission of microwaves through the simulated plate when the slit was aligned vertically. Therefore, we decided to leave the tape-polarizer in the horizontal direction and align the slits on the simulated plates similarly for further tests. This way, we could test microwave transmission almost purely in the horizontal direction, as vertical wave components would be almost entirely reflected.

To maintain consistency in the experiment, we tested all the simulated plates at the 3x intensity and maximum variable sensitivity setting on the receiver, and we kept a constant distance of 7 mm between the front edges of the transmitter and receiver. At this setting we had a base reading of 0.4 mA with no obstruction between the microwave transmitter and receiver. We replicated this reading as the start point for each sheet we tested. While we were testing, however, we discovered that we could better determine the microwave stopping efficiency of each plate by setting the intensity to the 1x setting. As a result, at the beginning of each trial we set the receiver to the aforementioned start point, then adjusted the intensity stetting to 1x and tested each plate at this relative setting. For each trial, we placed either a simulated sheet or a perforated metal sheet in front of the transmitter, slowly moving the sheet back and forth in the vertical/horizontal plane (while keeping the sheet in level contact with the front of the transmitter) to find the maximum sustained transmission reading.

We recorded the largest sustained transmission reading for each of the seven simulated plates and the three original perforated metal sheets. We then collected the data into tables and graphed the slit width against the greatest sustained transmission reading, as shown in the graphs on the previous page.

Conclusion:

With the data we generated by testing relative transmission of microwaves in terms of distance trials, it is evident that transmission decreases exponentially with the increase of distance. From our polarization trials, it is obvious that our microwave generator produced waves of uneven polarization, with the strongest wave component in the horizontal direction. From the plate trials, we demonstrated that the microwaves from our transmitter were entirely reflected by any plate with a hole size ≤ 5.0 mm. Because a conventional microwave oven door has holes approximately 1.5 mm in diameter, our experiment proves that such screens entirely prevent the transmission of microwave radiation, especially from a full-powered microwave oven.

Additionally, we can conclude from our distance trial that even in the event of a damaged microwave screen, significant radiation will be almost negligible at distances beyond one meter away from the oven.

The most significant limiting factor affecting the accuracy of our results was the apparatus used. The Pasco microwave transmitter/receiver produced microwaves of uneven polarization. Similarly, it was difficult to align the apparatus without producing erratic readings due to reflection and interference of microwaves.

TALKBOX: *Sound within Different Cavities*

Maguire Parsons, Sam Horn, and Wes Peacock

Abstract:

The shape of the human mouth and throat are unique in that they can produce a wide variety of frequencies solely based on their shape. Due to the elastic nature of their composition, the sound coming out is highly variable. The talk-box takes advantage of this fact, using the workings of the human voice box to form artificial sound waves into natural sounding vocal phrasing. We will explore how different sounds can be paired with human vocal formations hopefully discovering the best sonic accompaniment to the human voice. Having built the talk-box from scratch, we will try to compliment our music with scientific experimentation, using different frequencies, organic, digital, and even analog sounds to mimic human speech.

History:

The idea of the talk box originated in 1939 when Alvino Rey and his wife decided to use a carbon throat microphone to modulate his electric steel guitar sound. They coined their new sound "Singing Guitar," but the idea was not developed any further. The most famous talk box user is Peter Frampton. He mastered the device, and produced the 1975 album Frampton and the 1976 album Frampton Comes Alive! with the Heil talk box. From the release of these albums, Frampton's name became synonymous with the talk box.

Experiment:

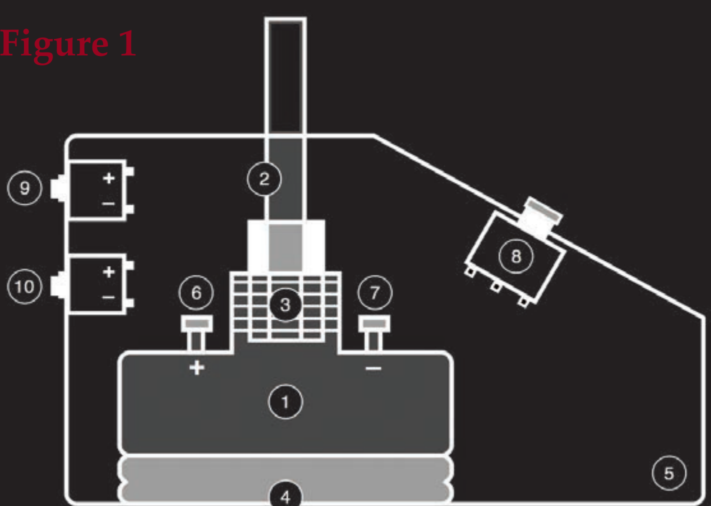
We have acquired a 60 watt compression horn driver, which is the sound-generating part of a speaker, to reproduce the signal of the instrument coming through a clear vinyl tube, which creates the "talking guitar" sound. The guitar sound comes through the tube, and then is modulated through the player's vocal cavities and the modified sound is then amplified by a microphone. The horn driver has positive and negative terminals which are connected to one ¼" input and another ¼" output jack to the instrument speaker, and in our case, a 25 watt guitar amplifier. The hardest part was to find a reducer to fit on the thread of the horn driver which connects the tube for a snug fit and no sound loss. Schematic is shown in Fig. 1 and the rig schematic is shown in Fig. 2

After making our own reducer out of PVC to create a snug fit for the tube, we began sanding it down to eliminate the loss of sound and create the tightest seal possible. With this seal, almost no sound is lost through the bottom of the PVC and there is a higher output through the tube which in turn creates a more articulate and vocal tone through the mouth cavity. See Fig 3. below for picture of compression driver with reducer and tube.

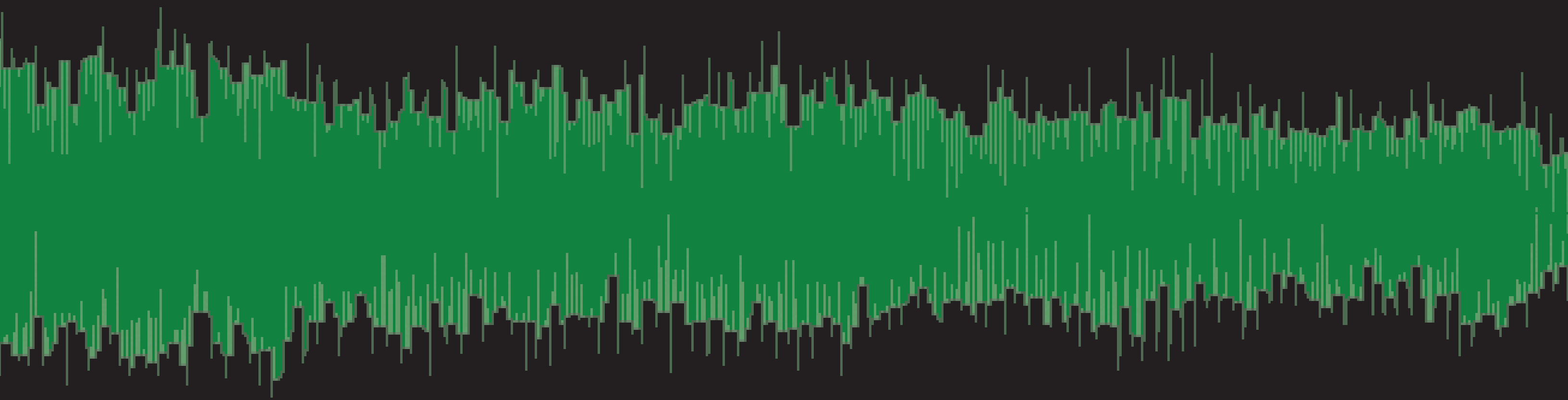
We then tested the driver with a combination of guitars and amplifiers and found a good balance with the 250k and 500k outputs of the driver paired with a 25-watt guitar amplifier. The impedance of the guitar signal to the amplifier is unmatched with the signal from amplifier to the compression driver which results in some signal loss and we hope to install a resistor inside of the enclosure to match the impedance and bring the output level up. We did most of our tests with a synthesizer which had an equal impedance match with the amplifier and driver and the best results were acquired with the same 250k/500k outputs of the driver.

The enclosure for the driver and tube is a 7"x 7" x 11" rectangular wooden box. We are going to modify the box by drilling a hole for an output jack and a hole on the top for the tube to fit through. We also are putting in a resistor for a guitar to prevent signal loss and unbalanced impedance. To prevent the rattling produced by

Figure 1



(1) Compression horn driver
(2) Clear tubing
(3) Throat of horn driver / tube holder
(4) Silicone caulk
(5) Case
(6) Positive terminal of driver (attached to (9))
(7) Negative terminal of driver (attached to (10))
(8) Footswitch (attached to (9) / (10))
(9) Instrument input jack
(10) Output (to amplifier)



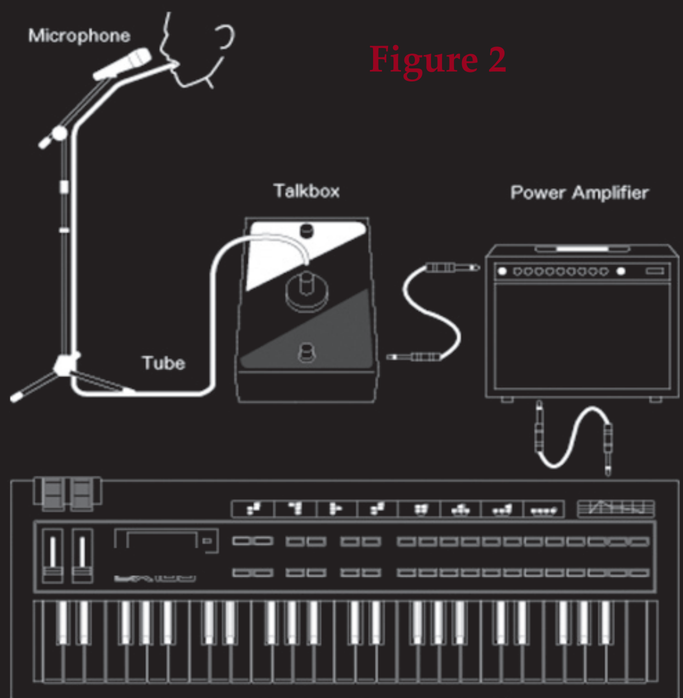


Figure 2

the driver touching the wood, we will coat the inside with a foam sealant to eliminate contact with the wood.

The talk-box has become an outdated tool for sound synthesis because of the limitations of the human voice box and advancements musicians have made in electronic synthesis over the years. We seek to find a happy medium between organic sound, synthesized sound, and the medium it is played through. We are testing how different shaped environments, such as the quasi-"voice-box" we want to duplicate, affect tonal quality and overall clarity of phrasing. It will likely not sound human or even musical at times, but different geometric shapes will certainly produce a unique sound which could be created into a new effect. We will construct these simulation chambers using a variety of different materials such as wood, steel and acrylic and compare that to the sound produced by the human mouth. After creating these chambers, we hope to go experiment in more depth with different materials inside those shapes to see how the sound is affected.

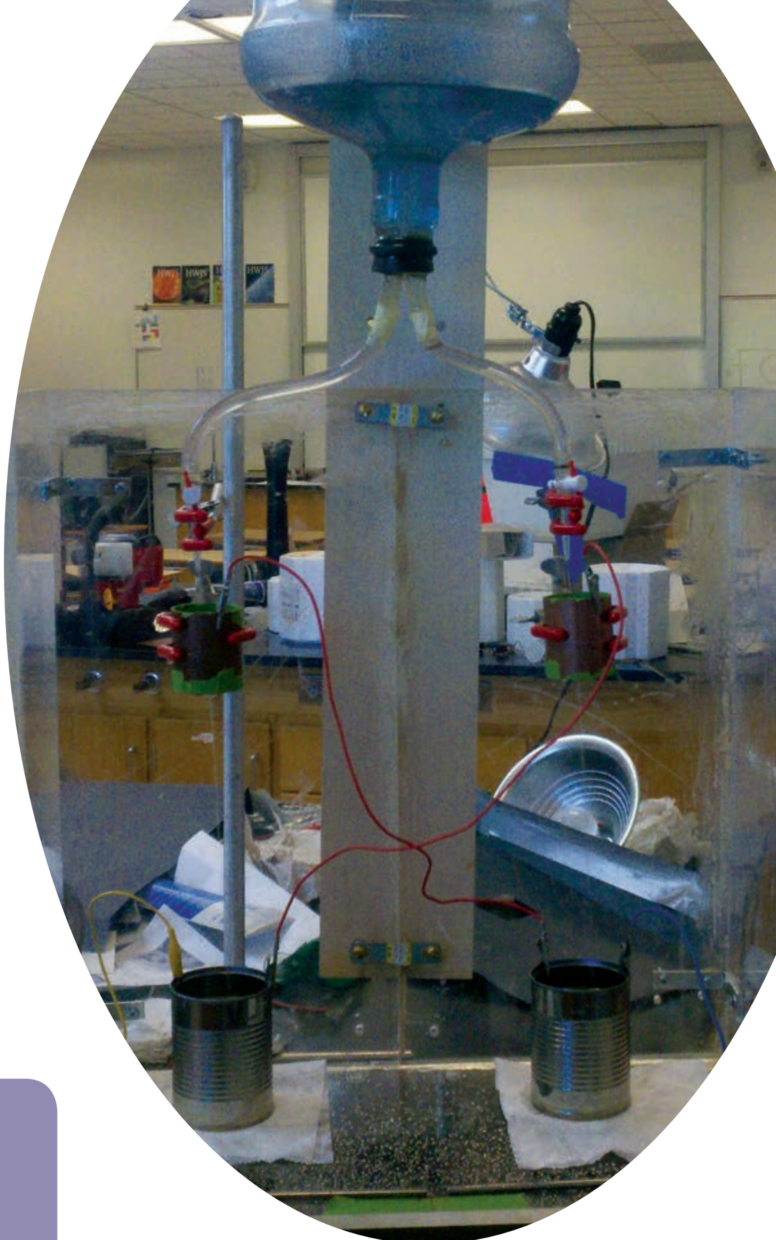
Conclusion:

In conclusion, our talk box is an attempt to link the fields of musical creativity and scientific innovation. This piece of equipment allows for a thoroughly human method of expression by using the voice with a synthesized component. In testing for the most organic sounding tone (robot voice), we have found that even vocal emulating synthesizers could not match the tonal quality of a guitar. The range of frequencies possible with an electric guitar, when formed by the human vocal cavity make even the worst singer sound like Aretha--if their guitarist is capable. It is possible to use the talk box to deviate away from the sound of a singer, but the point of our experiments was to do just the opposite. We wanted to see which synthesized sound with our own talk-box could sound like human phrasing, but found the further we fled from a simple amplified plucked string of a guitar, the less organic it became.

Figure 3

Experimenting with a Kelvin WATER DROPPER

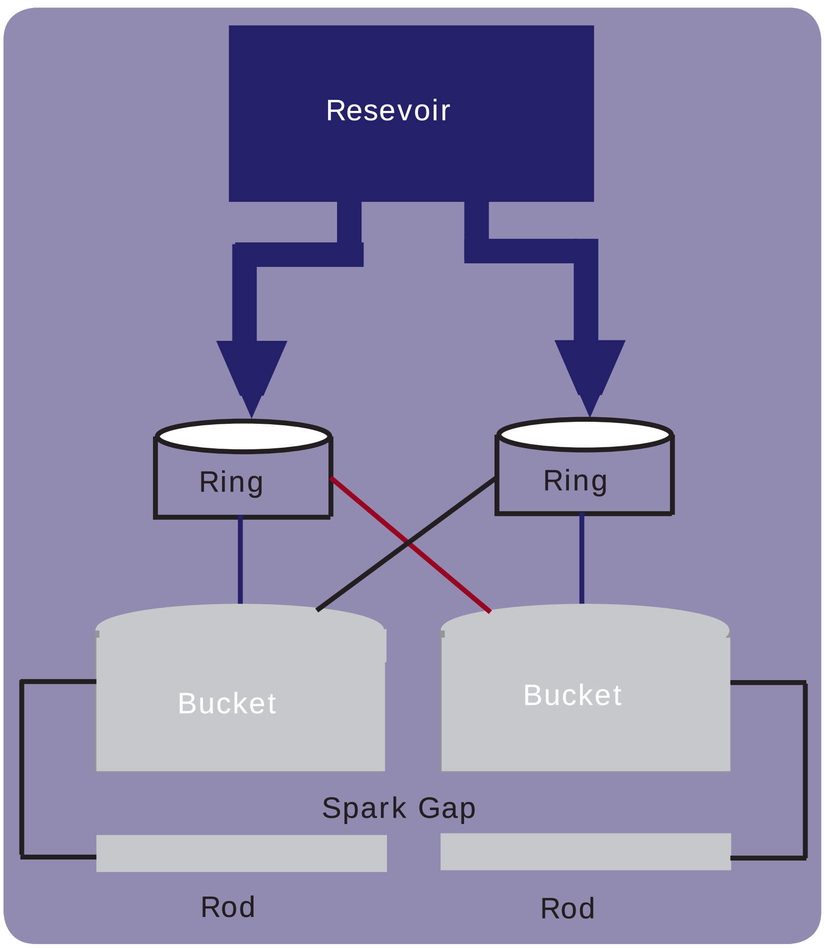
CHASE BASICH AND
MICHAEL LEUCHTER



Abstract:

The Kelvin water dropper is a device designed by Lord Kelvin in 1867. The basic function of the design is to convert the kinetic potential energy of water into electrical energy. In essence, this is a form of hydroelectric power.

The basic design of the generator is as follows. There is a large reservoir of water above two metal buckets and two metal rings. Each metal ring is above a metal bucket, but is electrically connected to the opposite bucket; they will share a charge. When one of the rings (and therefore the opposite bucket) becomes slightly charged, it will attract slightly charged water of the opposite charge. That water will then fall through the ring, without touching it, and land in the bucket below it, transferring a charge to that bucket. However, there are some details unique to our generator. In our generator, acrylic sheets are used to electrically isolate each part of the water dropper, as any unwanted movement of charge will ruin the experiment. Each part is attached to the acrylic so that it is not only isolated from the other parts, but also from any external sources.



We have a plastic jug acting as our reservoir, and we have wood to attach it to the acrylic. A two-holed stopper is in the jug, and has a piece of rubber tubing coming out of each hole, diverting the water from the reservoir in two directions. Each piece of rubber tubing has a stopcock from a burette which can be used to control the flow of water from the reservoir. Each stopcock will deposit water in a narrow stream through copper couplings into the metal soup cans. Each soup can is electrically connected to the opposite copper coupling so charge can be shared between the two as required by the Kelvin water dropper. The metal rods are connected to the soup cans in such a way that the rods will form the path of least resistance for the charge to travel. Thus we can expect the spark to travel in the space between the two metal rods.

For example, if, the left ring has a negative charge, then the right bucket has a negative charge as well. The left (now negative) ring will attract positive water towards it, which will fall into the left bucket, making it positive. As the left bucket is now positive, so is the right ring. The right ring will then attract negative water, which will land in the right bucket, making it even more negatively charged. After enough charge has built up, the Kelvin water dropper will need to discharge its energy; the negative charge and the positive charge will become so attracted to each other that a small spark will jump between the two buckets, starting the whole process over.

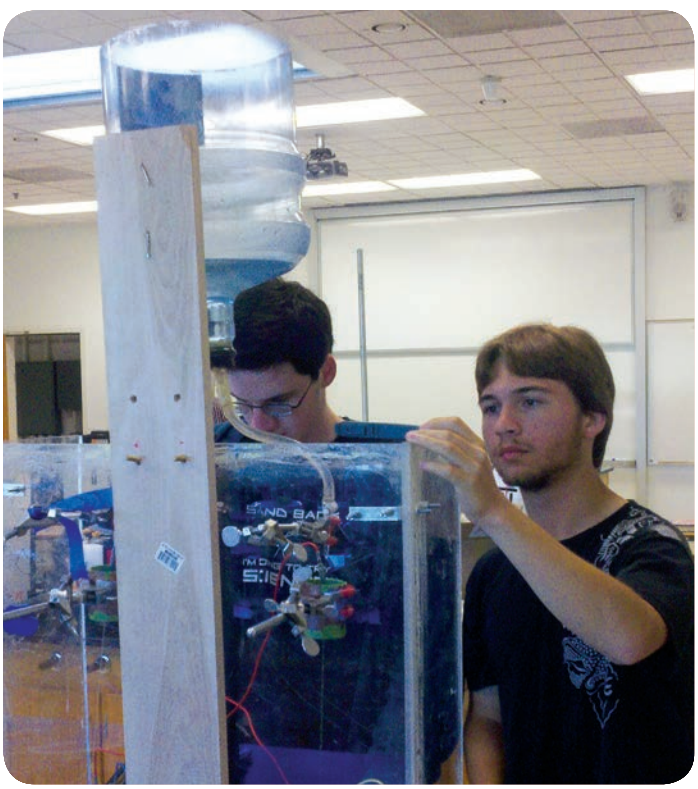
Introduction:

The purpose of our experiment is to use the design of Lord Kelvin's water dropper to create a viable generator. As we go on with our experimentation, we plan to find out what makes the generator more efficient and then to maximize the generator's efficiency.

We initially hypothesized that our generator would generate electricity and quite well, but we were not sure how to harness this power. We hypothesized that coupling size would have no affect on the experiment, but that coupling material would affect the charge created. Specifically, we believed that more conductive materials would generate more charge, and therefore more electricity. We also believed that adding more streams of water and more couplings would increase the charge generated. However, after some pre-trial calibration runs, we completely changed our hypothesis. We decided that our generator would not be a viable source of power due to its inconsistency, its low current, and the fact that compared to many other generators, it takes a long time to build up a decent voltage.

Procedure:

When we started experimenting with the water dropper, there were a few factors that we wanted to test, namely humidity, type of metal used in the rings, and distance between the rods. We were going to measure the number, frequency, and length of the sparks in every experiment, to figure out the relative efficiency of each variable test.



Since we wished to discover if this is a viable source of power, the first factor we tested was humidity. We have a relatively consistent device to measure the humidity (+- 5% confidence), so testing humidity was rather simple. By keeping the rods at the same length apart, keeping the type of metal the same, but doing the test on days of different humidity, we hoped for good results. However, we were rarely able to cause the rods to discharge, and never when the humidity was above 33%. Even at 33%, it only discharged a maximum of four times in one minute of starting the trial, and after those four discharges (usually within the first 30-45 seconds of the trial), it simply would not even come close to discharging. A couple times, at 27-29% humidity, we were able to obtain 10-15 discharges, but we once again encountered the problem of not being able to maintain a steady stream of discharges. We planned to test the effect of distance between the rods on the spark frequency by doing trials with the two rods at various distances varying from 0.2 cm in between the rods to 0.8 cm in between the rods, but after discovering how dependent on humidity the generator is, we determined that testing more elements of the generator was unnecessary.

Conclusion:

We believe that the Kelvin water dropper is not a very reliable source of power. As discussed earlier, the generator is very sensitive to environmental factors. This alone makes it an unreliable generator, since it cannot work effectively even 80% of the time. Also, we know, based on a little internet searching, that our generator produces between 10,000 and 20,000 volts at a very low current. Due to the low current and the time required to generate this voltage, we currently do not believe this to be a viable source of power in the future. Additionally, this creates a DC current, which is not used in the world today, except in small battery-powered objects. Therefore, although this research project was a very interesting experiment, it is not practical considering that not only does this generator not work much of the time, but also there are much more efficient and reliable ways of utilizing water to create energy.

Lasers: Wavelength vs. Dot Size

Kody Greenbaum and Jonathan Glassman

Lasers, by definition, are devices that emit light through a process of optical amplification. The word "laser" is actually an acronym for "light amplification by stimulated emission of radiation". Lasers have a multitude of uses in our daily lives such as barcode scanners, CD and DVD burners, and laser corrective eye treatment. Lasers are significant in modern medicine, weaponry, and even entertainment. The electromagnetic radiation (light) emitted from a laser can vary in wavelength, which allows for a wide range of uses. The wavelengths of lasers can even extend beyond the visible spectrum (there is currently speculation about creating gamma ray lasers), but in our experiment we will be focusing on lasers within the visible spectrum (See Figure 1).

Apparatus:

There are many different ways to construct lasers. In order to amplify the light, it must pass through a gain medium, which can be of any state of matter: gas, liquid, solid, or plasma. Various types of lasers with different gain mediums include gas lasers, chemical lasers, excimer lasers, fiber lasers, solid-state lasers, photonic crystal lasers, semiconductor lasers, etc. Typical laser pointers are solid-state, such as the lasers that were used in our experiment. Other necessary materials in our experiment included laser protective eyewear, a ruler, a cart, a clamp (in order to stabilize the laser pointer), a pencil, and masking tape. We performed our experiment in a long hallway.

Purpose:

The purpose of our experiment is to quantify the effects of wavelength and distance from target on the dot size of a laser beam.

Method:

We shined laser pointers down a long hallway onto a poster board from distances of ten, twenty, thirty, forty, and fifty meters. We performed multiple trials with each laser pointer (red, green, and violet), recording the dot size with a pencil each time. We measured either the length or width of the dot (which were different most of the time), staying consistent throughout each trial. We then graphed our results (Figures 1-3).

Conclusion:

Through analysis of our data and graphs, we were able to come to several conclusions. Our graphs have a consistent linear trend, which suggests that the relationship between distance and laser dot diameter is linear as well. Our first two graphs do not accurately depict the relationship between wavelength and laser dot size. This is because during the first three trials, we did not measure the longest diameter of each dot. We simply measured either the width or length of the dot, staying consistent for each wavelength (in order to accurately record the relationship between distance and dot size). During the third trial, the longest diameter of each dot was measured consistently for each color. Each laser was given fresh batteries before the third and final trial, which seems to represent our most accurate results. Our results from the third trial allow for the direct observation of the effect of wavelength on dot diameter. It appears that the largest dot diameter occurs for the green laser. Since the size of the dot is simply a matter of how the human eye perceives the radiation, it makes sense that the green dot appears largest. The human eye is most perceptive to wavelengths in the middle of the spectrum (yellow-green). Therefore it is no surprise that the green dot (540 nm) appears larger than the purple and red.

Our third trial was compiled over the course of two days of measurement at two different locations. All data points past 50 meters were collected at the Harvard-Westlake middle school campus in Bel-Air. The middle school has a 100 meter hallway that we were able to utilize for gathering some extra data. While we were not able to acquire data points for the green laser due to equipment issues, the additional data for the red and purple lasers was consistent over the greater distances with the prior trends we observed.

Discrepancies in the data can be understood as results of several factors. During earlier trials, we used a white poster board as a target for the lasers. We later switched to a black poster board, which was easier on the eyes due to less light reflection. This made it easier to record the dot size, and allowed for more precise measurements. During the first two trials, the batteries were not ensured to be fresh. This may have contributed to inconsistencies.

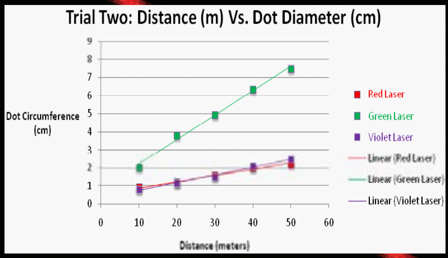


Figure 1

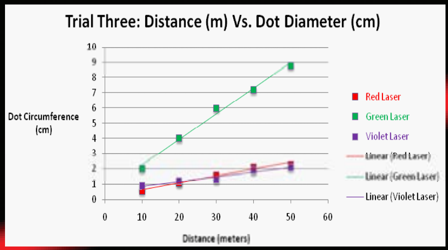


Figure 2

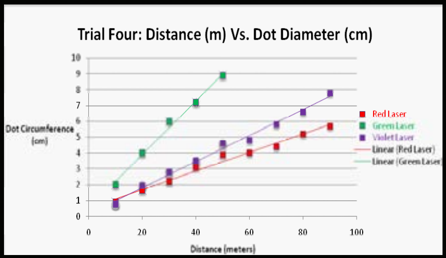


Figure 3

PITOT TUBES AND SUPERCOOLING

Kevin Schwarzwald, Graham Gallaher, and Colette Woo

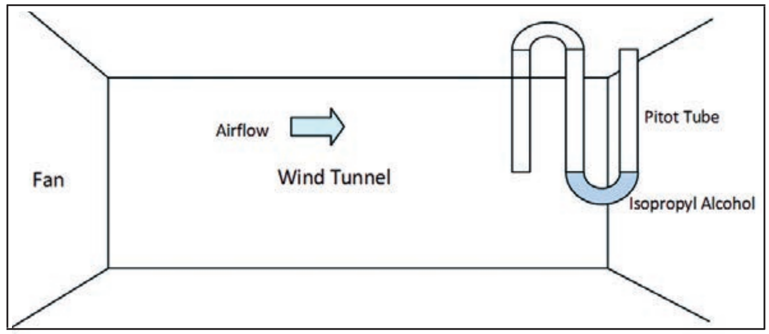
The purpose of this project is to identify solutions that could potentially be developed into life-saving devices. While small scale tests using primitive measuring devices and substitutes for the forces and materials involved in a real-world situation, this project aims to identify areas and designs that may warrant future study and investment.

Introduction:

In the early hours on the first of June, 2009, Air France flight 447 seemingly inexplicably disappeared. The likely cause was a simultaneous failure of all three pitot tubes, which led to a catastrophic failure of the fly-by-wire system. The pitot tubes were likely frozen when they encountered supercooled water in a storm system the plane was passing through. Supercooled water is extremely pure water which can exist in liquid form at temperatures far below its normal freezing point. When pitot tubes come in contact with this supercooled water, impurities were introduced to it and the water instantly froze over and prevented the pitot tubes from determining airspeed. Reports have demonstrated that this is a fairly widespread problem. The problem is so prominent, in fact, that the Federal Aviation Administration issued an Airworthiness Directive which required that all Airbus A330 and A340s fitted with the Thales Avionics pitot tubes, the type of plane which was assigned to AF447, to be refitted with the more reliable tubes manufactured by Goodrich. The Federal Register concluded that use of the Thales model can cause "airspeed indication discrepancies while flying at high altitudes in inclement weather conditions," which "could result in reduced control of the airplane." The design of pitot tubes has remained roughly the same since their introduction. As shown by the crash and the regulatory worry about the equipment, it is time to develop a better pitot tube. This project will attempt to do just that.

Pitot Tubes:

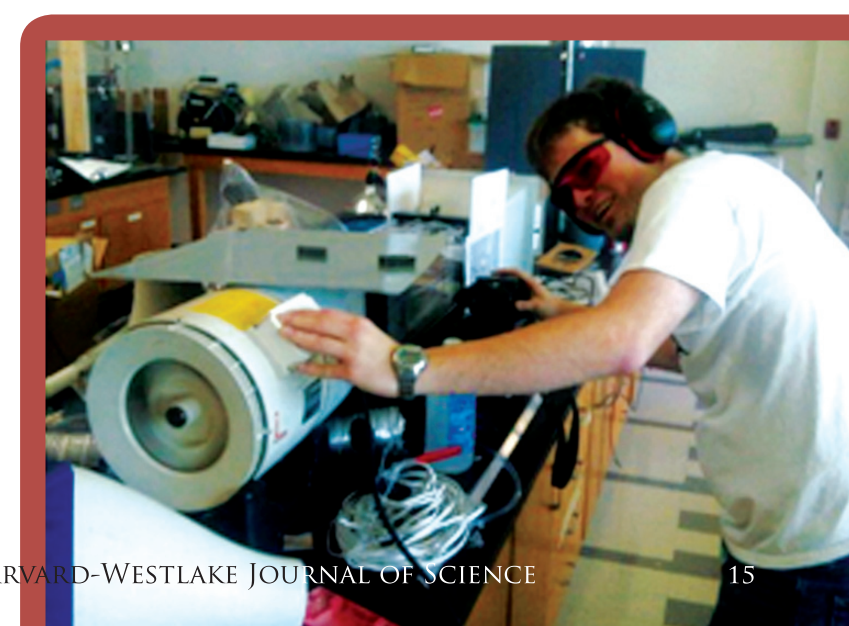
Pitot tubes measure pressure and fluid flow velocity. The most basic pitot tubes are tubes with one open end and one closed end. The open end faces the direction of fluid flow. The fluid within the tube cannot move out of the tube because one end is closed; the fluid within the tube is at rest. The faster the flow of the fluid, the greater the pressure is on the fluid at rest within the tube. By measuring the pressure within the tube and the static pressure, the rate of fluid flow can be determined. Pitot tubes rely on the one open end to gauge the pressure and determine the fluid flow velocity. Should the open end of the tube become blocked, the apparent pressure will be zero and an incorrect reading will be given. Airplanes relying on pitot tubes often have more than one in case one of the tubes becomes blocked. Airplanes flying through cold weather can often find that all of their pitot tubes ice over and give incorrect data. In these cases, airplanes rely on heaters to unblock the pitot tubes. If, however, the plane is flying through supercooled conditions, the heaters may not be able to keep up with the rapidly freezing vapor in the air. The pitot tubes will all become quickly blocked with no way to thaw the ice and will give inaccurate readings.



The Project:

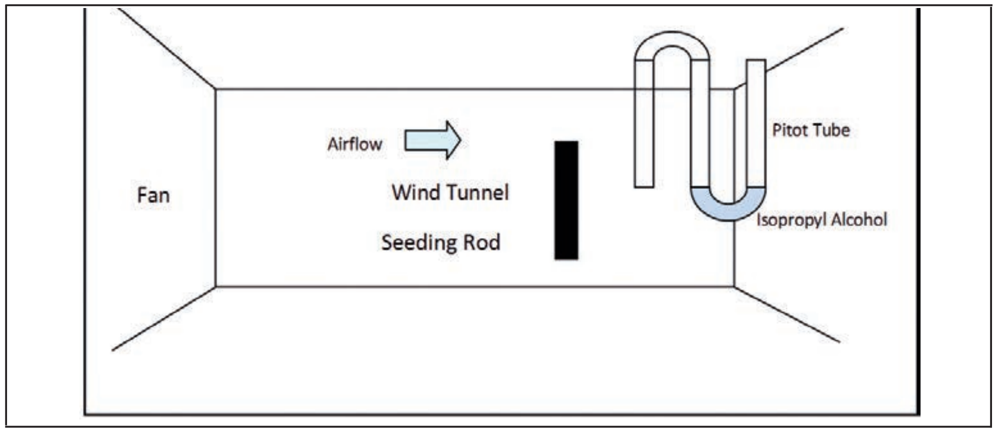
Our project consists of finding a way to make pitot tubes less prone to failure due to supercooled water. Using a small wind tunnel and a pitot tube, we will research what modifications we can make that minimize airflow disruption while lowering the risk of icing. The pitot tube apparatus consists of a vinyl tube inserted into the airstream bent downwards outside of the wind tunnel into a U-shape which is filled with isopropyl alcohol. The isopropyl will react to the changes in air pressure by moving up and down the tube. The changes in fluid level are recorded and compared to a preset calibration benchmark to determine airspeed. We will determine what acceptable variations in pitot tube accuracy are and reject designs that exceed those given levels.

The purpose of this project is to identify solutions that could potentially be developed into life-saving devices. While small scale tests using primitive measuring devices and substitutes for the forces and materials involved in a real-world situation, this project aims to identify areas and designs that may warrant future study and investment. Considering that the instrument's basic design has remained the same since its inception, with the only major changes being the addition of basic heating units and more sophisticated measuring equipment, perhaps, especially in light of the recent tragedy, it is time to reexamine the pitot tube.



Acceptable Error:

As airliners climb to higher altitudes, the density of the air around them decreases. This forces the airliner to fly in a very narrow strip of possible airspeeds to stay aloft. Because of the lower number of air molecules, they need to pass the aircraft's wings at a faster speed to generate the same amount of lift; therefore, the stall speed is increased tremendously. At the same time, the speed of sound, impregnable by most airliners due to buffeting that could threaten the plane's structural integrity and stability, falls, once again due to the lower air density. The small corridor between the stall speed and speed of sound is the only possible airspeed for the airliner to fly at to avoid a failure. This corridor, at the altitude and the airspeed of AF447, is a mere 25 knots (about 28 mph). The A330-200, the plane type assigned to AF447, has a commercial cruising speed of 865 km/h, or 467 knots. The margin of error is therefore ±2.68% (((25/467)*100)/2). This will therefore be the acceptable deviation of airspeed from deviation fo airspread from a benchmark test in the data.



De-Icing Boot Principle:

The most efficient method of deicing an airplane wing has been a point of contention among the aviation community since the 1920s. One of the first, most effective methods was putting rubber 'boots' on the leading edges of wings and control surfaces and then using pneumatic or mechanical pressure to expand the boots and crack any accumulated ice, which relative airflow would then carry away. Boots, though, had to be replaced every few and proper maintenance necessary to keeping these boots in working order was tedious and expensive. Other systems for deicing wings include electro-mechanical and thermal systems. Electro-mechanical systems generallyy use high-energy electromagnetic pulses to shake the ice off wing, "weeping-wing" systems which coat the wing with a thin coat of glycol-based (very low freezing-point) fluids, or some combination of the two. Thermal systems use heat to prevent and eliminate icing. Pitot tube deicing involves heated pitot tubes. Nothing else has ever been attempted on a large scale. This situation provided a unique experience for the group to explore whether any of the systems used for deicing wings could be modified to fit pitot tubes. The most obvious problem with these technologies is that they would all, in one way or another compromise the accuracy of the pitot probe's measurements. Since the hole which can get iced over must be open to measure air pressure, any chemical systems would be inapplicable to this situation.

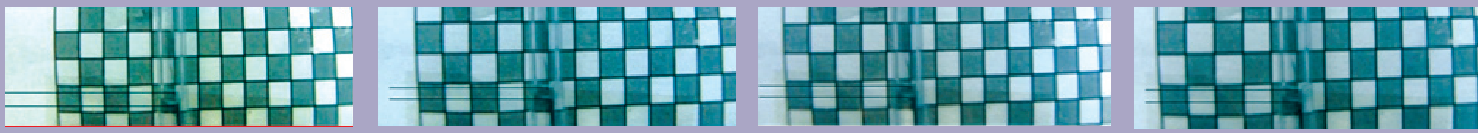
Block Time (s)	**3.58**
Unblock Time (s)	**5.32**
Time taken to stabilize (s)	**1.74**

The simplest and most effective option seemed to be adapting deicing boots to pitot tubes. These systems would not require great amounts of heat or electrical current, and could be installed on both airliners and lighter propeller and turboprop aircraft. The circular rubber boot would require special fabrication and replacement every two to three years, depending on how frequently it was used, if it is made of the same material as the deicing boots used on wings' leading edges. Since it would be much smaller, though, the cost of the unit itself, installation, and maintenance would be easily bearable. The most obvious problem with the boot is the disruption in airflow which would occur as it was iced over and/ or 'popped.' To determine how this problem could be mitigated, we disrupted and rapidly reintroduced the airflow to a simulated pitot tube in a wind tunnel with 22 m/s airflow. This would determine how often the deicing boot could disrupt airflow in known icing situations while still allowing the pitot probe to gather accurate data. Initial tests indicated that the time needed for the level of the pitot tube to gather an accurate reading (plus or minus about 2.5%) ranged from just over 1.50 to just under 1.75 seconds, which is much too long to be practical. It is reasonable, though, that at the airspeeds at which aircraft actually travel, with such a significant pressure differential and relative airflow of much higher speed, accurate readings would be possible to obtain in much less time. The deicing boot still appears to be the most promising avenue for research, but more is needed for this idea to progress to the point at which it would be practical and marketable. The deicing boot, if nothing else, would be a great emergency backup system to augment heating in keeping ice off of pitot probes in conditions of high volumes of supercooled water or other extreme weather phenomena.

Seeding Rod Principle:

Another possibility would be to introduce contaminants in the airstream ahead of the pitot tube to cause crystallization without affecting the normal operations of the pitot tube. Since supercooled water crystallizes nearly instantly after coming into contact with a contaminant, a deicing rod could be placed into the airstream to shield the pitot tube from the effects of crystallization. This experiment introduces obstacles into the airstream ahead of the pitot tube and measures their effect on the accuracy of the reading.

In this experiment, a contaminant (a pencil) was introduced at varying distances from the pitot tube to measure its effect on data collection. A benchmark value was first recorded with no perturbations in the airstream. The subsequent tests introduced the contaminant at distances of 5, 10, and 15



benchmark 10 cm 5 cm 15 cm

Distance from center of tube (cm)	% change in pitot tube level	% of benchmark
15	13.04	87.96
10	15.94	84.06
5	20.29	79.71

centimeters from the center of the tube. The collected data was compared to the benchmark and a percent difference was calculated and compared with the previously calculated maximum acceptable error.

As seen in the data, even larger distances to the pitot tube cause great differences in the measured pressure and therefore measured airspeed. Even the 15cm test showed a percentage change significantly outside the margin of error, being bigger by a factor of nearly 7. Distances much higher than this would most likely show a large decrease in effectiveness of blocking the ice from reaching the tube, since the lower pressure zone behind the rod would cause ice not caught by it to rush back into the airstream and onto the pitot tube. Though the pitot tube could be calibrated to respond to such a change in the airflow, the lower reported airspeed would then be much more susceptible to changes outside of the margin of error, potentially resulting in catastrophic stalls. In conclusion, this method of potentially preventing pitot tube icing due to supercooling would most likely be unsuccessful if attempted at a large scale. Therefore it is recommended that this design be dropped from further study and recommendation.

For the next phase of this project, the "deicing boot" model for a pitot tube described above will be further studied and refined. While the "seeding rod" design has proved unsuccessful, data collected from testing it will be used to design further possibilities, which will then be tested and analyzed.

PROJECT ICARUS: atmospheric exploration

Jacob Swanson, David Kinrich, Maguire Parsons, Sam Horn, Wes Peacock, and Ryan Gould

As a culminating project of our Studies in Scientific Research class, a few of us decided to test the limits of our atmosphere. We have refined a project from last year, hoping to take one step further, into space. A camera will be sent up to capture the journey, accompanied by a GPS system to track it along the way.

The capsule is built out of Styrofoam that encases the camera and phone, with a small hole cut into the side for optimum viewing potential, and is wrapped with steel cable to reinforce the impact upon landing. Attached is an extra casing housing the parachute and connecting the rig to our balloon, a design that is vital to our experiment's success. Connected to the extra capsule are Servo motors to release this capsule seamlessly, expose the parachute, and improve the design of last year's project with a program written by Jacob Swanson. Four D batteries are soldered together to give the camera and GPS system extra life, to withstand the nearly two hour trek from surface, to atmosphere's edge, and back down to earth.

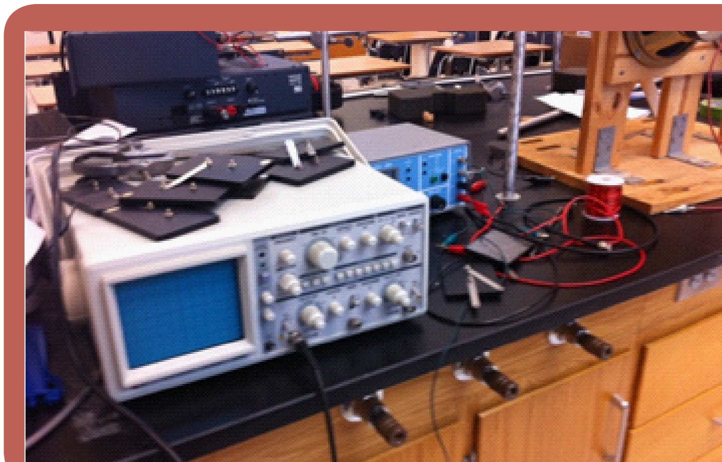
With clearance from the FAA we plan to execute our experiment later in May. We hope to minimize as many complications as we can, ultimately to get that final shot at 100,000 feet. With our flip video camera, we should get a clear video of the journey, and be able to recover the footage seeing that all of our mechanical and other refinements function properly.

The transmission of Sound through a LASER

Jasmine McAllister and Jacob Swanson

Introduction:

This experiment explores the transmission of sound via modulations in reflected light, a type of electromagnetic radiation.
This concept was first explored by Alexander Graham Bell in his invention of the photophone. In his design, he targeted sound at a reflective diaphragm, reflected sunlight off of this diaphragm into a gas filled chamber, and was able to hear audible sound from this chamber.
It was later discovered that the modulation of the reflected light caused temperature modulations in the gas which in turn caused a pressure modulation due to the volume restriction of the chamber.
Bell later replaced the gas-filled chamber with crystalline selenium cells, a substance whose electrical resistance varies with light. When the selenium cells were connected to an earphone, the sound behind the diaphragm was clearly audible.
Since Bell's discovery, his apparatus has been tweaked to the point where governments have used similar concepts in espionage technology, shining a laser off a window and interpreting the reflected light modulations into sound.
Our experiment is also a variation on Bell's discovery, making use of the more concentrated and direct light of a laser and a sheet of fiberglass to of varying widths to determine if this concept will also work with the much more flexible fiberglass medium and with which width it works best.



Concepts:

The laser microphone utilizes several key concepts. First of all, sound, in and of itself, forms a longitudinal wave of varying pressure through a medium, in this case air. A sound source, such as a speaker or mouth, is simply a tool that pushes and pulls the air around it. These pushes and pulls propagate through the air, and eventually leads to the same pushing and pulling at the destination, such as an ear, a microphone, or in our case a window. The next concept that our microphone utilizes is the reflection of light.

When the laser hits the window, the reflective surface "bounces" the light back at an opposite angle to the normal as the angle of incidence. When the window vibrates, however, the angle of incidence will vary, since the normal, which is perpendicular to the surface, is also varying. As the window vibrates over time, the reflected laser light will also be vibrating. Finally, our microphone utilizes the concept of solar cells. These components, which can convert light energy into a current of electrical energy, can absorb the reflected laser light. Since only portions of the solar cell can absorb light at once, the cell will only create a complete circuit and current when the vibrations of the laser move correctly. If the current from the solar cell is amplified, the current can again produce the pushing and pulling of air in a new speaker, creating a microphone.

Experiment:

Our experiment is very simple. First, we shined a laser at a mirror connected to a pair of speakers and received the reflected light with a solar cell. This solar cell was connected to an amplifier which was in turn connected to a speaker, and the sound was reproduced at that speaker.
This showed that all parts of the apparatus are functional, so if there is a change in sound transmission when we change the reflecting mechanism, the change will be due to that reflecting mechanism.
We also found that the sound was best reproduced at low frequencies and high amplitudes. We suppose that this is because high amplitudes cause the most dramatic modulations (we could also see this visually with the laser) and the modulations produced by low frequencies were slower and more easily recognized.
In the next part of our experiment, we will replace the mirror connected to speakers with a sheet of fiberglass. To cause the modulations, we will put a source of sound (speakers producing audible low frequencies, then a voice) behind the fiberglass sheet.
Although this has been done before with glass sheets, we do not know if this will work with fiberglass, although we predict it will since fiberglass is more flexible and sound will easily make it vibrate.
We will also test two different thicknesses of fiberglass, 1/16 inches and 1/8 inches, in order to determine which is best.

Transmission of Electricity Through The Human Body

Kayj Shannon, Vivek Pandrangi and Zach Scott

Getting Started:

Our project began as a serendipitous discovery in our Studies in Scientific Research class. SSR is an incredible class in which we are able to pursue any scientific field or interest of our choosing. Our current project of transmitting sound through a person stemmed from our original idea, to transmit sound with lasers. One day, we were experimenting with lasers and discovered that signals continued to be transmitted even when the laser was not on. Through the next few weeks we used the scientific method to find that the human body was conducting the electrical signal. We became intrigued with this fascinating phenomenon decided to pursue this as our new project.

Concepts:

The basic concept behind our project is the transmission of an electrical audio signal through the human body, rather than conducting it through wires. This signal is then run through amplifiers to boost the signal, and output through a speaker. Due the human body's high impedance, the low voltage signal from an iPod or signal generator can be safely transmitted; however, the signal is extremely weak on the receiving end, and must be amplified considerably if it is to be output to an unpowered speaker. Through much testing and experimentation we soon were able to gain considerable data, and fully explain the discovered phenomenon.

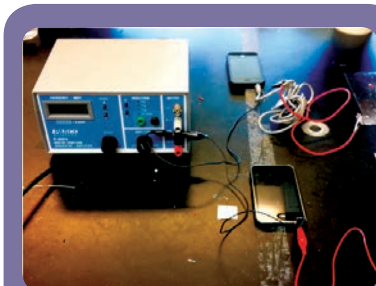


Figure 1

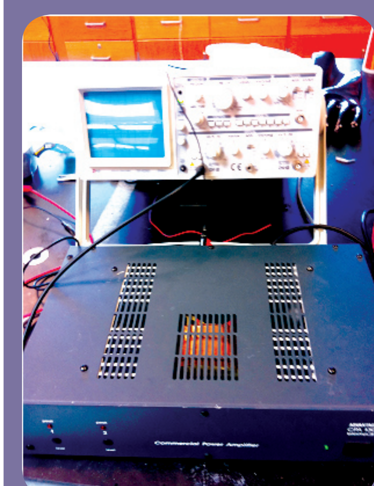


Figure 2

Setup:

The apparatus for the project consists of (1): the "transmitting circuit", a 3.5 mm input jack connected by one wire lead to an aluminum foil strip, with the other lead connected to an unpowered signal generation box (ground), and (2): the "receiving circuit", a second strip of aluminum foil, connected to the positive lead of an amplifier, which is then run through an oscilloscope to an unpowered speaker.

A signal-generating device such as an iPod is plugged into the input jack. To complete the circuit a person places each hand on either foil strip; the audio is conducted through the person, where it is then amplified by the amp, displayed on the oscilloscope and output through the speaker (3). The amplifier can be omitted if the signal is to be output through headphones. Once either hand breaks contact with the strip, the speaker output ceases. Any remotely conducting material will work to bridge the gap between strips, from tap water to a wire, but the allure is using a person.

Figure 3

Additionally, multiple people may participate, with one person on either side contacting the foil strip, and one or more people in between them; as long as skin-to-skin contact is made on any part of the body the signal will be conducted.

The Experiment:

The mechanism behind the project is the interesting effect that occurs when signals or current are passed through a very high-impedance device, in this case people. The equation $V = I*R$ is very useful when explaining this phenomenon. A person is a very non-ideal conductor, and while our wet insides are filled with ions that are conductive, our skin acts as a very effective insulator. A person's high resistance (R), combined with a very low signal voltage (~4 millivolts) ensures that the current passed through the resistor is extremely low as per $V = I*R$. The current is both harmless and invisible to the subject.

Though the signal is extremely weak, it is still coherent enough to be picked up and strengthened by an amplifier, then output through a speaker. Using the oscilloscope display, the signal can be tuned. While the basic background behind the project is simple, it suggests an incredibly large number of possible inventions. By using strips of aluminum foil tape, this phenomenon becomes much more user-friendly and interesting, as people can interface directly with the apparatus. By adding a row of resistors, each creating a distinct circuit, a touch sensitive volume control can be implemented.

Another input circuit can be added, allowing multiple audio signals to be mixed at different volumes. In addition, other audio modulation circuits can be created and interchanged, allowing a mobile DJ mixing station to be created. If unpowered headphones are substituted for the speaker the amplifier may be removed, as the tiny line-level signal transmitted is powerful enough to drive the headphones, effectively creating "wireless" headphones. In addition to these ideas, the technology can be applied anywhere due to the ease and portability of the apparatus.

The Relationship Between Light Intensity and Voltage in Solar Cells

Mitchell Oei and Kyle Woo

What comes to mind when clean, renewable energy is discussed? Usually towering wind turbines, roaring hydroelectric dams, and glistening blue photovoltaic cells. All three of these widespread and popular technologies have their pros and cons, but the latter, solar cells, are common and don't require a lake or a 100+ foot tower, making them the prime candidate for our foray into the field of renewable energy. Having thus decided on our chosen technology, we devised a test to see how the typical photovoltaic cell's output (measured in Volts) would be affected under varying levels of light. The following is an in depth explanation of our method and a detailed examination of our data and the conclusions we drew from our results.

Method:

Our setup was simple: rather than use lights of varying outputs and brightness to simulate different levels of light, we used a fog machine to simulate heavy cloud cover and reduce the levels incident light on the solar panel. Our setup involved having an acrylic plastic box which would house the light sensor and fans, which was mounted on top of a large solar panel. The rest of the exposed solar panel not directly below the box was taped off, preventing other light from hitting the panel apart from the square plot that the box occupied. Attached to this box were two tubes, one leading from the fog machine to the box and the other leading away from the box to the vacuum pump. A hole in the top provided the socket through which the light bulb was inserted.

The fans served to homogenize the fog mixture within the box, distributing the fog evenly through out the container. This ensured that the solar panel was receiving an even amount of light, and made our measurements more accurate. The vacuum pump allowed us to extract the fog, albeit at an ever decreasing rate (explanation later). The mirror captured the light incident on the solar panel from the light bulb, and reflected it into the light sensor, which was parallel to the surface of the panel. Our experiment ran like this:

1. Record the starting light intensity, which in our case was always 5248.7 lux
2. Fill tank to "100% fog density," or maximum saturation, upon which the fog would begin to leak through the seams of the tank. Pulse fans to homogenize the mix.

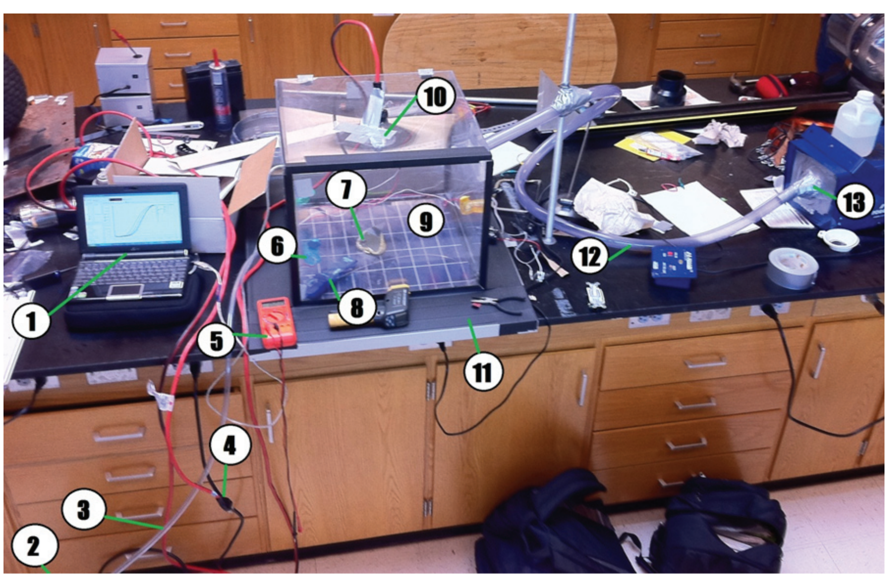
Key Points:

The output of solar panels are significantly limited by their efficiency.

The relationship between light intensity and voltage is linear, with a logistical maximum.

3. Remove fog machine tube from box and place piece of tape over hole to prevent excess fog from getting in or out.
4. Begin recording of data on the computer, which would record light intensity versus time, and turn on the vacuum pump. (keep pulsing fans)
5. At 90% of the maximum light intensity, (in our experiments it was 90% of 5248.7, which was 4723.83 lux) record the voltage. Repeat for subsequent intervals of 10% of the maximum light intensity (80%, 70%, 60%...10%), and record the corresponding voltage. Keep the fans pulsing for the duration of the experiment.

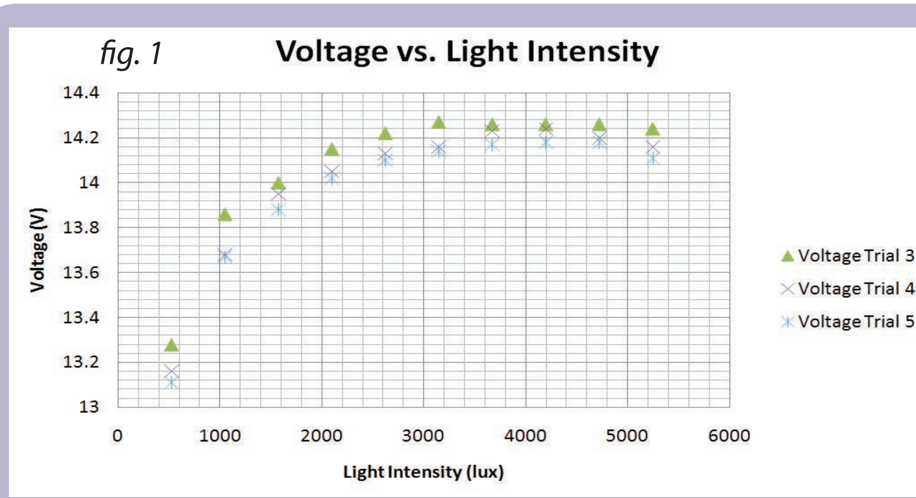
Our setup looked like this:

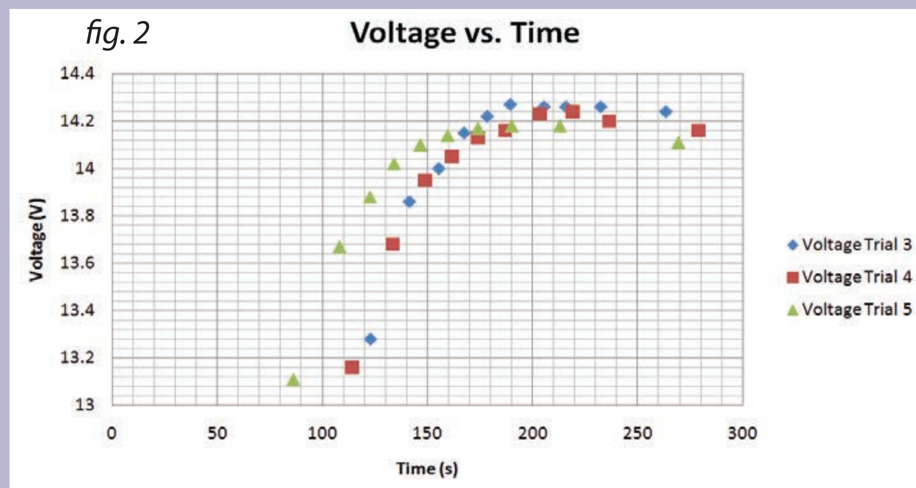


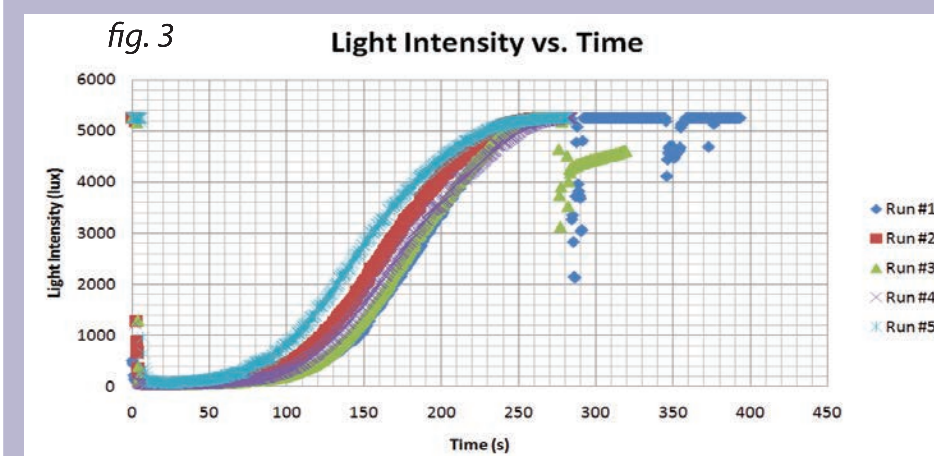
1. Computer
2. Vacuum pump (not shown)
3. Vacuum tube
4. Plug for the light bulb
5. Voltmeter
6. Fans
7. Mirror
8. Light sensor
9. Fog chamber
10. Light bulb
11. Solar panel
12. Fog tube
13. Fog machine

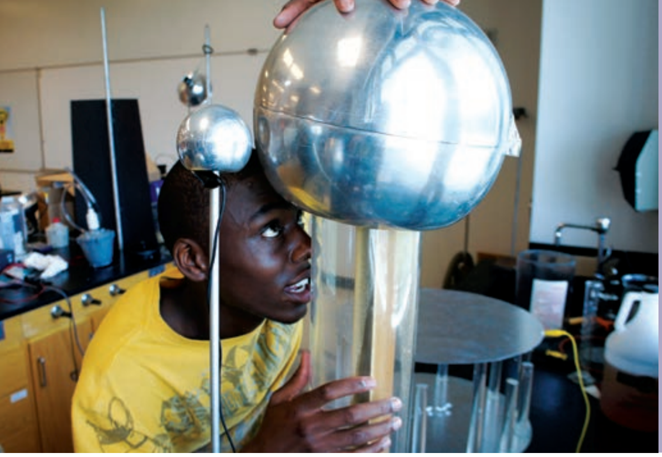
Analysis:

Our experiment was fraught with difficulty. Given our relatively inaccurate tools, there was a lot of error present in our data. For some mysterious reason, during our first two trials, the base voltage output of the panel hovered around 9 volts without any fog and relying solely on the light bulb, with external sources of light minimized. However, trials 3-5, which we performed at a later date, but under identical circumstances, the base voltage was closer to 14.2 volts (in fact, as Fig. 3 shows, the light intensity was roughly identical for all 5 trials). We have no explanation for this phenomenon, as we were using the same solar panel, same light source, minimized external light, and same fog mixture. Therefore, we had to either discard one of the sets of data, or to perform a general analysis based on the relative shapes of the graphs, since both sets followed the same general patterns. We opted for the latter decision, since we lacked sufficient time to perform more trials. The "S" shape curve of the graph shown in Fig. 3 is explained by virtue of how the fog was removed from the tank. Although the pump evacuated a constant volume per unit time from the tank, the amount of fog that was removed was variable. In the beginning, when the fog was at its maximum density, the air that the vacuum removed from the tank was comprised of nearly all fog. As the fog thinned in the tank, the amount removed by the pump approached zero. If you were to graph the density of the fog being removed as a function of time, it would display asymptotic behavior, approaching zero as time increased. This experiment would have been better run if we had a machine which could remove a certain volume of fog particulates per second, thus creating a linear relationship. However, since no such machine exists, and because we know the behavior of how the fog was extracted, we can still infer conclusions from the shape of the graphs. As seen in Fig. 1 the relationship between voltage and light intensity seems to be a logistical model, increasing at an ever decreasing rate, towards a maximum value, which in this case, would be the maximum voltage able to be supplied by the solar panel, given the light source, area of the panel exposed and the efficiency of the panel. The graph in Fig. 1 illustrates that past a certain light intensity, the voltage output was not significantly affected by increasing the light intensity. Fig. 2 shows similar logistical models, but these are explained by the nature of how the fog was evacuated from the tank. Since the fog was extracted at an ever decreasing rate, the light intensity must be increasing at a decreasing rate as well, and therefore, the voltage would also increase at a decreasing rate, as is clearly shown in Fig. 2. We can reasonably infer then, that had the fog been removed at a constant quantity over time, the graphs in Figs. 1, 2 and 3 would have exhibited a linear correlation. This is not to say that it would be an absolute correlation, since there is clearly a certain point that light intensity, when elevated past this point, fails to affect voltage (Figs. 1 & 2). However, the patterns in Figs. 1, 2 and 3 would have been linear, with the graphs in Figs. 1 & 2 eventually reaching a logistical maximum. We can conclude, given the inferences from our data and results, that the relationship between light intensity and voltage for a solar cell is a linear one, with a logistic maximum determined by the solar cell's area, its efficiency and light intensity.









Experiments with the
VAN DE GRAAFF
GENERATOR

James Lee and Alex Markes

Testing the Photoelectric Effect

In this experiment, our goal was to find the relationship between the intensity of the UV light and the intensity of the discharge. We hoped to do so by varying the wavelength of the UV source and the distance of the UV light from the metal dome. We decided to measure the intensity of the discharge by connecting the smaller ball to a voltmeter.

For our experiment we chose to test the Photoelectric effects efficiency in a vacuum and effect on a Van de Graaff Generator. A Van de Graaff generator works by electro statically charging a comb inside a metal dome with a moving belt. As the positive charge builds up around the dome, the potential difference between the large and small metal ball builds. Once the potential difference becomes too large and in an attempt to balance out the charge, the larger dome discharges onto the smaller ball.

The photoelectric effect is when electrons are emitted from a surface as a consequence of its absorption of energy. The surface gains this energy from electromagnetic radiation of very short wavelengths such as UV and visible light. As a result of the surface losing an electron, it becomes more positively charged.

When the photoelectric effect is applied on a Van de Graaff generator, we believed that the increased positive charge on the dome would create an even larger potential difference. This would result in a larger discharge onto the smaller ball.

We also found it interesting that few people had tested the photoelectric effect in a vacuum, so as another experiment we will also run tests on the effects shining UV light has on an electroscope. An electroscope is a device that upon making the top ball a certain charge, the bottom sheet metal will gill gain the opposite charge and be attracted to the ball and slowly rise.

First we decided to study the effects the Photoelectric effect has on a Van de Graaff Generator. After putting on our safety masks, gloves, and white long sleeve shirts, we plugged in the Van de Graaff Generator and ran some control tests. We observed how the Van de Graaff Generator worked without UV light on it, taking into account the time it takes for a bolt to jump at 5 inches, and the intensity of the bolt. After observing the Van de Graaff Generator alone, we made sure to discharge the Large Dome by bringing it in to contact with the small ball.

We had hoped to study the effects of UV light on the dome, but because of many problems, we were unable to do. Nevertheless, we still had a procedure to determine the effects of UV. In order to do so, we needed to coat the small ball with Zinc in order to help promote the photoelectric effect. Our first variation was to shine the UV light, keeping it at a constant distance from the generator, onto the small ball and measure the intensity of the bolt and the time it takes for a bolt to jump across when the small ball 5 inches from the dome. However, after doing so, we realized that there was either no or too small of a noticeable difference in time for us to measure the difference between shining the UV and not shining it. Another problem was that there was no way for us to measure the intensity of the bolt with the given amount of resources we had.

Next we decided to vary the distance of the UV light from the generator and see if the distance would affect the maximum distance the bolt would travel or the time it takes for a bolt to jump 5 inches. Again, we were sure to always discharge the large dome between trials in order to keep the starting charge on the large dome equal to zero. We did this many times, alternating between the short UV wavelength and the long UV wavelength, but again received no noticeable differences.

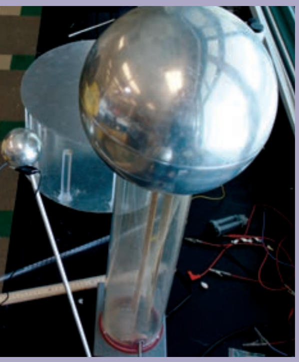
In our second experiment, we utilized Velcro to sustain the UV light inside of a vacuum bell jar that had the electroscope with its electrode leaves inside of it. We then proceeded to hook the vacuum pump up to the stage that the bell jar sits on. We did so in order to create the ideal situation for the photoelectric effect to occur. Our procedure to make this work was to, with our safety gear on, lift up the jar, turn on the UV light, and immediately put the jar back down and turn on the vacuum. By doing this we hoped to maximize the time that the UV light shined on the electroscope. If a change were to occur, it would be noticeable in the movement of the leaves, but unfortunately we were unable to find visible movement.

We had predicted that shining UV light on the small ball would both increase the intensity of the bolt and decrease the time it would take for a bolt to jump 5 inches. We also predicted that as we move the UV light away, the energy transferred would be less and thus the time it would take for a bolt to jump 5 inches would be longer when the UV light is farther.

In our electroscope experiment, we predicted that shining the UV light on the electroscope would give the ball a positive charge as electrons leave the zinc coating. Which in return, would cause the metal sheets at the bottom of the electroscope to rise, as they are attracted to the top.

In an ideal situation, where we had a perfect vacuum and better equipment, we believe that it would have been possible for our experiments to have had positive feedback, but because our resources were limited, we believed it was best to move on to different experiments that still pertained to the Van de Graaff generator.

What is the Van de Graaff Generator?



American physicist Robert J. Van de Graaff invented the electrostatic generator in 1929. It uses a moving belt to collect very high electrostatically stable voltages in a hollow metal globe that rest on the top of the stand that discharges onto a grounded object. The belt inside the generator gains positive charge and transfers it to the metal globe through a metal comb that is attached to it. Eventually when enough charge is build up, all the positive charges get attracted to an object with a relatively negative charge and discharges upon it.

Future Expirements

Aluminum sheets between the Van de Graaff generator's globe and grounding rod:

Due to the unsuccessful results from the original experiments, we decided to carry on with two other experiments. The first pertains to aluminum sheets and the for this experiment we are trying to determine if increasing the radius of holes in aluminum sheets will affect the van de Graff generator's ability to discharge across it. Our hypothesis here is that increasing the hole size will not significantly affect the van de Graff generator as the distance of the conductive aluminum sheet may increase slightly with the hole but not enough to escape the discharge of the van de Graff generator.

In our recent tests, we found that the increasing the hole size does not affect the van de Graff generator's ability to get rid of its charge; however it does affect the shape and intensity of the discharge. Instead of there being a straight and intense bolt, the discharge if forced to disperse around the edges of the holes and form a current stream of electricity in the shape of a cone. The discharges have not been as intense as normally as well. Normally there is a period of low constant discharge only visible with all lights off and then a massive burst of discharge visible even with the lights on. Instead we have found that the ball only has that low constant discharge unless we bring the sheet and electrode ball connected to the ground all within two inches of each other.

We plan to continue to run tests to validate our current findings. We also plan to use the fluorescent light to test the intensity of the discharge. The fluorescent light will always light up slightly when the Van de Graff is turned on; however, it really only shines brightly when large discharge from the van de Graff generator occurs. Using this we may be able to confirm our results that the aluminum sheets prevent large discharges from occurring, as the fluorescent light is not emitting a bright enough light.

Circular motion:

Another experiment also involves the Van de Graaff generator but is more of a setup than an experiment. The setup consists of two aluminum sheets with one connected to the positive output of the Van de Graff generator and the other connected to the negative output. For our Van de Graff generator, that would be equivalent to connecting one plate to the small positive ball and one to the large negative dome. Eight small conducting rods made of plexiglax and four large ones connect the two aluminum plates and help transfer the static electricity all across the plates. As seen in Figure 1, the rods will be arranged in a circle in the same manner in the diagram. The dark circles represent the four large rods and the lighter circles represent the eight smaller rods. A side view, represented by Figure 2, shows another angle to how the rods would be arranged. The larger rods allow for static electricity to be transferred between the plates and both the smaller and the larger rods transfer electricity around in a circle. The static electricity will flow around in a circle counter clockwise and can be demonstrated by placing an aluminum strip in the center of the device. Once the Van de Graff is turned on, the aluminum strip inside will begin to spin and float in mid air. We plan to create an experiment to determine what kinds of shapes and objects will be influenced by the static electricity

Our original setup consisted of 12 plexi-glass rods (8 short rods and 4 long rods), 2 rectangular sheets of metal (steel and zinc), and epoxy. After assembling the device as so in Figure 1, we attempted run some tests. However, after a countless number of trials, we received no results. Initially, we had believed that our experiment had failed, but we decided to make some crucial changes. We realized that because we had placed the rods on top of a pool of the epoxy, no real contact was made between the metal sheets and rods. The way the device worked was that static electricity had to flow from the positive to negative charged plates by going through the rods. But, the nonconductive epoxy did not allow that to happen. In order to allow direct contact, we decided to bond the rods to the metal plates by placing epoxy around the rod, allowing direct contact for energy exchange. Some other changes were cutting the square metal sheets into a circle to reduce the loss of energy leaked by the sharp corners of the rectangle, reducing the distance between the metal sheets from one foot to ¾ of a foot to allow for easier transfer of energy, and using thin strips of tin foil instead of aluminum tape to reduce the mass of the suspended object. The tin foil strips we are using now are around 0.05 grams as opposed to the heavy aluminum tape that was around 0.61 grams.

Due to our late discovery we have not had too much time to evaluate the complexities of the static electricity, but we have come up with some interesting observations and determinants of the success of the spinning spiral. One obvious determinant is the weight of the spiral.

The heavier the spiral, the less likely it is to be pulled up by the static electricity. Another determinant is the length of the strip used to create the spiral, or the height of the spiral. The longer the strip used, the taller the spiral is and the more likely it is to be pulled up be the spiral. Also the uniformity of the spiral is a determinant. We have observed that spirals that keep a uniform radius throughout and have pointed corners at each end tend to spiral and can in general keep going for longer before spinning out of control and out of the setup. Using these determinants, we believed that longer, thinner, spirals will spin better, yet we have not proved this and are still running tests. Although we know what shapes we want, keeping thin and long stripes of tin foil in the shape of a spiral has caused a problem. The stability of the tin foil can be a problem, as it tends to lose shape. In addition, any crinkles in the tin foil generally hamper the tin foil's ability to be affected by the static electricity.

The shape of the tin foil is also a big determinant. We are currently in the process of finding the ideal shape but it seems to be that the spirals are the best. However, other shapes like U-shaped stripes and circles still float, but are not able to keep a consistent pattern of movement. Instead, these shapes at times float around in the setup.

As we continue, we will attempt to find the maximum weight of a strip that allows it to float, and find the ideal shape for a perfect spiral spin. Also, we hope to figure out why the objects we put in there have a large tendency to go spiraling out of the setup. We believe that it has either something to do with the space between plexiglass rods or the uniformity of the circle sheets, but we will continue to experiment and see what happens.

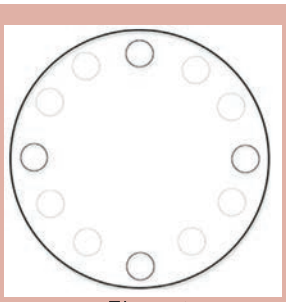


Figure 1

Figure 2

RX-7

Graham Gallaher

Racing is a popular sport; races from all sorts of racing from Formula 1 to NASCAR can draw crowds of 350,000 people or more to a single race. Racing involves both driver skill and engineering prowess by the design team. The best formula one teams will spend over $400,000,000 in a single season, the average NASCAR team spends about $120,000,000 per season, and still manages to make a profit of about $12,300,000 per season. Racing teams develop and tune their cars to perfection, so the only thing missing from professional racing seems to be a sense of frugality. Being a high school student, I am the perfect person to inject some budget-mindedness into racing by answering this question: can you build a car for $10,000 that is faster than any car you could buy used for the same amount?

The Jumping-off Point:

The car I chose as a base for my project is a Mazda RX-7; I was able to find the shell of a slightly-rusted 1981 Mazda, free of an engine, interior, transmission, any sort of usable suspension, wheels, windows, or virtually anything else which would make it drivable, for a paltry $800, including the fabrication and installation of a six-point roll cage, which the previous owner, an automotive enthusiast himself, was able to do in less than a week.

Methodology:

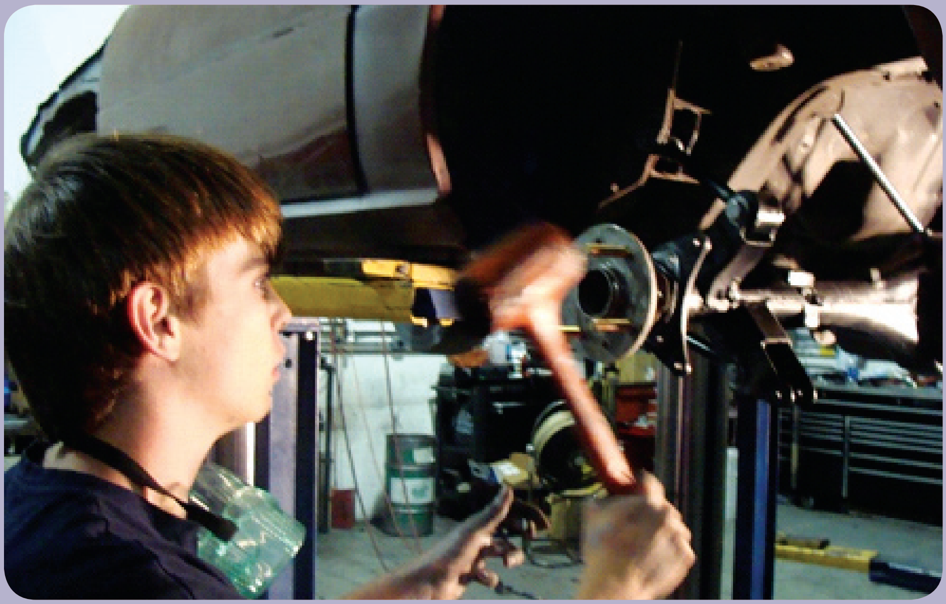
The car is not street-legal and doesn't need to be, so I will take it to race tracks to test it against other cars in terms of metrics including acceleration, braking, lateral-acceleration, and, indicative of all these factors, lap times. Shortly after I bought the car, I realized that the floor jacks and hand tools I had at my house would not be sufficient for the complete resurrection of a car which lacked virtually all the components which would qualify it as a car. I worked out an agreement with a shop owner in a slightly-seedy part of the valley which is rarely frequented by Harvard Westlake students. The shop owner told me his hours were 7 a.m. to 5 p.m. daily and that he was closed on Sundays, so I paid him a nominal sum to use his shop every day from 5 p.m. to 7 a.m. over the summer and Sundays during the school year. Through many long nights and weekends during which I could find the time to escape my homework, I brought the car back to a drivable state.

Procedure:

First, I spent about a week cleaning up the interior by sanding the entire interior and painting it economically with spray cans from the local hardware store. The spray job made quite a difference in terms of appearance. I started with a rusted mess, power-sanded every inch of metal on the inside of the car, sprayed about eight spray cans worth of paint on the interior, and ended up with a beautifully simplistic, functional interior. The interior lost a good portion of its sheen as I had to keep climbing in and out of it throughout the process of building the car, but it still looks incomparably better than it did when I first bought it. I scoured craigslist for parts which would enable me to wheel the car around and came across a great deal on a used set of light racing wheels. I had Toyo Proxy RA1 radial tires installed and was then able to proceed with the hard work.

I then installed the suspension to make the car a 'rolling chassis,' which I could roll in and out of the shop at my leisure. I got some MacPherson struts off of a 1985 RX-7 which I found in a salvage yard and plasma-cut and welded the struts so that they would accommodate the adjustable performance shocks I had bought. I then had to weld a spring collar onto the struts so that they would fit a coil-over-strut style spring perch. The result of this was a much firmer suspension than that which originally came with the car. The new suspension also lowered the car about four inches versus the stock suspension, which reduced the car's drag coefficient. I acquired an axle and differential, also from a salvage yard, and proceeded to paint those along with several relatively minor components, including the brake booster and pedal box. Once these were painted, I put the car on a lift and used a transmission jack to install them with the suspension.

I then tried to machine some brake rotors from a salvage yard so that they were smooth, but ended up machining them beyond the recommended minimum rotor width, so I bought four new brake rotors and rebuilt some calipers I found in a salvage yard from a 1985 RX-7 (discs all around, replacing the drums in my 1981). I re-packed the wheel bearings I found on



the salvage yard RX-7, and installed those. Now all I needed was to buy an engine, transmission, fuel cell, seat, and harnesses, as well as some minor parts, and to do some wiring and plumbing.

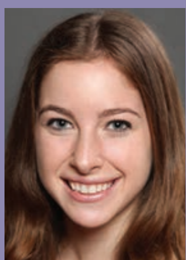
I found an engine on Craigslist for a few hundred dollars and sent it to an RX-7 specialist, who increased the car's horsepower significantly by boring out the rotary engine's intake and exhaust ports by a few millimeters. I found a five-speed transmission which I bolted to the engine, along with a flywheel much lighter than the stock one and several minor modifications to the oiling system. I bought some gauges and fabricated a panel to accommodate those gauges. For safety reasons, I had a professional install the fuel cell. I sent the car off to paint and installed a racing seat, which I had bought used and which ended up being too big for me. Since the seat was aluminum and I was learning TIG welding, I simply cut the seats along the welds, bent the aluminum, and re-welded the seat, then covered it with fabric. I sent the car off to a super-cheap paint shop and got it painted yellow (the color least likely to show minor imperfections in the bodywork), covered it in racy stickers and numbers. I then dropped in the engine and transmission, installed and properly jetted the carburetor, finished wiring up the gauges, and connected all the brake and fuel lines, most of which I had replaced with braided stainless steel lines. I installed a straight-pipe exhaust with a lava rock muffler then installed and properly-calibrated a brake bias adjuster, perfected the car's suspension geometry by setting up the best camber, toe and caster settings within one tenth of one degree of perfection. I also corner-weighted the car and set up the suspension by tuning shock rebound rate. All that remained was proper testing on a race track, which I performed at Willow Springs International Raceway.

Results:

My first testing day was a wonderful day in February during which I was able to dial the car in. I used such tricks as measuring the temperatures on the inside and outside of each tire to determine whether I had too much or too little camber (the angle between the centerline of the wheel and a vertical line), and used shoe polish to gauge how much the tires rolled over on to their sidewalls during hard cornering. I was able to determine that the ideal amount of air pressure in the tires is just over 32 psi at operating temperature (or about 28 psi cold). I was also able to determine that four degrees of negative camber on the front wheels maximized the contact patch during cornering and, therefore, allowed me to corner as quickly as possible. I spent about two hours total on the track and significantly more time perfecting everything from the proper pressure bias between the front and rear brakes (surprisingly far forward, though I was not able to measure this quantitatively) to what shift point would minimize my lap times (about 7,600 rpm). Even though it was this car's first time driving (and it was my first time driving it), it preformed respectably well, setting lap times in the mid to low 1:40s range at Willow Springs, a nine-turn, 2.5 mile road course. Once I perfected the handling of this car, get more comfortable with the way it drives, and improve my driving abilities, lap times around 1:35 should be achievable. This project has proven that building a car for $10,000 certainly can produce an end result much faster than anything which could have been bought second-hand with the same amount of money. I was able to keep up with Mitsubishi Lancer Evolutions, Subaru Impreza WRX STis, Honda S2000s, Porsche Boxsters, and many cars which cost much, much more than $10,000, so I count this project as both a great learning experience and an unqualified success.

SUMMER RESEARCH

Eager to continue their studies in science over the summer, many students take advantage of research opportunities at local institutions. Students intern for physicists, biologists and chemists, gaining experience in unique disciplines through opportunities often not available to them at school.



NATHANSON'S/CHRONICLE

Catherine Haber '12

"I loved being able to experience first-hand testing, something that I had never known about and that I'm very interested in. It was really cool to have a hands on experience like that."

Dr. Mark Coehn

Cognitive Neuroscience Center at UCLA Brain Research Institute

"As a high school student, working next to post doctorates and performing the same tasks for two summers was invaluable."

Dr. Deborah Krakow

UCLA Departments of Orthopaedic Surgery and Human Genetics

NATHANSON'S/CHRONICLE

Justin Cohen '11

NATHANSON'S/CHRONICLE

Charlie Stigler '11

"Before, I had only done programming, not the theoretical upper level stuff. It gave me a good look at research in its entirety."

Dr. Deborah Estrin

UCLA Center for Embedded Networked Sensing

"The most valuable part of interning was learning the lab techniques and how to write a scientific paper that I could present in front of professtional researchers."

Dr. Susan Lee

Children's Hospital, Proteomics Core Facility

NATHANSON'S/CHRONICLE

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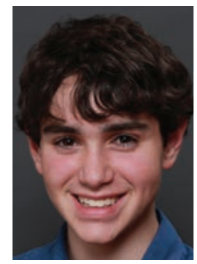

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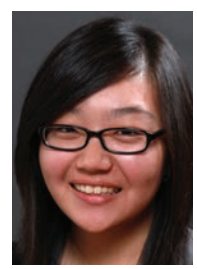

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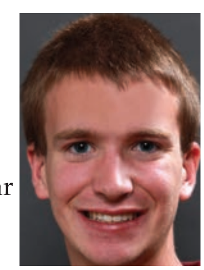

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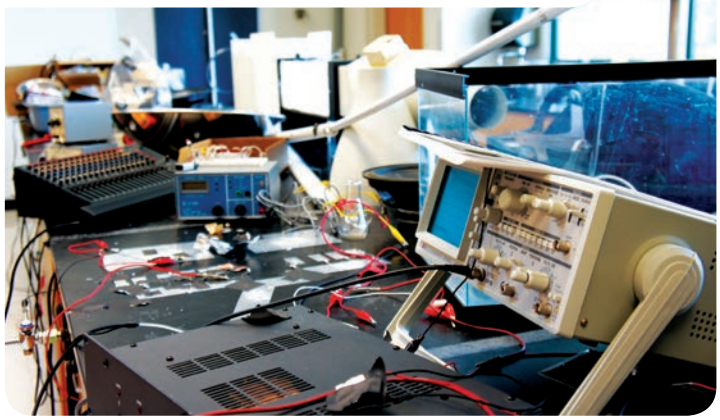

What's America to do?: a comment on SSR

Dr. Antonio Nassar

What are the conditions to give rise to more innovations vis-à-vis the ever growing number of scientific problems? What's America to do?

We need a change of paradigm in our schools. The emphasis should be on research at all levels and especially at a young age. Crucial factors for innovation are the freedom to pursue ideas in a less-structured environment, the freedom to fail and the freedom of access to information in the broadest sense. So, we need more than ever lots of Studies in Scientific Research. Our Harvard-Westlake Studies in Scientific Research (SSR) class has set an example on how to pursue this goal. It provides our young students with a less structured environment to inspire students to think in new, more creative ways. In SSR, the students' creativity allows them to explore and put into action ideas in a relaxed and playful atmosphere that is still quite constructive. SSR students are encouraged to be daring, positive, optimistic and unrelenting and most importantly, to dream hard, which is the most inspiring element in the American character.

There is no doubt that innovations are crucial to our survival and prosperity. Americans get particularly very excited about innovation. So, it is fundamental to insert into the American culture a higher regard for scientific research at all levels. Most important is the need to promote the interest in and regard for science and technology in our youth. That's what America should do.

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