HWJS

HARVARD-WESTLAKE JOURNAL OF SCIENCE • ISSUE 2 • SPRING 2008

MICROWAVE OPTIMIZATION

BUILDING ELECTRIC SCOOTERS

MICROBIAL FUEL CELLS

ELECTRIC CAR MODELING

HARVARD-WESTLAKE'S OIL WELLS

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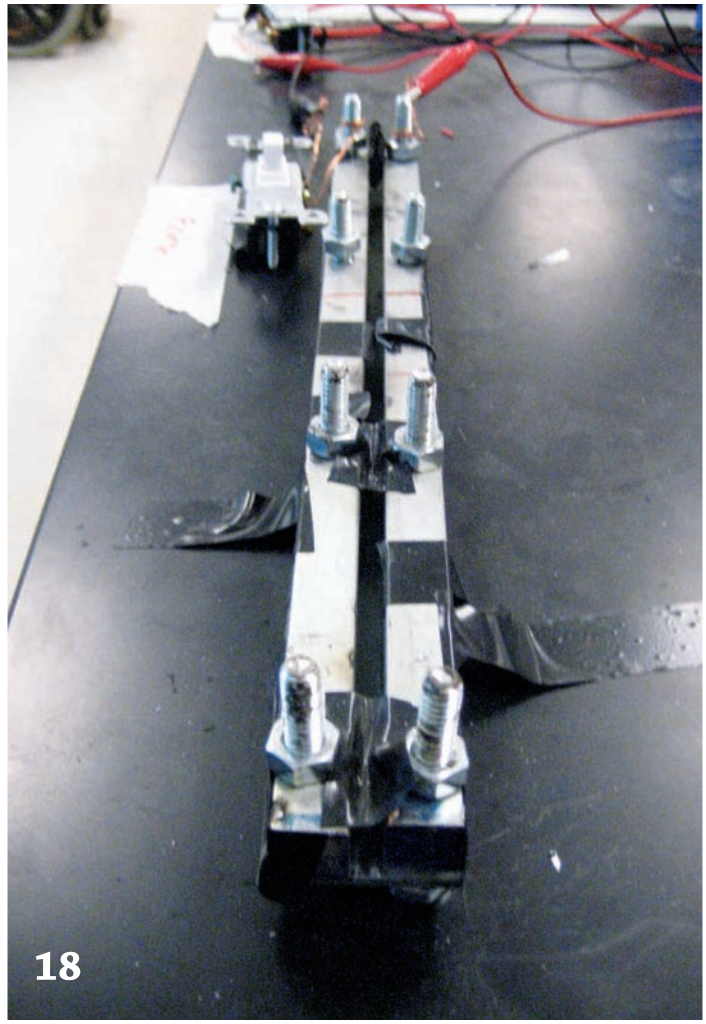

MATTHEW EDWARDS

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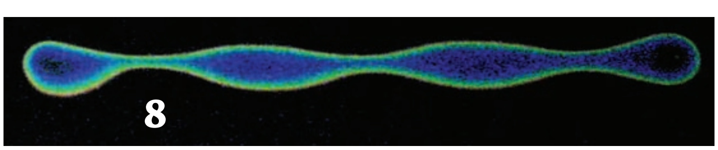


WILL BASKIN-GERWITZ

Harvard-Westlake
Journal of Science
3700 Coldwater Canyon
North Hollywood, CA 91604
www.hwscience.com/HWJS/index.html

From the editors

Continuing the legacy

Last year's DSSR class gave the program a huge leap forward. Doubled in size, this year's two classes led the way to greater recognition.

The Journal's founders, Allen Miller and Justin Chow, were faced with a daunting task: legitimize an eccentric elective class by creating a highly visible publication. They explained that the first issue was "starting a legacy" and we believe they did just that. Harvard-Westlake attracts a diverse group of talented young adults and each one, from chemists to playwrights to lacrosse players, is in some way directed and shaped by our spectacular science department. Directed Studies in Scientific Research (which will be renamed Studies in Scientific Research next year) provides an opportunity for any student with an interest in science and technology to get some hands-on experience, a rare and invaluable opportunity at the high school level.


DON HAGOPIAN

William Baskin-Gerwitz

Unlike the Harvard-Westlake Journal of Science team last year, which had to focus on laying the foundations with the first issue, we have worked hard to build on their commendable efforts. DSSR blossomed from a group of 20 students to two full-sized classes and from strictly seniors to students from the entire upper school. With this issue, we tried to showcase the many different projects that were researched throughout the year—a multifarious mix of everything from microbial fuel cells to plasma rail guns.


DON HAGOPIAN

Matthew Edwards

Additionally, we wanted to highlight how out of this multitude of separate projects there was often a common theme that tied students together; for example, many teams chose to focus on alternative forms of energy and other important issues facing modern society. A sincere thank you is due to everyone who made the Journal possible. None of these projects could have been completed without the guidance and support of the Harvard-Westlake science department, especially Dr. Nassar, who always pushed our imagination in addition to our intellect, never rejecting a proposal for being too outlandish.

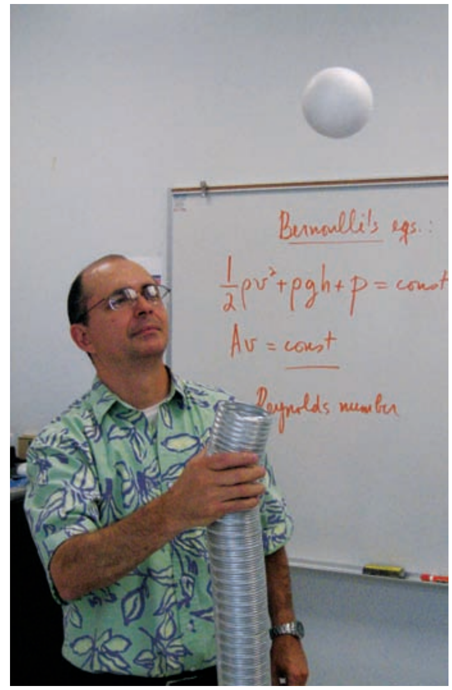

DON HAGOPIAN

Gordon Wintrob

We hope you enjoy learning about the many exciting fields that we explored this year through the more traditional research articles that make up the bulk of this publication. But also check out the interesting and informative pieces on science and technology news, which investigate the groundbreaking research that goes on around the globe. The first issue of the HWJS planted the seeds of serious research at Harvard-Westlake; we hope this Journal will solidify the foundations and help propel the program to further success.

Oil! (sort of)

By Dr. Antonio Nassar, Director of the Scientific Research Program

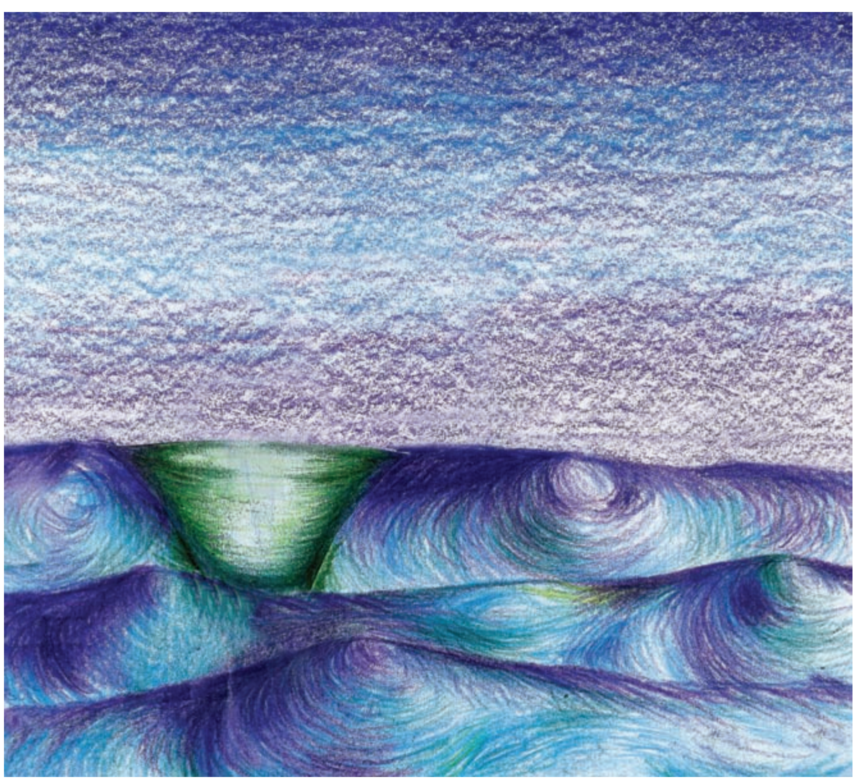


DR. ANTONIO NASSAR, Director of the Scientific Research Program, jokes around during one of his physics classes.

No, you don't need to anticipate any derricks coming out of Slavin Field. But that doesn't mean Harvard-Westlake can't put up its own wells and strike it rich in a fashion that less different than you might think.

> *"I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."*
> *—Isaac Newton*

An inspiring article in the New York Times by Thomas Friedman entitled "Israel Discovers Oil" points out that in the last year Israeli venture capitalists (VCs) poured about $1.4 billion into high-tech start-ups. Actually, these VCs are investing heavily in young college students and innovators, and these youngsters are their oil wells.



They are truly empowering their youngsters to imagine and to act irrespective of hierarchies or fear of failure. Indeed, Einstein's maxim, "Imagination is more important than knowledge" has been materialized. And that is also our motto in the Directed Studies in Scientific Research (DSSR) course. While our DSSR class parallels the Israeli project on a smaller scale, the course seeks to engage even younger students in scientific research.

The only way for the United States to stay ahead in this increasingly flat world is to fire up, empower, and invest in a greater number of young minds by enabling them to start researching at an early age. This nation needs to build a comprehensive research program without delay to address the current world challenges by facilitating interactions in research among all educational levels. To this end, DSSR has provided an environment to inspire students to think in new, more creative ways.

DSSR is a student-driven program that has a completely different structure than any other course at our school; formal lectures are replaced by individual guidance, and a large component of the learning process evolves from student-student interactions. DSSR is a course for young science students to undertake small-scale, year-long research projects. Students discuss and collaborate with one another in their research, working through difficulties together, learning from one another, and broadening their scientific background.

In DSSR, the students' excitement and creativity have allowed them to explore and put into action ideas in a more relaxed, and playful atmosphere that is still quite constructive. According to the great physicist Richard Feynman, the role of playfulness in creativity should be always encouraged because you never know when the horseplay could inspire a future Nobel Prize winner. Listen to our young HW students in DSSR as they talk, scream, learn, and try things out, because they see science as fun. Students may not have a lot of knowledge about their project at first, but they do possess significant imagination. With nurturing, these students are the potential oil wells of the future that will never run dry.

MATTHEW EDWARDS

Microbial Fuel Cells

THIS MICROBIAL fuel cell, Fig. A, consists of an anode jar on the left, a cathode jar on the right, and a salt bridge between them. The salt bridge is filled with a gel that allows the transfer of electrons but hinders the passage of cations between the two halves of the cell.

BY LEON MOSKATEL

The Preparatory Phase

Microbial fuel cells are an emerging method of generating electricity whose basic input is accessible pond water. The purpose of this project is to design, construct and begin optimizing a fuel cell based on the anaerobic respiration of bacteria in waste water. First, I built a basic skeleton of a cell to optimize the setup for my experiments. I then improved the skeleton to accommodate the necessary precautions for dealing with the microbes. I tried to improve the reliability of the structure and the conductivity of its salt bridge. I constructed several of these cells over the course of my experimentation to test different types of microbes and chemical setups and determine the most efficient combination.

The concept of a microbial fuel cell is not novel. A microbial fuel cell is an electrical cell containing bacteria that convert nutrients present in wastewater into electricity. The bacteria in this anaerobic environment use nutrients to promote the Krebs' cycle and generate electrons that are captured by the anode and circulated throughout the cell

The basic skeleton of the cell consists of three parts and is shown in Fig. A. Two plastic jars, which act as the anode and cathode of the cell, are connected by a piece of half-inch polyvinyl chloride pipe. Each jar is left intact except for a one-inch hole cut in the side of each jar. The PVC pipe, which acts as a salt bridge, holds a gel made from a solution of distilled water, agar powder and sodium chloride. The gel facilitates the transfer of electrons and blocks the transfer of cations. Noncorrosive electrodes are inserted into each of the jars through conventional screw-tops. Ultimately the anode jar is sealed to ensure anaerobic respiration. The cathode jar is continuously aerated to introduce oxygen which prevents a build-up of carbon dioxide.

Much of the work I have done has centered on improving my salt bridge. I produced two batches of gel with the hope of finding a correlation between the molarity of NaCl and the conductivity of the salt bridge. I have been unable to detect significant variation in conductivity due to changes in molarity. However, samples which have dried out show less conductivity than those that have been routinely wetted and stored in a moist environment.

I then tested the fuel cell to determine the resistance in the cell over time. For this purpose, each jar was filled with a saline solution and a weak known current, roughly 1.3 A, wasrun though it. I determined resistance by observing current and voltage over time.

Those results were used as inputs in the standard voltage equation to find that as time increases, resistance will decrease linearly as shown in Fig. B.

The resistance should eventually reach an asymptote before zero, since a resistance of zero is not possible, but it did not reach it due >>

The microbial fuel cell uses bacteria to turn wastewater into electricity, providing a clean, renewable source of power.

to time constraints on the experiments. Throughout the experiment, the temperature of the liquid in the fuel cell remained constant at room temperature.

For the fuel cell, this means that even though the initial resistance in the cell is rather high, the resistance will drop as time progresses, and the cell will become more efficient. This is important for experiments where bacteria are introduced and optimization of the microbial cell becomes the focus of the project.

The Bacterial Phase

The microbial part of the experiment required a water source containing bacteria found in anaerobic benthic sediments. I found a convenient water source in a local pond on the Harvard-Westlake School campus.

The anode jar was filled with the wastewater that contained bacteria, and the cathode jar was filled with a saline solution. The cathode jar was aerated using an aquarium bubbler, and the anode jar was sealed. I measured the current using a standard multimeter for 20 minutes with a data measurement taken every 30 seconds. The data was plotted as voltage vs. time to determine the behavior of the cell after the introduction of the medium. This data shows that the cell eventually comes to an equilibrium voltage.

After bringing the salt bridge to the equilibrium value, I ran a short trial that suggested a general decline in voltage over time.

I then ran two more trials, taking data manually every 30 seconds. These trials were run for 70 minutes and 80 minutes. The 70 minute trial demonstrated similar behavior as the earlier 34 minute trial. The 80 minute trial differed from the other trials in that after an hour, the voltage began to increase.

A Lab Pro unit was acquired for automated data recording, allowing substantially longer trials. The practice trial, 60 minutes, with the equipment continued to verify my general hypothesis that voltage generally decreases over time.

The next step, the 5.5 hour trial, shared the same characteristics as the previous trials, except it was administered over a longer time period. Theoretically, the voltage should eventually reach 0 mV because the bacteria will have used up the substrate and will no longer be able to produce electricity.

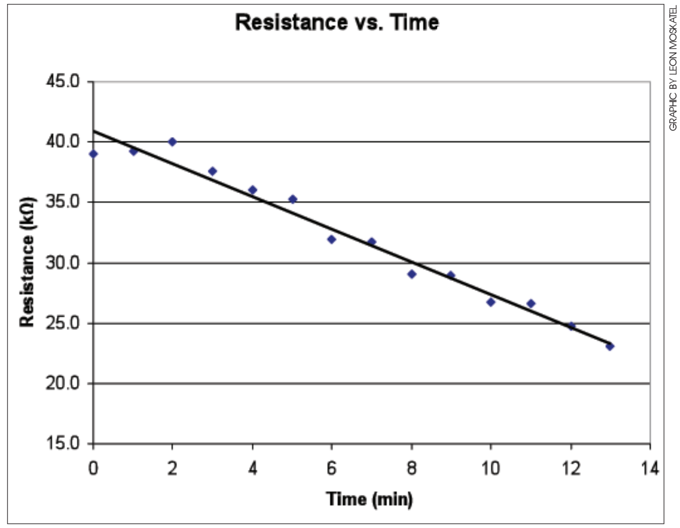


FIG. B. SHOWS the decreasing resistance over time, calculated from current and voltage. Over this section, the graph is linear.

Two important behaviors can be observedf from the 5.5 hour trial. First, the short term patterns are very consistent with the early short term trials. Second, this trial reached two basic equilibrium voltage points where the voltage hovered for an extended period of the experiment, at about 70 mV and 40 mV, as seen in Fig. C.

Over the progression of the many different trials, the patterns remained the same, but the equilibrium voltages did not. The trials that were run earlier tended to have higher equilibrium voltages than those that were run later. This is attributed to the general deterioration of the salt bridge over time.

There is a great future in microbial fuel cells. Already, small ones are being designed to power pacemakers using the body as a power source and large ones are being used to help power a brewery in Australia using its recycled wastewater.

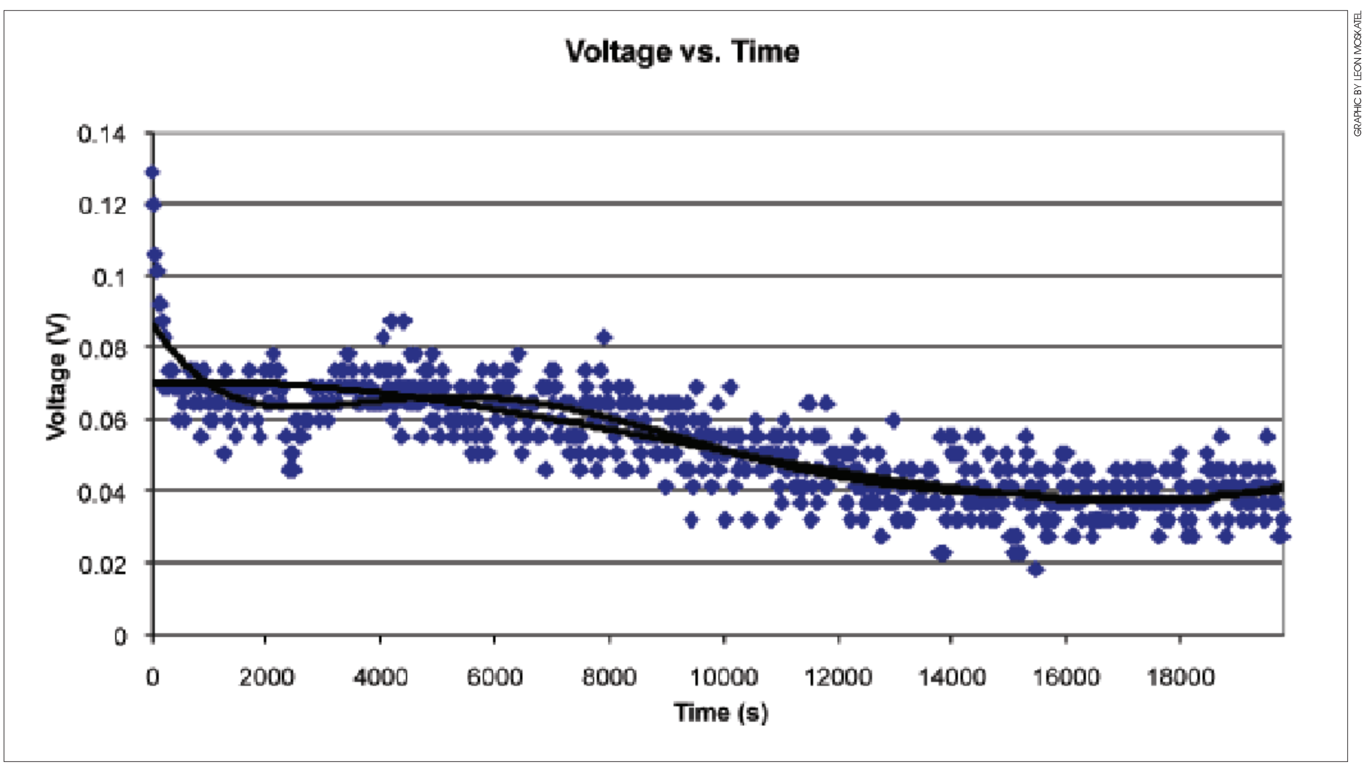
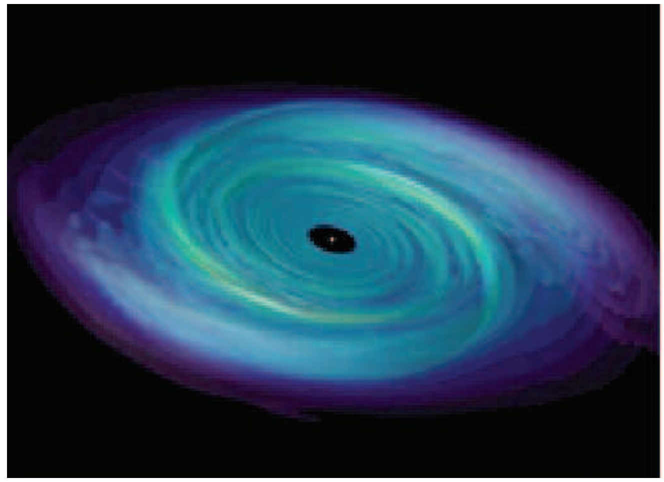


FIG. C SHOWS the relationship between voltage and time over a period of more than five hours. Two equilibrium voltages can clearly be seen, one at .07 V and one at .04 V. The overall trend shows decreasing voltage as the experiment goes on.

Measuring Arches star brightness

By Chris Ballard



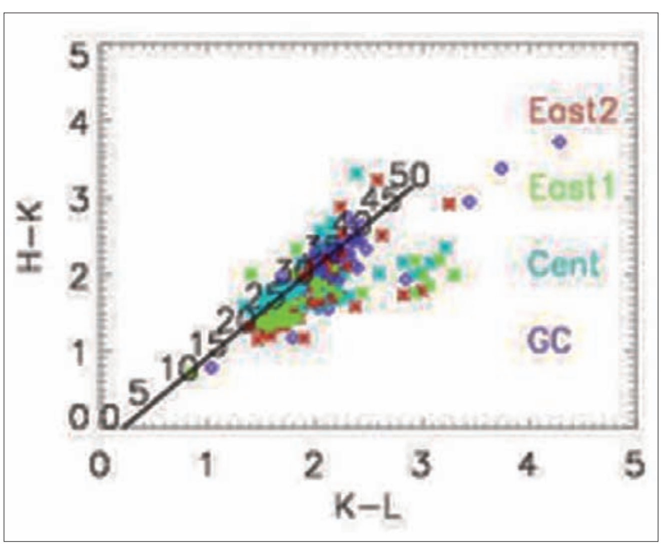
COURTESY OF CHRIS BALLARD

FIG. B IS a computer generated image of an accretion disk, a circle of interstellar material pulled towards a large star.

Imagine you are standing at the edge of a forest. Would you be able to look through the forest and see anything else besides trees? Of course not; the forest is far too dense. This same logic applies to stars: no one on Earth should be able to see any black night sky. Instead, the sky should be perpetually lit by the starlight beaming across the universe. Why, then, can one only see relatively few stars in the night sky when looking from the surface of the Earth? This phenomenon is caused by the massive amount of dust and interstellar material that floats between planets, filtering out light. The only way to discover and research stars that are blocked by this interstellar material is through the use of infrared or x-ray technology, which can observe bands of wavelength that are able to pass through this interstellar material unfiltered.

My research in the UCLA astrophysics department last summer involved analyzing infrared data regarding a group of stars known as the Arches Cluster, which is blocked by a huge cloud of dust thought to be near the center of the galaxy. The cluster is comparatively young (2.5 million years old) and is approximately 25,000 light years away from the earth.

There are at least 1,000 known stars associated with the Arches Cluster, and it is believed to host a few thousand more, ranging from the size of our sun to 100 times the size of our sun. My job involved using raw data to obtain measurements of observed physical properties of the stars in this cluster. For example, I calculated the flux of each star, which is the raw measurement of the brightness of the star. Additionally, I calibrated this data so that I could characterize the stars further. In order to begin this task, I learned how to use IDL programming and IRAF, which are computer program toolsets commonly used by astrophysicists. Using these tools I calibrated the data recorded on the L, H, and K bands of wavelength. These bands are all near-infrared wavelengths and cannot be seen with the naked eye. From these calibrated data sets, I calculated the magnitude, the brightness converted to a logarithmic scale, of each star. I then created color-color and magnitude-color graphs. For example, I graphed H-K vs. K-L, K vs. H-K, and K vs. K-L.



GRAPHIC BY CHRIS BALLARD

FIG. A GRAPHS data from the near infrared spectrum and suggests the presence of excess sources.

The difference in magnitude between two wavelength bands is called the color and represents the temperature of each star. Using this correlation to temperature, the graphs helped us to understand the properties of the stars.

I then adjusted for the extinction, the amount of dust between Earth and each star, again using IDL. With these graphs I identified excess sources, stars that have unusually large colors at long wavelengths and do not follow the expected graphical pattern of the majority of stars, a trend which is caused by extinction.

Despite interstellar dust, the brightness of distant stars can be measured with data from the infrared and x-ray spectrums.

Excess sources are critically important because they are caused by dust very close to the star and thus provide a view close to the star's environment. The excess source stars were all on the order of four to eight solar masses and were among the fainter stars in the cluster. Fig. A reveals that the majority of stars adhere to a best fit line.

The points below and to the right of the trend line represent the excess sources and suggest an interesting relationship between the star and the dust close to its surface.

Although many theories attempt to explain excess sources, more research must be done in order to fully understand their existence. The first and most likely theory out of those that have been proposed is that these stars have an accretion disk around them.

An accretion disk is a disk of dust and other interstellar material that is pulled in towards a star. This possibility is exciting because these disks can potentially turn into planets like those in our solar system.

Another theory is that these stars are cocooned in dust from the shedding of their masses. Others suspect that excess sources are caused by the bow shock effect; as part of the moving cluster, some of the stars simultaneously collide with a nearby cloud of dust.

The cluster has many very large stars on the order of 80-100 solar masses. The radiation and winds coming off these massive stars should evaporate any disk or dust cocoon present on any less massive stars. The final question that must be asked as research continues on this topic is how can these disks or cocoons exist on the lower mass stars?

Standing waves in microwave ovens

By Will Baskin-Gerwitz and Matthew Edwards

Introduction

Microwave ovens, which use electromagnetic radiation to vibrate polar molecules and produce heat, have become important kitchen appliances and are useful as tools for studying electromagnetic radiation, harmonics, and alternating currents. Consisting of a cavity magnetron, a high voltage transformer, a capacitor and a microcontroller, a microwave oven is a complex and unique system for heating food. The most important component of a microwave oven is the cavity magnetron, which produces electromagnetic radiation from high voltage direct current.

As microwaves enter the main cavity of a microwave oven, they are either absorbed by the food or rebounded off the walls, interfering with each other. Destructive and constructive interference creates regions inside the cooking chamber that heat at different rates. This pattern of nodes and antinodes results in uneven heating of food and is one of the focal points of our research project. We also examined safety of microwave ovens, methods for calculating the wavelength of the microwave radiation and effects due to antennas placed within the microwave cavity.

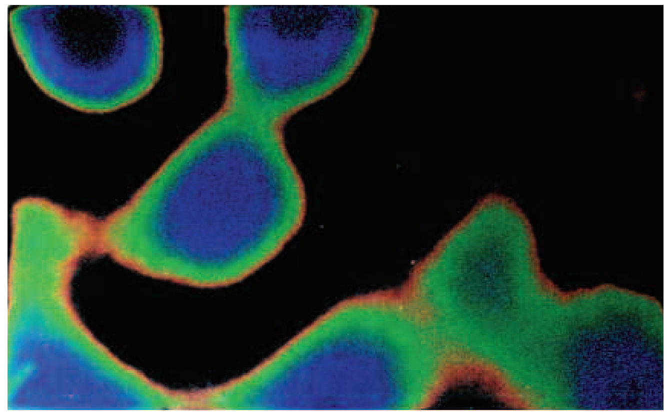
As part of our experiment, we took apart a broken microwave oven, cataloguing the parts. The toxic and dangerous nature of parts of the cavity magnetron prevented us from taking apart that component any further; the ceramic used in the magnetron causes lung disease and cancer.

Microwave radiation in enclosed spaces forms standing waves, producing regions of variable heat and inducing alternating currents in antennas.

The procedures that came up in our research for mapping the pattern of hotspots within a microwave leave much to be desired in terms of accuracy, flexibility and precision. Wet chemical paper, though accurate, must be placed horizontally within the microwave cavity to prevent the liquid from running and ruining the results.

Instead, we decided to use thermally sensitive liquid crystal paper to map temperatures inside the cavity; the paper can be cut and folded, and it displays up to five different temperature ranges. Since we had no record of this type of paper being used for this purpose, the first part of our project was an optimization of the experimental procedure for using liquid crystal paper to map microwave nodes.

The liquid crystal paper is sensitive to temperature changes between 30°C and 35°C. Below 30°C the paper is black. As the temperature rises, it turns first red, then green and finally blue. If the temperature goes above the measurable range, the paper turns black again. Regions that are black because they are too hot to register on the paper tend to be inside blue circles, whereas regions that are black because they are too cold are outside red circles. Metal pieces in our microwave occasionally reached temperatures which permanently damaged the liquid crystal paper, forming white blisters or melting holes in the paper.



WILL BASKIN-GERWITZ

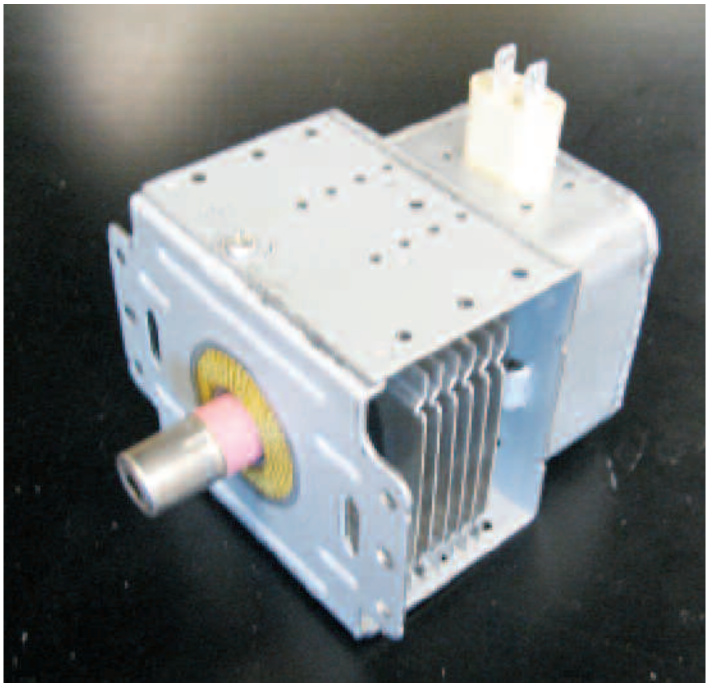
THIS SAMPLE picture from the optimization experiments shows the pattern of hotspots that appeared inside the microwave.

Optimization

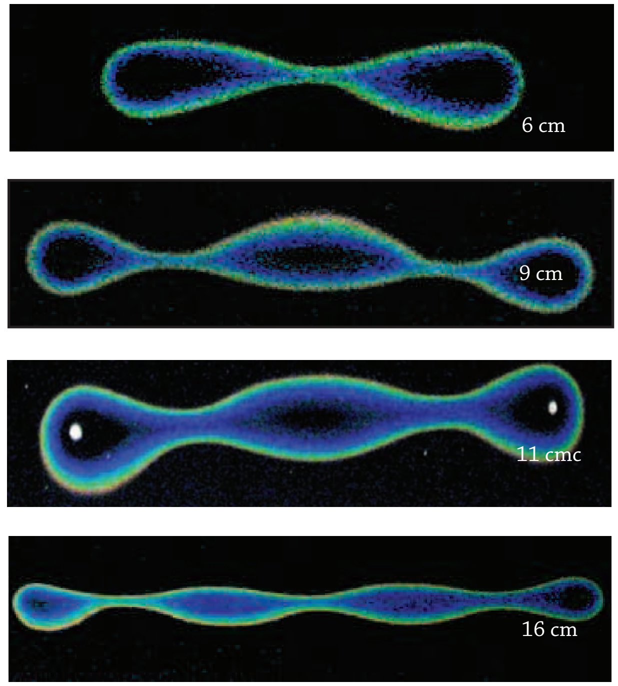
In our first trial, we placed a square foot of liquid crystal paper on a glass plate in the center of the microwave, set a small beaker of water in the corner, and turned the microwave on at varying time and power settings. When we had determined the best combination, we began to raise the glass plate on polyvinyl chloride pipes at one centimeter increments. The most difficult challenge we had to overcome was the reflectivity of the liquid crystal paper itself. We used a black backdrop and dimmed lights to remove ghost images of the room and the camera from the paper as we took photographs. With subsequent trials, our method evolved; we removed the glass and PVC pipe structure, placing vertical pieces of liquid crystal paper in the cavity, because the pipes were interfering with the node patterns. Eventually, we produced the method described below.

We covered the interior walls of a Kenmore model no. 721.66029 microwave oven with pieces of cardboard. Although this did not seem to make the pattern inside the microwave more regular, it did enable the liquid crystal paper to be set up more accurately. We then placed a fitted piece of liquid crystal paper inside the microwave vertically at a distance measured from the left wall of the oven. Placing the paper vertically instead of horizontally minimizes interference, because nothing is needed to support the paper. A small amount of water was placed inside the microwave oven, and the oven was turned on for a period of ten seconds. This resulted in an uneven pattern of heating of the liquid crystal paper and as a result a pattern of nodes and antinodes appears as in the picture above. We recorded the pattern present with a digital camera and used a black backdrop to prevent the reflectivity of the liquid crystal paper from producing ghost images. The images were modified using a photo editing program to make the patterns easier to discern.

As a result of the optimization experiments, we successfully mapped the patterns formed inside our microwave oven. A perfectly regular microwave cavity would have produced an even pattern of hotspots. However, the cavity for a commercial microwave is made irregular deliberately to minimize the effects of hotspots and produce more even



MATTHEW EDWARDS



ALL PHOTOS BY WILL BASKIN-GERWITZ

LEFT: THE MAGNETRON taken the microwave we disassembled; the model is fairly standard. RIGHT: THE HEAT patterns that appeared when we placed pieces of copper wire in the microwave. The pictures are not to scale relative to each other.

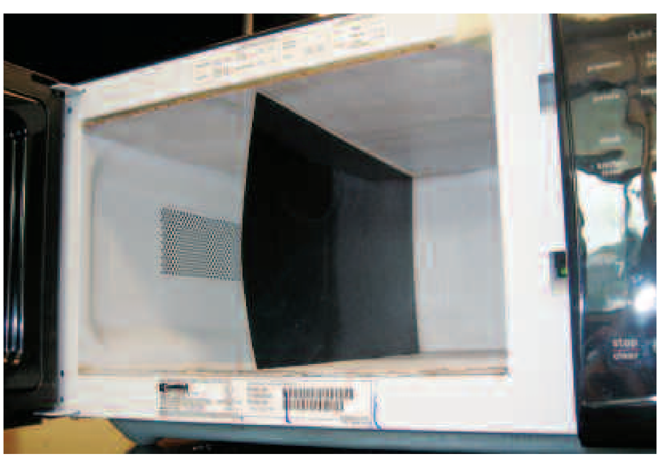
heating of food. We initially inserted fake walls made of cardboard in an effort to make the pattern more regular, but this had no noticeable effect. We continued to use the cardboard pieces in the microwave because they helped keep the liquid crystal paper straight and allowed for more accurate placement of any beakers of water required for a given experiment.

Determination of Safe Aperture Size

In our second experiment, we attempted to determine the size of the smallest hole penetrable by a microwave. To do this, we removed one of the pieces of cardboard and coated it with tin foil. The foil-cardboard barrier absorbed or reflected the vast majority of waves that hit it. Thus, when we placed the paper behind the foil and cardboard, none of the waves would get to the liquid crystal paper and the paper would not heat up or change color. After placing the cardboard in the middle of the cavity, we cut a small hole in the middle of the cardboard and the foil, making it larger and larger on each subsequent test.

The initial setup of the microwave for this experiment is similar to that in the optimization experiments, except that a piece of cardboard covered in three pieces of tin foil was placed vertically in the middle of the microwave. We used the piece of cardboard that had been covering the left wall of the microwave, so for this experiment, that wall was uncovered. Experiments determined that using only one piece of tin foil allowed measurable heat signatures on the far side of the foil, whereas three pieces cut the microwave penetration to negligible quantities. The piece of liquid crystal paper was placed near the left wall of the microwave cavity (so that the tin foil was between the magnetron and the paper). We placed 25 mL of water on the right side of the tin foil, as well as several small pieces of liquid crystal paper to make sure heat was being generated by the microwave. We turned the microwave on and then took a picture of the liquid crystal paper, replacing the water in the microwave. We drilled a small hole in the cardboard and tin foil, and enlarged the hole for each successive set of pictures.

Although we found significant penetration of the foil shield through a hole roughly one centimeter in diameter, the data from this experiment is not particularly reliable because it was particularly susceptible to contamination. Even in trials with no hole in the tin foil, some signal appeared on the far side of the barrier, suggesting leakage. Electrical arcing and heat signatures from foreign sources also may have influenced results in this experiment. In addition, we ran into serious problems with our materials, forcing us to abandon the retrials for this experiment until a later date.



MATTHEW EDWARDS

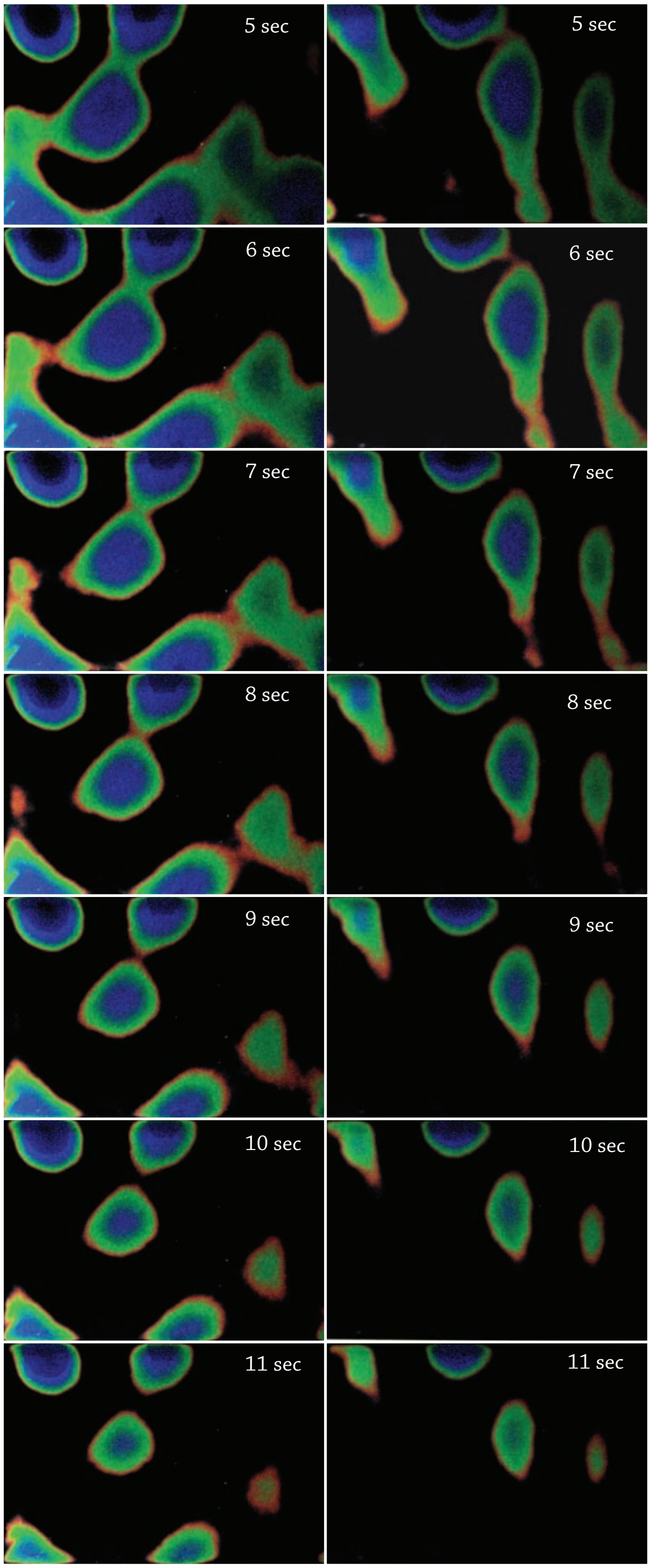
THE MICROWAVE that was used for the experiments. Most of the experiments set up the liquid crystal paper in this fashion.

Antennas and Alternating Current

The final set of experiments we conducted resulted from the accidental discovery that pieces of wire heat unevenly in microwave ovens, forming patterns of nodes and antinodes along their length. Using carefully measured pieces of copper wire, we set out to catalogue and describe the appearance of these nodes.

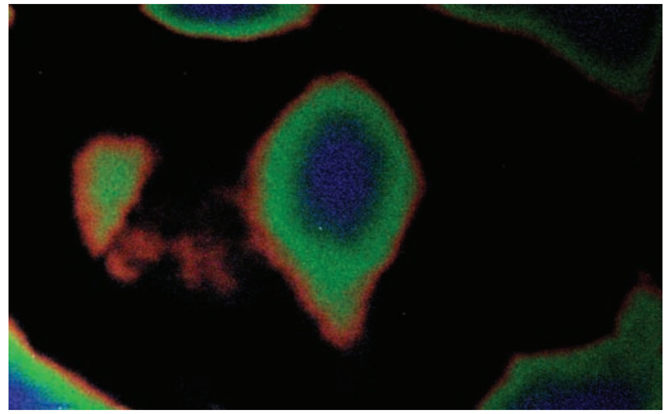
In the first part of this experiment, we cut pieces of copper wire at one centimeter intervals and then measured the number and positions of hotspots that appeared. We used a method similar to those developed in earlier experiments; the wire was taped to a piece of liquid crystal paper and exposed to microwave radiation for up to ten seconds. Consistently, hotspots appeared at the ends of the wires. Wire pieces longer than 8 cm had another hotspot in the middle, and even longer wires had more hotspots.

We determined that the radiation inside of the microwave was >>



ALL PHOTOS BY WILL BASKIN-GERWITZ

A TIME progression of the decrease in heat from the microwaves as the liquid crystal paper cools down.



MATTHEW EDWARDS

ANOTHER OF the temperature images. The center node was our microwave's largest hotspot, stretching over several slides.

inducing an alternating current in the wire; as a result of the current and its inherent resistance, the wire began to give off heat. We do not know why the heat pattern formed the shape that it did, but we do know that the shape of the pattern does not depend significantly on the position of the wire in the microwave, the composition of the wire, or the gauge of the wire. However, smaller gauge wires heated up much faster than larger wires, igniting the paper on several occasions. The length of the wire pieces affected the number and position of the nodes that appeared; longer wires had more hotspots, although the hotspots were always evenly spaced.

As a side note to this experiment, we realized that the pieces of wire were acting as antennas for the electromagnetic radiation in the oven cavity. A simple antenna should be a quarter of a wavelength long, and we realized that a piece of wire shorter than that would not pick up the emitted electromagnetic radiation efficiently. Pieces of wire shorter than 3 cm showed significantly less heating than pieces of wire more than 3 cm long. Given that the wavelength of the waves inside the microwave was about 12.2 cm (based on the frequency given by the manufacturer), this procedure seems to provide a rough estimate of the wavelength of the electromagnetic radiation.

Conclusion

The greatest difficulty we faced in this experiment was dealing appropriately with arcing, in which enough charge builds up at a specific point to overcome the natural resistance of air and create an electric arc between two points. This generally occurs as a result of placing metal inside the microwave. The intense light and heat generated by an electric arc can burn through paper and cardboard, melt aluminum foil and copper wire and damage the interior shielding of the microwave. We reduced the likelihood of an electric arc by arranging any pieces of metal we placed in the microwave so that two sharp points were never in close proximity and by placing some water in the microwave as a heat sink. On the few occasions when arcing did occur, we quickly turned off the microwave, keeping damage minimal. These tended to be when we had significant amounts of aluminum foil inside of the microwave that formed crinkles and gaps, which are the conditions that most commonly produce arcing.

The other recurring problem we faced throughout our set of experiments was that the liquid crystal paper picks up not just microwaves, but heat signatures in general. While this includes the microwaves, it also includes other heat sources such as the microwave lamp, our fingers, and any metal or water in the microwave. We tried to minimize this effect by covering all light sources; fortunately, the node pattern we were looking for is very distinct from the patterns created by other sources.

The timed photographs allowed us to observe the patterns as they cooled, providing a better idea of the real centers of heat in oversaturated photographs.

Sequences of ten photos show a given piece of liquid crystal paper at one second intervals as it cools after being removed from the microwave. The rate of cooling is dependent on the temperature of the room and the desktop, and did not relate to the pattern of nodes in the microwave.

The experiments we conducted demonstrate some of the effects that microwave radiation has in microwave ovens. As microwaves are used more and more frequently for an ever widening variety of tasks, a solid understanding of the principles behind their effects will be vital to their success.

Building an electric bike

By Katie Barcay, Michael Kim and Daniel Ozen

We began the year in Directed Studies in Scientific Research with concerns for the exhaustion of natural resources, particularly fuel. With this in mind, we formed a group focusing on the production of our own biodiesel and the implementation of the alternative fuel in a functional vehicle. However, after weeks of researching different procedures, we eventually realized the project was not feasible.

The production of biodiesel is a delicate process that requires fine filtering of vegetable oils, along with the use of fuel additives. Without the right equipment, the process of making biodiesel creates much more harmful emissions than petroleum, such as nitrogen oxide and hydrocarbons. Further, massive deforestation must occur to make room for the necessary crops which are often planted in nitrogen fertilizer and tilled using diesel-powered tractors. With this knowledge, we concluded that such a project would be counterproductive to our goal

Our discovery of the adverse effects of biodiesel sharply interrupted our plans for research, but also opened our minds to the complexity of this global issue. Exposing the quandary underneath the very public issue of alternative fuels heightened our desire to continue researching alternative energy resources and modes of transportation.

COURTESY OF WIKIPEDIA.COM

THIS PICTURE shows an electric bicycle similar to the one that has been outlined in the article.

Through further research, we stumbled upon the electric bicycle, often denigrated as the degenerate form of one of the world's most eco-friendly transportation methods. But after discovering that a long-hailed alternative energy source could be potentially disastrous, we began to wonder— why could the shunned, illegitimate child of electric power and manpower not prove itself a green technological advancement?

In an ideal world, a bicycle is a practical mode of transportation, but in a city like Los Angeles, where a local commute is still a relatively long distance, the thought of biking almost anywhere is daunting to most, and, as a result, our streets are gridlocked with cars.

The solution to the problem could very well be the electric bicycle, which allows the individual to bike without the agony of uphill climbs and pedaling to normal speed from a stop. This power-on-demand system makes the bicycle more accessible to those who are less fit or have a fairly long commute. Fascinated not only by the idea of the electric bicycle, but also by its form, we focused our research in the mechanics and production of the machine: the making of an electric bicycle.

Although the specific mechanics for building the bicycle were intricately planned out and are explained below, our group encountered several pitfalls that hindered our progress. Specifically, the need for a machine shop to manufacture the parts required to accurately build the bicycle was a limiting factor. Also the creation of a new rear wheel sprocket caused unexpected physical problems, since the preset gear ratios that were precisely calibrated to run the bicycle properly suddenly became misaligned.

How to build an electric bicycle

Begin by installing the rear sprocket onto the back wheel of the bicycle. This sprocket will connect the rear wheel to the motor sprocket, allowing for transmission. The rear sprocket should be 114 tooth, made to fit the #35 roller chain which will connect it to the motor sprocket.

Before installing the rear sprocket, mark where the spokes of the rear wheel will come into contact with it and drill several holes into the sprocket at these points. Then, after removing the rear wheel from its axle, connect the sprocket to the spokes of the wheel, holding it in place with nuts, bolts, and washers.

Mount the motor sprocket onto the motor axle using the set screw included with the motor sprocket. The motor sprocket should be 9 tooth with a 5/8 inch bore, made to fit a #35 roller chain. Knowing roughly where the motor will sit behind the seat, place the motor sprocket so that it lies flush with the rear sprocket. Fine adjustments can be made to the motor sprocket once the motor itself has been mounted.

Using a manufactured seat post tray, mount the motor behind the rear wheel of the bicycle. First, drill holes into the tray to hold the motor in place. Then mount the tray to the frame of the bicycle and bolt the motor into the tray.

Fitting the chain from the motor sprocket all the way around the rear wheel sprocket, measure the length needed, remove the excess links, and reconnect the chain so that it fits snugly. At this point, make sure that the motor sprocket is completely in line with the rear sprocket, so that the chain is not at an angle. If it is, it will cause unwanted stress and wear on both it and the motor.

Use either a saddle bag to hang the battery off the bicycle frame or create a battery mount by clamping metal runners to the bicycle frame and then strapping the battery in place on those runners.

Mount the motor controller to the front of the battery using a pair of cable ties.

Install a twist-grip throttle to the right handlebar of the bicycle and adhere silicon rubber to the handlebar to create a secure fit if there is not one initially.

Connect the leads from the battery to the motor controller using 4 gauge cable. Next, connect the motor itself, soldering where necessary or using crimp connectors in order to ensure that the motor remains safely attached.

> The electric bicycle is an efficient alternative to oil-based transportation which has the advantages of a bicycle while removing the necessity for human power.

But as mentioned in the introduction above, the real question was how energy efficient the electric bicycle could possibly be. Ingrained in the backs of our minds was the analogous pitfall of nuclear fusion: the energy required to actually fuse two particles together is so exorbitantly high that the process is widely regarded as an energy inefficient procedure. Thus it raises the question for the electric bicycle: will the start-up energy of the bicycle (i.e. the initial foot pedal) paired with the energy released by the battery more than compensate for the energy converted into mechanical energy within the bicycle?

We hope we have opened your eyes to one possible solution to our energy and transportation problems.

Traversal time of Gaussian wave packets through simple potential barriers

By Andy Lucas and Jonathan Lee

Many studies have been done before using computational models to analyze the traversal time that is required for a particle to (presumably) tunnel through a potential barrier. However, these studies have often used plane waves to study the effects of various energies on the traversal time and have neglected to look at real wave packets, and have also failed to consider the effects of changing variables such as mass. Using a flexibly built computational model for the linear Schrodinger Equation, we were able to analyze the effect of these variables.

A flexible computational model for the linear Schrodinger Equation using real wave packets instead of plane waves allows for analysis of the effect of several additional variables on traversal time for a particle through a potential barrier.

Simple theoretical considerations

One reason why plane waves were used in most previous simulations was because they have constant energy. Unfortunately, these Hamiltonian eigenfunctions are not normalizable; therefore, real free particles must be wave packets - made up of a continuous "spread" of energies. Using a Gaussian wave packet instead allows us to analyze the effects on real particles, not on particle beams (for which particles may still not have perfectly known energies anyways).

The Gaussian wave packet is given by

$$\Psi(x,0) = \frac{1}{\sqrt[4]{2\pi\sigma^2}} e^{-\frac{1}{4}\left(\frac{x-\mu}{\sigma}\right)^2}$$

For the rest of the discussion, the width of the potential barrier will be given as w and the height as V_0. The potential energy is given by $V = V_0$ for $0 \le x \le w$ or $V = 0$ otherwise. The traversal time is determined by Δ = $_c$ - $_0$, where $_c$ is the first time for which, for a given probability P,

$$P = \int_w^\infty \left|\Psi(x,\tau_c\right|^2 dx \Rightarrow P = \int_0^\infty \left|\Psi(x,\tau_o\right|^2 dx$$

We will use the notation

$$k = \sqrt{2mE} / \hbar$$

Calculating barrier width

If the width is w, then the traversal time, which will be notated from here on out as Δ is approximately given by the formula

$$\Delta\tau = w / \langle v \rangle = mw / \langle p \rangle$$

Therefore, $\Delta \propto w$.

Calculating height of the barrier

It is difficult to analyze the effect of height. Assuming that the average value of energy is less than V_0, then the eigenfunctions inside the potential barrier may be approximated by $\Psi = Ae^{-lx}$ where

$$l = \sqrt{2m\left(V_0 - E\right)} / \hbar$$

Consider that $\Psi(0)/\Psi(w) = e^{-lw}$. The (meaningless) probability value over this wavelength is therefore $p = A^2 / (2l(1 - e^{-2lw}))$. If we approximate that traversal time is about inversely proportional to this,

$$\Delta\tau \propto \frac{1}{1-e^{-2lw}} \propto \frac{\sqrt{V_0 - E}}{1-e^{-C\sqrt{V_0 - E}}}$$

for a constant C.

Calculating standard deviation of the initial wave packet

All Gaussian wave packets have an uncertainty given by

$$\sigma_x \sigma_p = \hbar / 2$$

Thus, the uncertainty spread in momentum is given by

$$\sigma_p = \hbar / 2\sigma_x$$

Let us assume that all of the wave packet will be transmitted (as such, the approximation should only be valid for small percentages). The distribution of $\varphi(k)$ approximately represents a Gaussian distribution; i.e. $\varphi(k) = A\exp(-k^2\sigma_x^2)$.

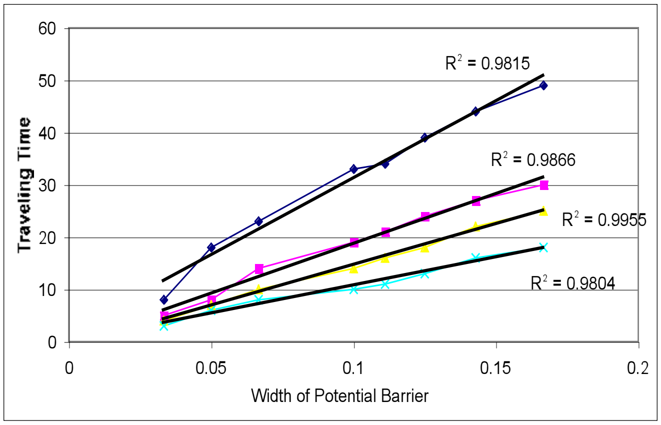
Therefore, by increasing the standard deviation σ_x to $\sigma_x' = \alpha\sigma_x$, we can effectively think of this as also changing the standard deviation of $\varphi(k)$ from σ_k to σ_k / α. Let us approximate $\Delta\tau$ as it is given by the basic formula stated earlier, and let k be such that

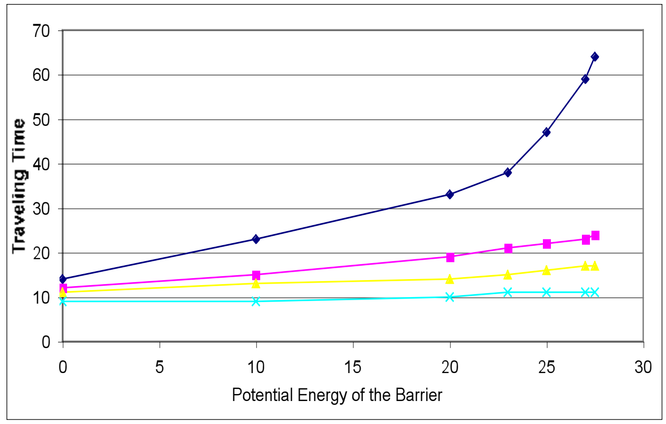
$$\frac{P}{2} = \int_{k_o}^{\infty} Ae^{-\left(k^2/2\sigma_k^2\right)} dk$$

for some given probability P. Now, suppose that σ_k has become σ_k/α. Correspondingly, this critical k_c value is now given by $k_c = k_0/\alpha$. Since $\Delta\tau \propto k^{-1}$, then $\Delta\tau \propto \alpha$ and $\Delta\tau \propto \sigma_x$.

Calculating mass of the particle

We can determine the wavelength composition of a free particle indirectly through the variable k, and a Fourier transform. The spread of wavelengths as given through the wave number k is independent of mass. Since $p = (h/2p)k$, the momentum is also independent of mass. Therefore, since we can approximate that





THE GRAPH at left shows $\Delta\tau$ vs. w. Varying the width of the the potential barrier resulted in less deviation from the theoretical values. At right, the graph of $\Delta\tau$ vs. V_0 illustrates the effect of changing the potential.

$$\Delta\tau = mw / \langle p \rangle$$

we see that $\Delta\tau \propto m$.

Experimental results

The correlation coefficient for the trendlines corresponding to the appropriate approximate relationships between $\Delta\tau$. The R^2 values are listed on the graphs. The dark blue line on the graphs refers to the time for P = .1; the pink, P = 0.05; the yellow, P = 0.03; the light blue, P = 0.01.

Width of potential barrier

The results obtained by varying the width of the potential barrier deviate from the values given by theoretical predictions by less than the other three variables discussed in this paper. What is more impressive is that the approximation is quite accurate even at large potential barrier widths. The obvious classical result also holds true at the quantum level.

Finally, note that the values of $\Delta\tau$ and any of the variables are only relative and have absolutely no physical meaning. The associated unit is not important.

Height of potential barrier

Using the approximation that $E \approx \sigma_p^2/2m$ we find that $E \approx 3$. Therefore, our approximation should be valid for most of the data points. However, we do not see any sort of approximate square root relationship between $\Delta\tau$ and V_0.

Also note that the most likely wavelengths to tunnel through have higher energies, so the expectation value of E is not a good choice for use.

Standard deviation of the initial wave packet

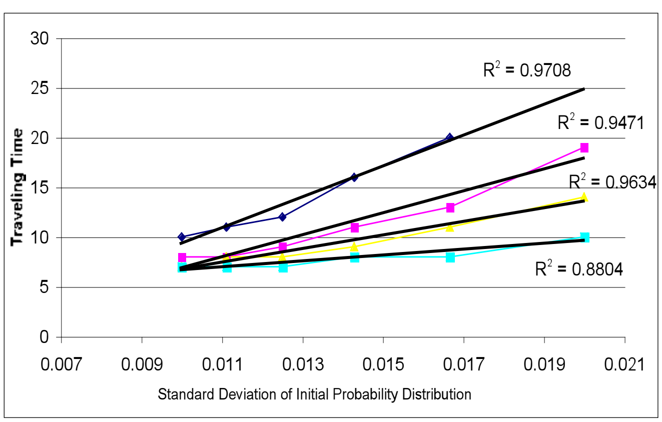
The standard deviation, σ_x, of the initial wave packet follows, at first, a linear approximation to the curve, as is demonstrated by the R^2 values. Yet, as the value of P, probability, and σ_x increase, there seems to be increasing deviation from this approximation. Still, it is valid for small values.

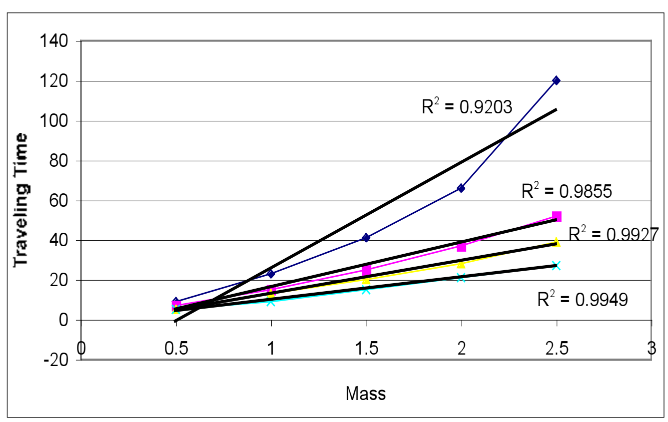
Mass

For the most part, the mass is reasonably predicted by the data, particularly at the lower values. There does seem to be significant deviation from the theoretical linear approximation, however, at larger masses and values of probability, P, as usual.

Conclusion

In conclusion, the computational model was effective in demonstrating reasonable traversal time approximations while varying several variables such as σ_x, m and w, although for V_0, there was no optimal way to approximate the traversal time. In considering the width, there seemed to be no deviation from the linear relationship between w and $\Delta\tau$, even at larger widths. However, for all of the other variables, there was clear deviation at large values. Nevertheless, the model was able to demonstrate when the theoretically-derived approximations were valid or not, in a problem almost impossible to solve theoretically.





AT LEFT, the graph of $\Delta\tau$ vs. σ_x highlights that the approximation is only valid at small standard deviation values. $\Delta\tau$ vs. m, shown in the graph at right, again reveals that the theoretical values are more accurate when the variable is small.

DSSR 2007-8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THE ROSTER

- Self-sustaining gym
- The Arches Cluster
- Building an electric bike
- Plasma armature rail gun
- Creating a self-balancing scooter
- Solar refrigeration applications
- Solar insulation of a modern house
- Plant oil stove efficiency
- Non-diffracting beams
- LED experimentation
- Listening in with lasers
- Standing waves in microwave ovens
- Quadrotor UAV technology
- Measuring skyglow
- Electric car modeling and efficiency
- Traversal time of Gaussian wave packets
- Microbial fuel cells


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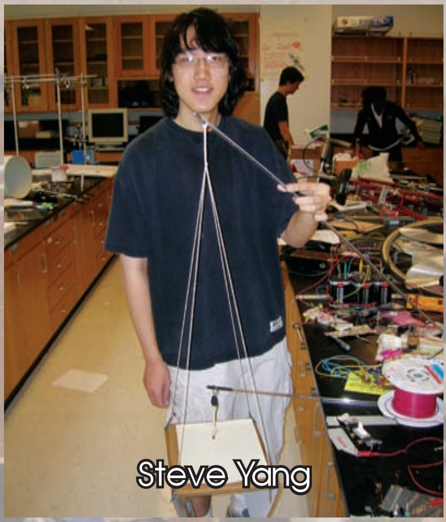
Lesley Whitaker, Rebecca Gotlieb and Madison Stanford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Solar cell refrigeration

By Rebecca Gotlieb, Madison Stanford and Lesley Whitaker

Our Directed Studies in Scientific Research project aimed both to improve the efficiency of solar cells and to expand the applications of solar power. We believe that advancing the use of alternative sources of energy is imperative because our current sources are politically, economically, and, most importantly, ecologically irresponsible. We focused on solar energy as an alternative power source because it is essentially unlimited and under-harvested. Moreover, this field of study allowed us to maintain our goals of practicality, innovation, and affordability. In keeping with these goals, we developed a water bag mechanism to improve our cell efficiency and applied this new system to power a thermoelectric refrigerator.

The photoelectric effect is key to the function of solar cells. Light carries energy from the Sun to the Earth and strikes the cell. The absorption of photons provides the energy to free electrons in the material of the cell. The flow of these freed electrons is the generated electricity. In other words, electromagnetic radiation is converted to electrical energy through the photoelectric effect.

> The photoelectric effect is the key to the solar cell and allows an expansion of the applications of solar cells and an increase in their efficiency.

The equation for the photoelectric effect is

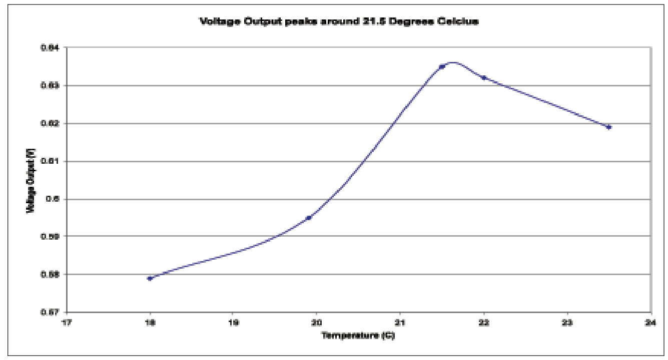
$$KE = hf - W$$

where KE is the kinetic energy of the photon, h is Planck's constant, f is the frequency of the light, and W is the work function. The energy of the escaped electron is equal to the energy of the photon minus the energy needed to free the electron from the metal. Since the energy of a light wave is proportional to frequency, only light with a high frequency will have enough energy to displace the electrons of the metal.

One aspect of solar cell efficiency we hoped to improve was the configuration of the cells on the solar panel. Most store-bought solar panels have a fairly arbitrary configuration of cells that does not necessarily maximize the power output for the specific device to which it is applying a voltage. In order to maximize power output, we used the equation:

$$P = \frac{\varepsilon^2 R}{(R+r)^2}$$

where ε is the electromotive force (emf) of the solar cell when exposed to a particular amount of light, r is the internal resistance of that solar cell, R is the resistance of the device powered by the solar cell, and P is the amount of work the device can do per unit of time. The graph of P as a function of R peaks when R = r, meaning that power output is maximized when the total internal resistance of the solar cell configuration is equal to the resistance of the device being powered. In order to achieve the maximum power output for our apparatus, we calculated the internal resistance of a single solar cell. First we used a voltmeter to measure the potential difference between the two terminals of the solar cell when exposed to a certain amount of light. Without current flowing, the internal resistance of the solar cell had no effect, so we were simply measuring the emf of the solar cell under those particular light conditions. We then connected the solar cell to a circuit of known resistance, R, and



GRAPHIC BY REBECCA GOTLIEB, LESLEY WHITAKER AND MADISON STANFORD

THIS GRAPH shows the dependency of voltage on temperature and the solar cell's maximum efficiency

measured the voltage, V, between the terminals. We used the following equation to calculate the internal resistance of a solar cell at a particular light intensity:

$$V = \frac{\varepsilon R}{(R+r)}$$

From these calculations, we were able to determine the internal resistance of the solar cell at that particular light intensity. For our apparatus, this was approximately 9.2 Ω. We determined a configuration of solar cells, some in parallel and some in series, such that the total internal resistance was equal to that of our thermocouple module. This maximized power output. But solar cells are semi-conductors; consequently, they do not follow Ohm's Law and their internal resistance changes based on light intensity. In order to further understand the effect of varying light intensity on internal resistance, we also hope to experiment with different frequencies and intensities of light, including different colors in the visible spectrum and infrared light.

In our research we found that key factors affecting solar cell efficiency are temperature, the build-up of grime on the cell, and the amount of light that actually reaches the cell. We saw the effect of these factors for ourselves in the lab. We observed that voltage output peaks at around 21.5° C, that additional grime decreases efficiency, and that placing a magnifying glass between the cell and the light source increases the voltage output. Our initial idea to optimize these factors was to have a constant stream of water over the solar cells. The water pressure would prevent grime from accumulating on the cells and refracting light. Finally, the water itself would act like a magnifying glass so that more light would reach the cells. We ultimately determined that pumping water over the cells would be energetically costly, so we settled on our water bag mechanism, in which we filled a durable clear plastic bag with water, evacuated it of air, and laid it on top of our solar cells. Although a stationary water bag over the cells does not prevent the accumulation of grime, it is much more energy efficient than the pump method and still helps control temperature. Furthermore, the water bag system is even more effective at magnifying the light than a pumped stream of water. The water bag mechanism approximately tripled the solar cells' efficiency from about 0.5 V to about 1.5 V under our experimental conditions.

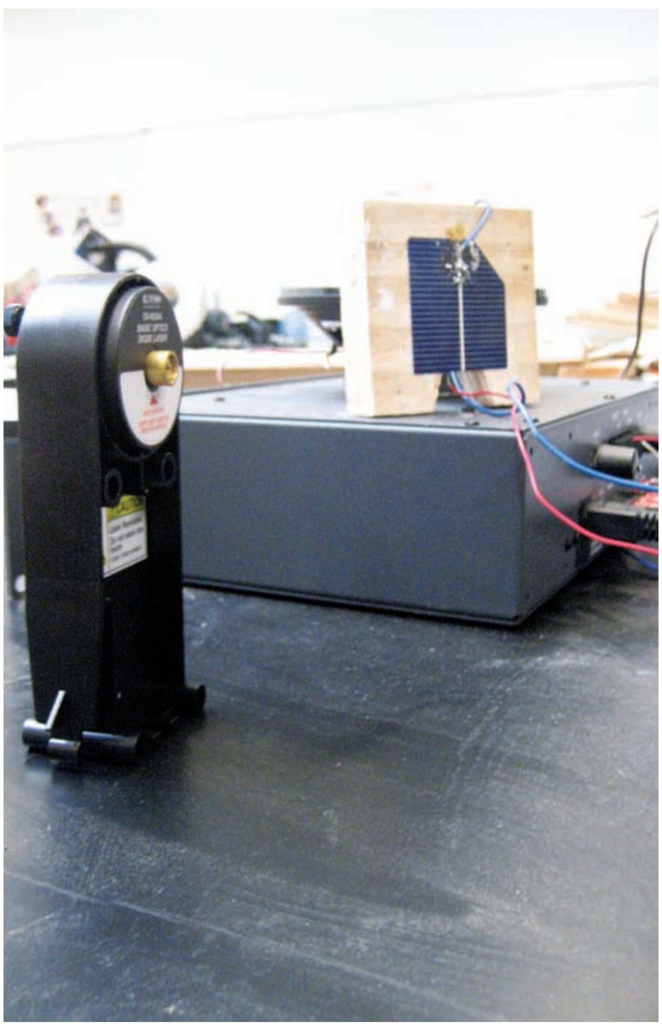
Having successfully constructed a design for more efficient solar cells, we set out to use our solar cells' power for a thermoelectric refrigerator. A thermocouple, an integral component of the thermoelectric refrigerator, is a device comprised of a pair of two conducting metals and uses an electric potential difference to create a temperature gradient. We used the voltage from the solar cells to create a temperature gradient for the refrigerator. To set up a thermocouple, two wires from the same type of metal are attached to either terminal of the voltage source. A dissimilar wire is then used to complete the circuit. Since the current is flowing in the same direction throughout the circuit, the positions of the metals with respect to the current are switched between the two junctions. For example, current may first flow from constantine to iron and then from iron to constantine. This causes one junction to get cold while the other will get hot. By isolating the cold junction, it is possible to make a thermoelectric refrigerator.

Eavesdropping via solar electronics

By Alexa Bagnard and KC Kanoff

The ability to eavesdrop through a window is a fascinating concept that many would think to be impossible. Using a laser reflected off a window pane, a solar cell, an amplifier and a speaker, we have attempted to create a simpler version of Alexander Graham Bell's photophone. During the 1880s, Alexander Graham Bell devised a system for modulating light from the sun and receiving this light some distance away where it could be converted into audible sound. Eventually, Bell connected a sensitive earphone to selenium cells, which could clearly reproduce a voice from the mouthpiece. This device would become the photophone.

The photophone is the commonly recognized progenitor of many modern optical communication devices. This device made it possible to listen to conversations inside distant rooms through windows. It is this laser microphone system, a modern variation of Bell's photophone, which we have attempted to reproduce. Our goal this year has been to mimic the systems created by professionals at a fraction of the cost.



MATTHEW EDWARDS

THE LASER and solar cell setup that we used to measure the distortion of the glass pane in response to sound.

To perform this experiment we used panes of window glass of different thickness and smoothness, a silicon solar cell, a neon laser, an audio amplifier, a speaker, and a boom box. We placed the window glass between two metal rods that were connected to a piece of wood. It is necessary for the window to be propped up with minimal contact so that it is free to vibrate, but we have struggled with this because the metal rods make the window less responsive to audio waves. The radio is then placed as close as possible to the window without touching it.

The laser is set up on the other side of the window, at a chosen angle of incidence. In this lab, we used a solar cell as our receiver, which is placed on the same side of the window as the laser. The angle at which the laser hits the solar cell is important because some solar cells can be overdriven by a bright laser beam, causing some of the modulated light signal to be clipped when converted to a voltage.

> A modified photophone uses a laser to measure vibrations of distant windows, allowing a listener to eavesdrop on conversations in far off buildings.

We turned off the lights and placed the solar cell in a covered box with a single entry hole cut out in front so the reflected light could pass through. This prevented the solar cell from receiving light from the environment, which would be reproduced as unwanted audible noise. Signals from the solar cell are sent by a wire to an amplifier and then to a speaker.

The radio produces sound on one side of the window, which causes the window glass to vibrate, changing the center of curvature of the window and causing the focal length of the window to change. As a result, a varying divergence is created in the reflected laser beam. These variations in the energy density correspond to the original audio information coming from the radio. The variation in energy density at the solar cell causes the voltage across the cell to fluctuate. The modulated light energy density carries audio information to the solar cell, which in return transforms it into a fluctuating voltage. The voltage signal carries the original audio information and is sent to the amplifier where it is amplified to a level that can drive the speaker. The sound that produced by the speakers is recognizable as that being produced by the boom box.

We began experimenting with tapping the glass and listening to changes in the sound produced by the speaker. We then tried talking behind the glass but that proved to be unsuccessful since the glass did not measurably flex. Next we tested whether the smoothness of the glass effected the sound produced. We discovered that using a coarse piece of glass, which we called rough glass, diffracted the laser beam causing it no longer to hit a single point on the solar cell. As a result, the angle at which the laser hit the solar cell no longer changed as we tapped the glass and thus there was no detectible change in audible sound coming from the speaker.

Building rail guns

By Robert Barry

The physics behind rail guns

A rail gun is simply a mass driver that takes advantage of the Lorentz force created by a current-carrying loop. Two parallel rails are hooked up to a cathode and an anode, and when a conductive armature is inserted between the rails, the circuit is completed and current starts to flow. This creates a magnetic field at a right angle to the rails, which interacts with the current flow in the armature to create a force between the two rails that is perpendicular to the armature and parallel to the rails. If the armature is free to move, acceleration proportional to the input current occurs.

Plasma armature rail guns

A plasma armature rail gun is one that uses some sort of plasma to bridge the circuit gap instead of a solid armature. The easiest way to create plasma between the two rails is to start with a solid state armature, such as a strip of aluminum or gold foil, then apply enough voltage so that it will undergo ionization. During this process, the foil has enough energy pumped into it that it vaporizes and becomes a gas. That gas is then energized to the point where it becomes plasma, which is conductive and can complete the circuit. This state is difficult to achieve because of the containment factor. The voltage must be large enough to convert the foil to plasma on first touch; otherwise, the foil molecules will simply vaporize and disperse, breaking the circuit. Secondly, if heat dissipation is too great, then any plasma that is created will lose all its energy as soon as it is made, which again will cause it to change states and break the connection. However, even with these difficulties, there are several advantages to plasma armatures. In a solid-state armature rail gun, one must be very careful that the slug does not heat up too much and then deform and weld to the rails. This problem limits the amount of voltage that can be safely applied. In contrast, when using a plasma armature, high voltage is no longer a problem but a necessity, for it is needed to convert the initial armature into plasma. Also, with the exception of the initial contact site, there is significantly less wear on the rails when using a plasma armature. Also, this setup can be used to propel a slug of almost any nature, including non-conductive projectiles. The firing of the unlinked projectile produces little to no corrosion. The use of plasma to bridge the circuit gap can thereby both greatly extend the life of the gun and preserve the condition of the projectile.

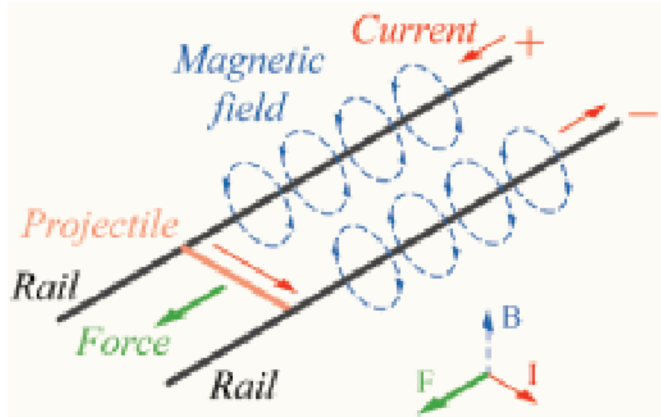
> A plasma armature railgun creates a field and uses Lorentz force to accelerate a mass to significant speeds.

The initial design

The initial design of my rail gun was simple. Two one-inch by one-inch steel rods, each one foot in length, were sandwiched between two sheets of high impact Lucite and bolted down, leaving a ¼ inch gap between the rails. At first the bolts were used as a spark gap firing mechanism: in order to fire, the operator would touch the leads from the power source to opposing bolts in the rails. The initial power source was a capacitor bank containing a large number of smaller capacitors in parallel. These initial capacitors were 400 μF and rated for about 2.5 V. The charging circuit was constructed from 6 V batteries wired in series and was connected to the capacitor bank via a resistor to regulate the voltage. When the capacitors were charged, the batteries were disconnected and the capacitor leads were used for spark gap firing of the device. The armature that was initially used was a dense tinfoil square constructed by folding the tinfoil back upon itself and loaded about one inch from the back breach. The size of the round increased friction but ensured the armature would maintain contact with the rails throughout the firing.

Testing the initial design

As test firings demonstrated, there were several problems with the initial design. The physical layout of the device proved to be effective and sturdy in all areas, but it too dissipated heat too effectively. The rails and gap were too large for the amount of power that was being used. As a result of this problem and the energy-inefficient spark gap firing, no plasma was created. Both these problems could be remedied by the addition of more power to the system. It was simple enough to add more capacitors, but there was a problem with the bank. The low voltage ratings of the smaller capacitors made them significantly less stable when subjected to the immense power requirements of a rail gun. In the discharge cycle of the capacitor bank, it was common for a capacitor to overload and then explode. This in turn would cause a cascade effect leading to larger energy buildup in the remaining capacitors, which then also exploded. The only truly successful component of the initial tests was the charging circuit, which required no modification.

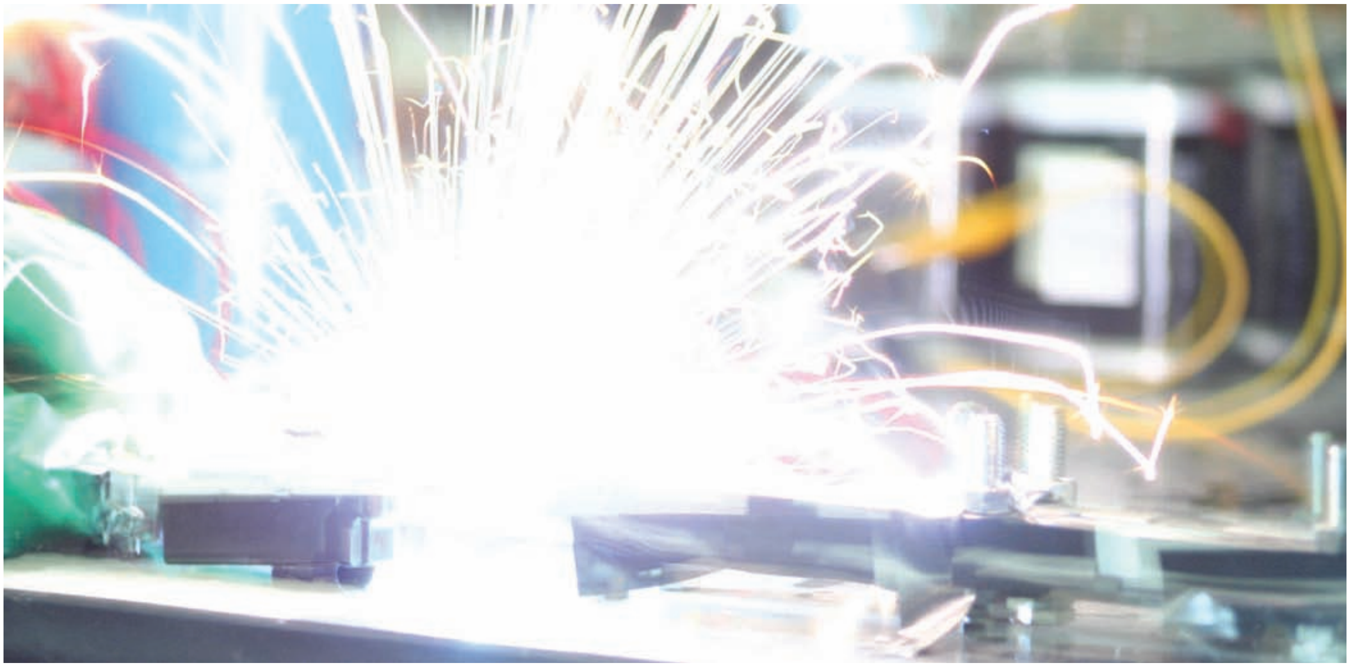


GRAPHIC COURTESY OF ROBERT BARRY

FIG. A SHOWS the effect of Lorentz force while a rail gun is being fired; rail guns use well known physics principles.

ROBERT BARRY

FIG. B IS a picture of my rail gun being fired. The blue spark is a piece of tin foil being vaporized to create plasma.



THE SPARKS in Fig. C are a result of the vaporization of material that occurs due to the high voltage used in the rail gun. One of the blue capacitors is just visible in the background, and the rail gun extends to the right.

Implementing changes

In order to remedy the capacitor circuit problems, I used the same design but with multiple capacitors of a larger capacitance. This way any charge overflow could be safely contained and the system would still be very safe to work with. For this purpose, 50 F, 3.2 V capacitors were purchased. These created a noticeable improvement due to the increased energy provided by the higher volt rating, but the capacitance was too high. An entire discharge took about 3 minutes, which meant that while there was enough energy stored in the bank, the power delivered was too small to generate a notable force.

Instead of immediately changing capacitors, I decided to change the shape and density of the projectile to reduce friction and the energy required for ionization. I determined that the most effective shape for these new projectiles was cylindrical, which could be produced by wrapping a small length of tin foil around a pencil. This new design ensured constant contact while keeping the density at a much lower level.

Even with all of these changes, there still hadn't been any plasma produced thus far. This was because of the enormous amount of heat dissipation that occurred during firing. Since heat dissipation is intrinsic to the device, there was very little that could be done save dismantling it entirely and rebuilding with different materials. The top sheet of Lucite was removed. This slightly increased heat dissipation, but allowed the operator to change the length of the barrel and observe any effect. Reducing the barrel size did create a marked improvement to the movement of the projectile within the barrel; however, still no plasma was created, so I turned back to the capacitors.

Although I previously focused on capacitance alone for the capacitors in the rail gun, other factors needed to be considered. Enough joules of energy have to move through the projectile in the first instant of contact to ensure ionization; therefore, a capacitor with a higher voltage rating was needed.

Two new capacitors were ordered, each with a capacitance of 46,000 μF and a voltage rating of 100 V. A test was run using just one of these capacitors and encouraging results were produced. When contact occurred in the spark gap, the two electrodes welded together and sheared off at the contact point. Even without very much containment, some plasma was produced and accelerated. This was a huge leap forward, but brought to light some large issues as well. Firstly, there was a huge amount of energy wasted by using a spark gap firing system, as demonstrated by the effect produced on the electrode leads. Secondly, discharging the capacitor after use still produced a large amount of energy, which meant that all the stored energy in the capacitor was not used during the firing cycle. This was because the sides that had been in contact with the rails had been sheared completely off, leaving the top and bottom relatively unscathed. This meant that all the plasma produced came from the sides of the foil projectiles, and after these sides converted and accelerated forward, contact was lost with the remains of the projectile. Thirdly, the removal of the top sheet of Lucite, though making the barrel significantly easier to load, clean, and vary in length, caused a containment problem. Plasma was directed upwards in addition to outwards during firing.

The spark gap problem was fairly simple to remedy—all that was needed was a switch. The addition of a switch ensured that almost no energy leaked out of the circuit before encountering the armature, and made the discharge cycle significantly more predictable. Charging and firing switches are now incorporated into the design, and should the capacitor bank grow much larger in the future, the addition of a discharge switch might be necessary. The simple addition of the switch caused an enormous improvement in performance without any change to the projectile; enough force was generated to shoot plasma out of the end of the barrel.

However, in firing consistent contact was not always maintained long enough to ensure enough energy input into the system. The projectile shape has been a more difficult problem to solve. It is clear that a shape of very low, uniform density is required. This ensures that ionization occurs simultaneously throughout the projectile and there is no loss of conduction. Preliminary testing indicates that more consistent firing can be achieved by using a strip of foil cut into small squares, which can be overlaid to achieve increased density if required. Adequate containment was achieved simply by replacing the Lucite top, but damage to the Lucite at the initial firing point is significant enough to require occasional replacement. The addition of the second capacitor greatly increased the consistency and magnitude of the firings to the point where plasma expulsion was more consistent. This led to the conclusion that significantly more power was needed, and so I obtained three 6200 μF, 350 V capacitors. This called for an increase in the power of the initial charging circuit.

Once I purchase additional batteries, my research will continue. All results thus far have indicated that the plasma armature rail gun is a viable candidate for further and large scale testing. Given the proper advancements, all of which are within close reach, there is nothing to prohibit widespread use of plasma armature rail gun technology.

Taking measurement of nighttime skyglow

By Sandra Cohen and Claire Seifert

Those from urban areas might notice that when they gaze into the night sky away from the city, many more stars are visible. This is caused by a type of light pollution known as sky glow. Sky glow is scattered artificial light in the atmosphere that is refracted back towards the ground. This phenomenon, known as Rayleigh scattering, is dependent on the wavelengths of the artificial light as well as the amount of aerosol present the atmosphere. Sky glow in urban areas, where there is a significant amount of aerosol, reduces contrast in the night sky to such an extent that only the brightest stars are visible.

Measuring sky glow

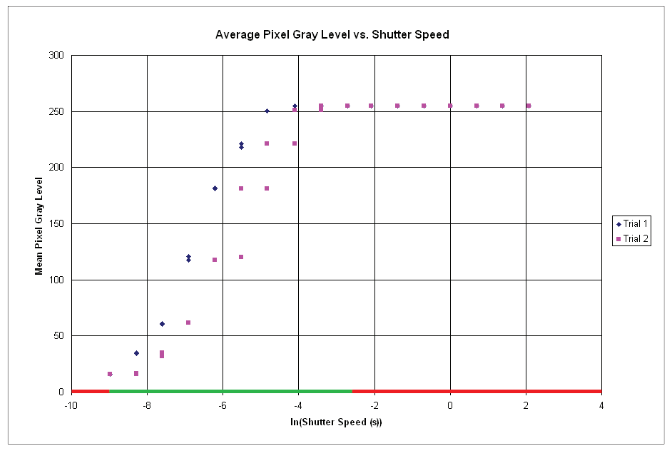
For our experiment, we used digital photography to quantitatively measure, in terms of light magnitude, the amount of sky glow in the Los Angeles area. We first measured the dynamic range of our Nikon D70 camera in order to know its light sensitivity. Our graph shows average pixel gray level vs. shutter speed that was used to determine dynamic range. The green region indicates the dynamic range of the camera, while the red region indicates shutter speeds outside this range. The dynamic range of the Nikon D70 included shutter speeds from 1 to 17 milliseconds.

> Rayleigh scattering of artificial light in the atmosphere causes sky glow, which reduces contrast in the night sky and hides all but the brightest of stars.

After finding the dynamic range of our camera, we took digital pictures of the night sky from the same location in Los Angeles. We only performed the experiment if there was no fog, haze and clouds, as well as little to no moonlight. Using the dynamic range to maximize light sensitivity of our camera, the pictures were taken with exposure time 15 seconds and f/2.8. We then made a histogram of the pixel gray levels of the yellow rectangular section marked in the graph using ImageJ, free downloadable image processing software, and used this histogram to determine the brightness of the faintest stars detected by our camera, known as the limiting magnitude of the camera at the zenith. The zenithal limiting magnitude of the sample picture as indicated by the mean shown in Figure 3 was about 5.523. From our data set of nighttime pictures, we found the overall limiting magnitude at the zenith in Los Angeles to be about 5.21.

A zenithal limiting magnitude of 5.21 is a Class 6 on the Bortle Dark-Sky Scale Two. This indicates a bright suburban/urban sky with no trace of the zodiacal light, a whitish glow produced by sunlight reflecting off atmospheric dust particles. Any indications of the Milky Way are apparent only toward the zenith.

The sky within 35° of the horizon glows grayish whit, and clouds anywhere in the sky appear fairly bright. The Triangulum Galaxy is impossible to see without binoculars and the Andromeda Galaxy is only modestly apparent to the unaided eye. The naked-eye limit is about 5.5,



GRAPHIC BY SANDRA COHEN AND CLAIRE SEIFERT

ON THIS graph, we show the determination of the dynamic range for our camera, which will help us measure skyglow.

and a 32-cm telescope used at moderate powers will show stars of magnitude 14.0 to 14.5.

Sky glow has been modeled with a linear relationship between city population and an inverse 2.5 power relationship with city radius. This relationship, known as Walker's Law, is commonly written as

$$I = CPr—2.5$$

where I is the sky brightness at a 45° elevation to the zenith, P is the city population, r is the city radius and C is a constant.

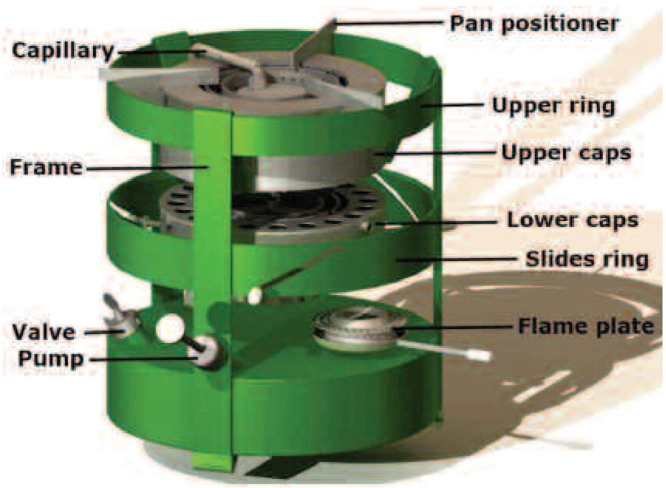
Addressing the light pollution problem

In 2003, National Geographic reported that the night light interferes with the biological rhythms and behavior of nocturnal animals, noticeably harming hundreds of different species of birds and reptiles. According to eco-group studies cited in the report, birds migrating north become disoriented and collide with night-lit towers while flying through well-lit territories. Additionally, reptiles have also been victims of the artificial light. Newly hatched turtles require a dark sky in order to properly migrate towards the sea. Due to sky glow, they too lose their orientation, making the voyage back to sea almost impossible.

Many different organizations such as the International Dark-Sky Association and the Fatal Light Awareness Program (FLAP) have been created in order to address the consequences of light pollution on wildlife. Awareness has generated enough concern in some states to initiate various ordinances that enforce a reduction in usage of light wattage and products that emit direct light. Charities like Friends of Acadia and state governments in Colorado and Maine have enhanced these new regulations, forcing town officials to submit a lighting plan specifying location, type, intensity and height of light fixtures. Certain astronomy institutes have also been funded to use lightings with lower wattage to decrease sky glow and improve astronomical conditions. Scientists and naturalists believe that with more research, awareness, and action, this problem can be improved with the mere flip of a switch.

Plant oil stoves

By Kevin Long



GRAPHIC COURTESY OF KEVIN LONG

THIS SCHEMATIC diagram of the stove my project is based on shows the key components of the cooking device. Several of these parts need to be modified to improve efficiency.

A plant oil stove has been developed to replace stoves which use kerosene as a cooking fuel. The fuel being used is inedible straight vegetable oil instead of bio-diesel, which would have to be processed and refined. The ultimate goal of the endeavor is to promote rural energy independence by encouraging the use of a renewable energy source instead of non-renewable sources like kerosene.

When the plant oil is heated in a pressure stove to just about its vaporization temperature of 300°C it cracks.

Part of the oil is vaporized, but carbon deposits are left behind. These carbon deposits block the burner parts, especially where there are bends and restrictions like such as the capillary and nozzle.

My goal was to modify the current stove design, which can only run for two hours before clogging up, so that the stove could be run for ten hours without having cleaned before that time period.

I had two ideas to fix the problem. The first was to insulate parts of the fuel delivery system to localize and control where the fuel cracks. The other idea, which was more expensive, was to add lines that could be switched during the burning process. I decided to add four additional lines with a manual switch at a commonly clogged part of the fuel line. Although one line might clog, others would be open to run the fuel to the burner. This option would be more expensive and require more instruction and care on the part of the buyer.

> A stove which burns plant oil can be used instead of a standard stove to promote energy independence, but the stove design must be subtly changed.

Non-diffracting light beams

By Shawn Wong

Diffraction, a property of light waves, causes light waves to propagate outwards from their source and scatter in a cone-like shape. Although a laser beam seems to be straight and seems to have a diameter that starts off small, the diameter will grow as the laser beam covers a longer distance.

GRAPHIC COURTESY OF SHAWN WONG

DURNIN'S BESSEL beam's central antinode does not diffract over distance.

Physicists believe that a beam can be created that overcomes the effects of diffraction; unlike other light beams, this beam does not expand over distance and remains at the same width. The precision of a non-diffracting beam can be used in areas such as ultrasonic technology, where accuracy is vital.

Durnin's solution to Maxwell's equations uncovered a class of non diffracting beams; Durnin's Bessel Beam, or the J_o Beam, which has a focused central beam that propagates in a non diffracting manner and is surrounded by concentric rings, as shown above. Theoretically, the central maximum of the Bessel beam does not change in diameter in proportion to distance.

However, these solutions are not integrable by a Riemann sum and thus cannot actually be represented. Mathematically, the beam would require an infinite amount of power over a vast area because it would produce an endless number of concentric rings. Although Durnin's equations are physically unfeasible, it is possible to create a quasi Bessel beam through several methods.

One procedure that can be used to create this quasi-Bessel beam is through the use of a circular double slit.

By directing a laser beam through the annular slit, a central beam that undergoes minimal diffraction can be produced.

Utilizing this method, I was able to observe and experiment with a quasi-Bessel beam, noting several of the properties predicted.

In the test, I was able to observe the pattern created by the Bessel beam along with its nondiffracting central maximum. I came to find that the central maximum of the Bessel beam did not significantly change in diameter when I varied the length of the beam. One observation that I found is the loss of noteworthy intensity in the central beam because of the obstruction caused by the annular slit.

A known property, which I was unable to test, is the fact that Bessel beams are self reconstructing; if an obstacle were to be placed in front of the beam, the waves spread around the obstruction and reconstruct later in the beam's path. This finding is significant because it may show that Bessel beams are not a traditional direct beam, and in fact a spot that is actually formed by the resulting pattern.

Further research into this subject can possibly allow for breakthroughs in precision technology for the future.

> A non diffracting beam of light resists the natural tendency of light to spread out from its point of origin and can reconstuct itself after obstacles.

Building a sustainable electric fitness center

By Garreth Anwar and Daniel Meer

In response to the increasing popularity of fitness centers and the growing global awareness of environmental issues, we have attempted to design an environmentally-friendly, self-sustainable gym. This futuristic gym would incorporate an assortment of power generation methods ranging from human generated power to solar paneling. Our end goal is to make a gym blueprint that combines electricity producing exercise machines with efficient construction technologies such as thermal retentive building materials, a pervasive hydro-power system, and a lighting system using light emitting diodes. We hope to reduce energy costs by 40-60% and provide healthier environments for tenants, enhancing their well-being and performance.

We started the project by studying other electricity-generating machines. Initially, we researched the efficiency of wind power and concluded that it would be inefficient on a small scale because of city regulations and lack of strong winds in a compact urban location. We concluded that solar power alone would not be able to provide sufficient energy unless we had a large building with direct access to the sun for most of the day. However, when used in conjunction with other systems of electrical generation and conservation, solar power would allow for a significant reduction in the environmental impact of the gym. Having decided to incorporate some solar power, we then examined hydro-power.

A gym that uses its own exercise machines to generate its power would save money in power costs and be environmentally friendly.

One idea would be to make the entire gym a water circulation system that the exercise machines would pump water around. The water would be pumped into a water storage unit on the roof that would regulate the downward flow of the water into a water wheel system for the generation of electricity. Although this could be an effective means of producing electricity, it is too expensive and complex for an initial design. Finally, we examined human-generated power by establishing the average number of certain types of machine in a gym and then studying the efficiency of each at generating electricity.

We had to determine the average potential current that each machine could generate. To do this we built a few models. Our first model was an adaptation of the Fitness Flyer, a mechanical machine with a similar ergonomic movement to an elliptical trainer. One major problem we encountered was our inability to find powerful horseshoe magnets large enough to generate useful current, while being small enough to mount.

For our second project we combined a magnetic trainer with a bicycle and retrofitted the magnetic resistance unit with an additional perpendicular magnet, creating a current between the two super-coils. The electricity produced from a small version of the solenoid reached ten amps; we anticipate generating more energy with the full version. We have also re-designed, but not tested, a manual treadmill, a rowing machine, and a Stairmaster. We established rough estimates of energy efficiency based on the calories burned meter of each machine. The simplest and most efficient machines are the rowing machine and the bicycle. The manual treadmill is fairly efficient and is one of the most popular machines, but it would require significant mechanical changes to work in our project.

The Stairmaster proved fairly complicated as we were not able to obtain a concept design for the functioning mechanical resistance because it is affected by the computer input. All of these generating machines could be brought together in a large gym and linked in series to a capacitor with a steady discharge rate, giving the gym a steady power source independent of the fluctuation in usage of the machines.

We think that using some or all of the methods outlined here would create significant energy savings for the average gym. Conserving energy leads to lower costs and helps to preserve the environment.

DANIEL MEER

DANIEL MEER

THE BICYCLE track stand with two magnets shows in the two photos pictured above. The coils are not shown, but would be around the two magnets on either side.

Light emitting diodes

By Steve Yang

COURTESY OF STEVE YANG

IN FIG. B, three light emitting diodes shine on a piece of tin foil, producing a variety of colors and some white light.

Light Emitting Diodes, or LEDs, are small, pinhead-sized globs of plastic and metal that are currently considered to be one of the most efficient sources of light. The most efficient white LED is capable of producing twenty times the lumens/watt (a measure of light bulb efficiency) than a standard incandescent bulb, and is more energy efficient than even fluorescent lights. Although a relatively large number of LEDs is needed to produce the same amount of light as a standard bulb, their small size makes LEDs very useful in a variety of applications. These experiments could have been done with other light sources, but LEDs provided a cost-effective alternative and in some cases vastly simplified the setup.

Measuring planck's constant

In this experiment, created by Wayne P. Garver, Planck's constant was measured through an application of the photoelectric effect. The photoelectric effect is the process by which photons greater than a certain frequency have the potential to displace electrons when striking a metallic surface. The specific frequency is dependent on the type of metal being used. Planck's constant is significant because the research leading to its discovery revealed that energy exists in distinct, fixed amounts at the atomic level. Because LEDs emit light confined to a very narrow frequency, they were used in this experiment to provide the light source. The stopping voltage could be measured by using the circuit in Fig. A. After taking various measurements, the most accurate value of Planck's constant I calculated was 6.02 x 10^{-34} using a yellow LED. Unfortunately, this value is still significantly off from the current value of Planck's constant.

Additive color

A quick demonstration of additive color can be done with red, green, and blue LEDs connected to a potentiometer to control the intensity of the light. As demonstrated in Fig. B, some white light was created by pointing the LEDs toward a piece of foil. Other secondary colors can also be seen.

The ability to mix together different amounts of red, green, and blue light to create nearly all colors is based on the way that the eye perceives light. The eye is particularly attuned to three colors or wavelengths, somewhat arbitrarily defined as short (blue), medium (green), and long (red).

Separate proteins in the eye detect these colors differently and send messages to the brain that determine how much of each color the eye picks up. The brain then translates this information into the specific color.

This principle is currently the foundation behind most video electronics and, using the RGB system, nearly seventeen million colors can be created.

The only materials needed for this experiment are red, green, and blue LEDs, three batteries, three potentiometers, a breadboard, and some foil.

> The light emitting diode is one of the most efficient sources of light, producing at twenty times the efficiency of a standard incandescent bulb.

Lissajous figures

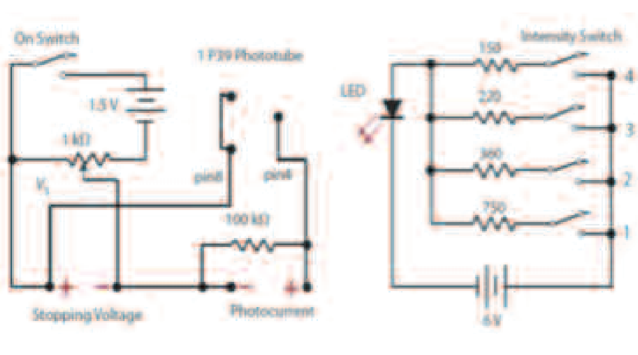
Lissajous figures are brilliant, rectangular patterns created with harmonographs.

Harmonographs are usually very large platforms that slowly swing below a central point (acting as a pendulum), and a separate drawing tool unattached to the platform. The drawing tool can either be moved by being attached to an additional pendulum, or it can be fixed.

One of the problems with this experiment is that at a small scale, the friction between the drawing utensil and the paper distorts the results. This experiment, created by Luka Vidic and Mika Kos, solves this problem by replacing the traditional pen or pencil and paper with a small LED flashlight and phosphorescent paper.

Unfortunately, the LED currently used is not strong enough to make a noticeable impression on the paper. Either the pendulum-platform moves too quickly and does not have a chance to react or it moves too slowly and the pattern is lost.

In addition, the patterns cannot be preserved as of yet because they slowly fade over time or become ruined when exposed to light. An alternative to this setup would be to simply use photo paper in place of phosphorescent paper and preserve the patterns directly.



GRAPHIC COURTESY OF STEVE YANG

FIG. A SHOWS a circuit which can be used to measure stopping voltage. The LED plays an important part in this experiment.

Physics of quadrotor technology

By Patrick Cambre

> The quadrotor's upgrades on helicopters make it ideal for the next unmanned aerial vehicles.

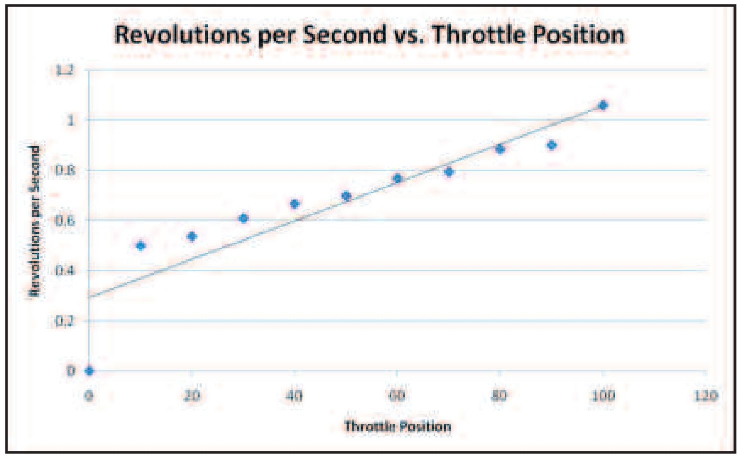
From reporting traffic on the news to flying the sick to hospitals, the helicopter has become a vital part of modern society. In recent years, quadrotor technology has emerged as a possible replacement for or supplement to today's helicopter fleets.

A quadrotor is a craft with four propeller blades mounted in a horizontal square. By adjusting the speed and therefore the rotational torque generated by each of the motors, a quadrotor can hover and move like a helicopter. Electronic gyroscopes and accelerometers detect any slight change in the orientation of the craft and act accordingly to keep it in equilibrium. Since quadrotors rely only on the changes in motor speed, they are less complex than helicopters, which rely on expensive and complicated variable-pitch blades. Quadrotors are also safer, as the blades are often completely enclosed within the frame of the craft. These advantages over helicopters have been increasing the role quadroters play in aviation.

Since they are easy for a computer to control, quadrotors are often used in the unmanned aerial vehicles (UAVs) being developed today. These UAVs have demonstrated the capability to monitor large areas reliably and have proven themselves to be excellent platforms for aerial photography.

My research centered on the physics of quadrotors. In particular, I wanted to determine the relationship between the strength of the motors and the flight dynamics of the quadrotor. Using a popular consumer quadrotor, the X-UFO, I was able to take measurements of rotational speed, a good indicator of the torque that was generated by the craft when the rudder is applied. As I adjusted the throttle position, I noticed that the craft rotated faster as more throttle was applied. I was able to determine that there is a linear pattern for this relationship. Unfortunately, it is difficult to know how much torque each motor generates. In addition, the rotors on the craft that slow down may keep moving, generating a small amount of opposing torque that slows the rotation. I noted that as motor speed increased, the torque generated by each propeller increased, and the rotational torque in one direction is what causes the craft to rotate.

The future is bright for quadrotor technology, with applications for everything from airport security to pipeline maintaince. Improvements in electronics, computing, and robotics will continue to improve the autonomous nature of quadrotor UAVs. Boeing has financed a research study into a quadrotor able to carry as much cargo as a medium sized airplane but able to land in an area suitable for a helicopter. Applications such as these are the future of this relatively new technology.



GRAPHIC BY PATRICK CAMBRE

CAMBRE GRAPHED rotations per second in order to come up with this linear relationship between throttle postion and rotational velocity.

Energy use at home

By Robby Lewis

> This "green" house aims to be efficient by minimizing heating and cooling costs through solar energy.

For my project, I chose to modify the basic house to increase its energy efficiency. One of the largest energy costs for a home is its heating and cooling. The installation of efficient insulation helps reduce heat loss, and, using the heat given off by the sun, it is possible to increase the ability of the building to absorb heat energy and disperse it throughout the home and increase the heat capacity of the home.

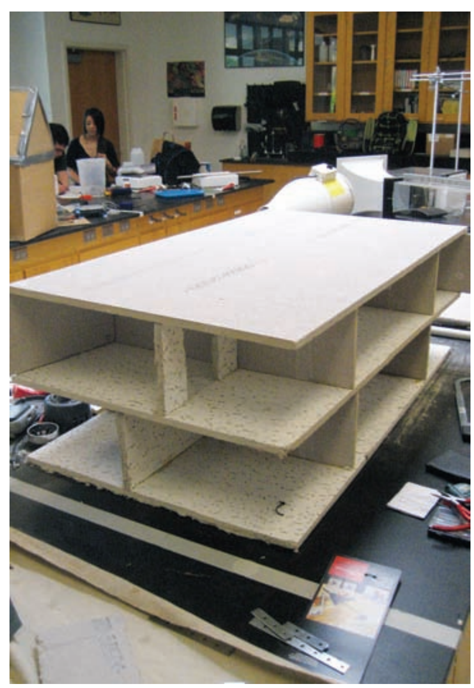
To continue with my trend of simplicity I created the plans for a very simplified two story house that includes space for three bedrooms, two bathrooms, a kitchen, a den, and a sunspace.

Inside the sunspace is a substantial quantity of thermal mass, a material that has the ability to absorb large amounts of heat, balancing extreme air temperature variations. By providing a temperature balancing effect, the thermal mass in the sunspace lowers the energy necessary to keep the house climate controlled.

Other changes that did not make it into my model that can harness the energy of the sun to lower energy costs include but are not limited to: skylights, thermal energy storing walls, and natural architecture to block the sun where it will strike the strongest.

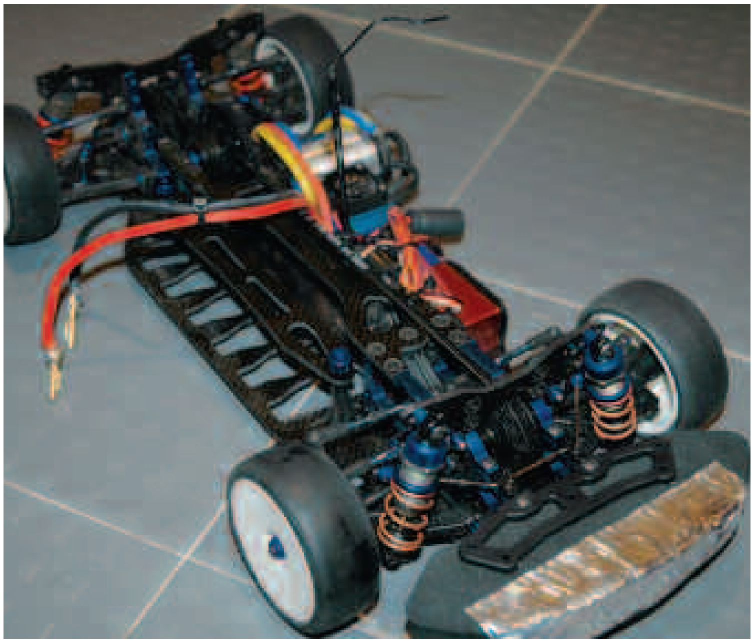
Combining these energy efficient changes with well placed insulation will lower the energy cost of my model house.

While my simple house model may not incorporate all possible changes, it represents a step towards reducing energy inefficiency.



MATHEW EDWARDS

LEWIS USED a model house that he built to run most of his experiments.



RORY HANDEL

THE CAR that Handel and Lawson used to measure the efficiency of the lithium polymer battery. Fully charged, it can run for 34.3 miles.

Modeling electric car efficiency

By Rory Handel and Carl Lawson

With oil prices reaching new heights, we decided to look into electricity as a source of alternative energy for transportation. In our project we set out to determine the feasibility of running an electric car on the newest lithium-polymer batteries by building and testing a scale model of a full size car.

First, we had to determine the power to weight ratio of the full-size car we were scaling down. As our average benchmark car we chose the Audi A4, which has a power to weight ratio of 0.0583 horsepower per pound. Next we calculated the target weight of our scale car. The electric motor supplies 0.8756 horsepower, so in order to match the power to weight ratio of the A4, the scale car would have to weigh 6.82 kilograms.

Then, we calculated the relative distance traveled for the scale car. The A4 has a tire circumference of 63.87 inches, so its tire rotates 992 times for every mile travelled.

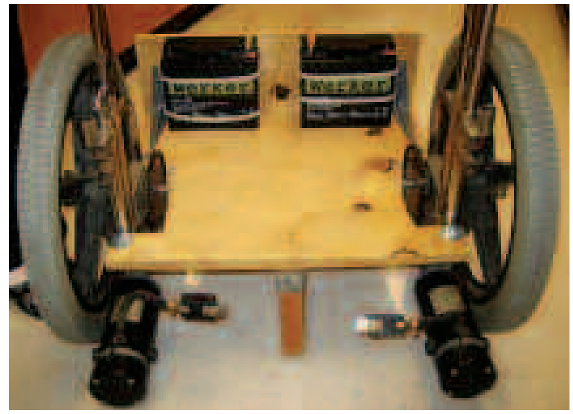
The scale car's tire, with a circumference of 8.0625 inches, travels 7998 inches over the same number of rotations. This provides a ratio of 1 real mile to 7.92 scale miles.

Knowing the scale distance and weight, we could test the battery life of the lithium-polymer battery.

To do this we ran the car on a treadmill at 8 mph (63.4 scale mph), or approximately average highway driving speed, for 166 seconds. In this time, the car traveled 2.93 scale miles and used .7 volts of its 8.2 Volt capacity, giving an efficiency of 4.19 scale miles/volt.

With a capacity of 8.2 V, the car has a maximum range of 34.3 miles at approximate highway speeds.

Although this range was low it could easily be increased by linking multiple batteries together. However, lithium-polymer batteries are expensive and need to be regulated by complex battery management systems. These batteries are a viable option for powering a car, although the high price tag means they are not cost effective. Additional testing beyond the scope of our resources will be needed to determine the longevity and durability of these batteries. We hope to run more tests at different speeds to determine the efficiency at city speeds and in stop and go driving.



CARTER CHANG

A ROUGH prototype of the Segway the group made.

The Segway

By Carter Chang, Zane Ma and Gordon Wintrob

The Segway is a two-wheeled, self-balancing transportation device. Using gyroscopes and accelerometers, the scooter can maintain its upright orientation with a passenger on board. As our project, we plan to construct a working self balancing scooter.

In order to obtain all the parts at a low cost, we purchased an old wheelchair, which came with two DC motors, wheels, a metal frame to connect the motors to the wheels, and a control box to run the motors. We also purchased two rechargeable batteries, some mechanical construction parts, a microcontroller and gyroscope. For the platform we decided to use plywood because it is strong, cheap, and easy to work with. We needed to rewire the control box to translate the gyroscope signal into motor movement.

> The Segway, a self balancing two wheeled scooter, provides a fun and convenient form of transport.

The plywood chassis has two foot stands parallel to each other and facing forwards. Two wheels were attached on the outside of the foot stands at a slight inward angle to improve balance and stability. All the other components of the scooter were placed beneath the foot stands.

A gyroscope is a device for maintaining orientation, consisting of a spinning wheel. The large angular momentum of the gyroscope resists changes to the orientation.

An accelerometer is a device for measuring acceleration, which is the sum of external forces acting on an object divided by the object's mass. We will combine the accelerometer with the gyroscope in an inertial-guidance system, so the scooter will be able to balance without an outside reference.

The microcontroller connects and manages all the components of the scooter. It uses inputs from the accelerometer and gyroscope to determine how much power to supply the motor so that the wheels stay beneath the center of gravity of the scooter. The microcontroller can also be programmed to turn off the engine if the bar tilts too far forward.

When we finish the coding of the microcontroller, the rest of the project will consist of calibrating the parameters to adjust sensitivity and other variables. We also intend to improve the safety features of our scooter. We would like to have a display that informs users of battery life, and a kill switch to ensure that the motors can easily be deactivated.

5 things...

COURTESY OF GOZEROG.COM

At the University of Washington, engineers developed an exoskeleton to allow humans to easily lift hundreds of pounds and run 20 miles per hour. In order to do it, the engineers created hydraulically actuated limbs and renewable power supplies.

COURTESY OF TACTICALWARFIGHTERGEAR.COM

For 100 million dollars, you can be the first private citizen to land on the moon. Or, for the more reasonable price of $3950, you can fly on a specially modified airplane that flies in parabolic arcs to simulate the effects of weightlessness.

During reentry into Earth's atmosp
experiences temperatures up to 150
contrast, the outer layer of the sun
6000 degrees Celsius.

OLPC, One Laptop per Child, wants every child in the world to have computer access So they developed a $200, child-friendly, rugged, power-saving laptop. At the launch of the OLPC program, customers paid $400 to sponsor a child. Each sponsored child, as well as the customer who paid, received an OLPC laptop. In order to save on costs, OLPC developers chose an open-source operating system that will allow users to modify their computer to fit their needs.

COURTESY OF ONEGADGET.COM

Even though many different
mole rat and the owl, are kno
modification during hunting
human trait. Research by Jil
and Paco Bertolani of Cambr
misconception. The scientist
chimpanzees sharpening bra

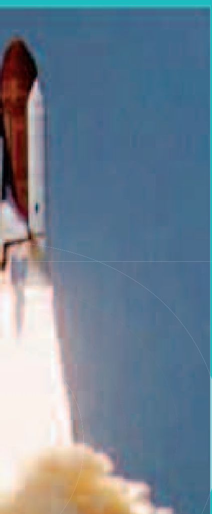
COURTESY OF ENGADGET.COM

Blu-Ray discs are capable of storing five to ten times the amount of data that DVDs can store. Conventional DVDs use red lasers to access the recording layer, which is below a protective polycarbonate cover. The polycarbonate layer prevents the laser from reaching a smaller focal point, leading to memory tracks that must be spread apart. With Blu-Ray discs, however, the polycarbonate is below the recording layer, allowing a higher energy violet laser to access the memory tracks at a smaller focal point that allows more memory tracks to be added, increasing the capacity of the disc.

5 things...

—By Ian Cinnamon and Gordon Wintrob

..that will boggle your mind


COURTESY OF NASA.GOV

Not only is Apple's iPhone good lookng, but it contains a touch screen, an accelerometer, proximity sensor, and ambient light sensor. With the just released SDK, programmers will be able to develop programs that take advantage of the sensors – such as interactive games and car crash detectors.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...here, the space shuttle ...00 degrees Celsius. In ... is four times hotter at

Atomic clocks in use around the world today are so accurate that they will lose less than one second every 200 million years.

...animal species, such as the ...own to use tools, significant ... was believed to be a uniquely ...l Pruetz of Iowa State University ...idge last year overturned this ...ts observed a group of female ...nches in a Senegalese savanna.


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Amazon's Kindle, a "Wireless Reading Device," allows customers to download books from Amazon for a discounted price of $9.99. The Kindle takes advantage of electronic ink, which allows the screen to display the page without a constant source of power. This new technology allows the Kindle to only require its battery to be recharged every other day.

Teams led by Shinya Yamanaka of Kyoto University and Junying Yu of the University of Wisconsin developed a technique to harvest stem cells without the ethically controversial destruction of human embryos. The researchers used a virus to add four new genes to skin cells, coaxing the cells, known as fibroblasts, into several types of tissue. One significant drawback was that the modified cells often became cancerous tumors. Yamanaka reported in Nature Biotechnology that he was able to prevent the cells from becoming cancerous by inserting only three genes.


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