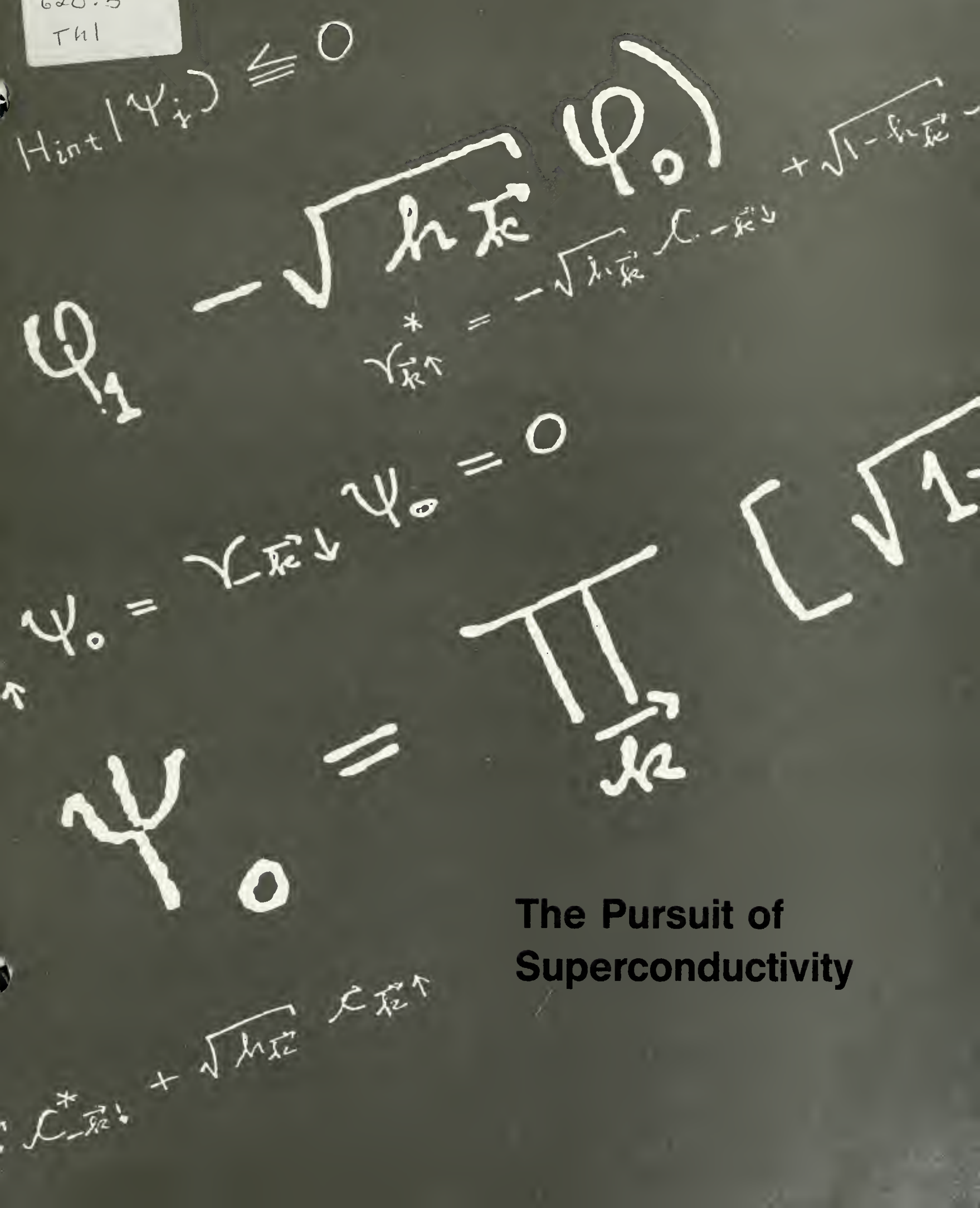
illinoisTechnograph

November 1987 Newsstand $1.40



The Pursuit of Superconductivity

KAI

SUPER OPPORTUNITY...

...to work for the leading supercomputer software developer!

Programming systems for state-of-the-art computer architectures are being developed by Kuck and Associates, Inc. (KAI). We are working with a number of start-up companies and established manufacturers of high-performance systems. Programmers will become familiar with a broad range of hardware and software systems. Several of these computer systems are in-house for program development and performance testing.

KAI's program restructuring software and numerical libraries currently lead the field. We are now developing advanced systems that aid the user in exploiting high-performance architectures ranging from superminicomputers to supercomputers like the Cray X-MP. Software for vector and parallel machines with various memory hierarchy constraints is under development.

We seek people with an interest and background in:

Technical

- Development Programmers
  - Fortran, C, Ada, Pascal
  - UNIX, VMX, Alliant Concentrix, Sequent Dynix
  - High-performance architectures
  - Optimizing compilers
  - Program restructuring
  - Numerical algorithm analysts
- Support Programmers
  - Testing and benchmarking
  - Supercomputer applications

Administrative

- Management
  - Technical managers
  - Software development
  - Technical sales
- Marketing
  - Market research
  - Publicity and promotion
  - Technical writing
- Administrative and clerical

KAI is an expanding company located in Champaign-Urbana, Illinois. We provide competitive salaries and benefits, and offer a tremendous growth potential. We are programming the next generation of supercomputers! If you would like to be a part of this team, please send:

1. Resume
2. Transcript of all courses
3. 3 letters of referral
4. Current visa status
5. Date available for employment

Kuck & Associates, Inc.
1808 Woodfield Drive
Savoy, Illinois 61874
(217) 356-2288
Attention: Scott Pickard

illinoisTechnograph

November 1987 Volume 103, Issue 2

Illinois Technograph. Room 302 Engineering Hall, Urbana, Illinois, 61801, phone: (217) 333-3558.

Illinois Technograph (USPS 258-760) Vol. 103 No. 2 November 1987. *Illinois Technograph* is published five times during the academic year at the University of Illinois at Urbana-Champaign. Published by Illini Media Co., 620 East John St., Champaign, Illinois, 61820. Editorial and Business offices of the *Illinois Technograph*: Room 302 Engineering Hall, Urbana, Illinois, 61801, phone 217-333-3558. Subscriptions are available for $7.25 per academic year. Advertising by Littel-Murray-Barnhill, Inc., 1328 Broadway, New York, N.Y., 10001; 221 N. LaSalle Street, Chicago, IL, 60601. *Illinois Technograph* is a member of Engineering College Magazines Associated.

Mother Nature-Professor of Engineering

In order to function effectively, the engineer should be quite familiar with the disciplines of mathematics and science. It is necessary, however, to define exactly which fields of knowledge, among the many loosely labelled as "science", are of value to the engineer in his or her annointed task. At the University of Illinois, the physical sciences are traditionally defined as physics and chemistry. However, since the engineer must deal with matter and energy in nature, one might be curious as to why the engineer's background in the physical sciences is not extended to the domain of natural science by the addition of biology to his educational program. After all, the College of Liberal Arts and Sciences has found a place for biology, as its program requires at least one biology course, even for non-science majors.

The traditional argument against the inclusion of biology in a standard engineering curriculum revolves around the fact that the additional hours of study this change would require could overburden the student. Considering the challenging and extensive training our students receive at the University, this claim wields considerable merit. However, perhaps biology could be fit into a schedule in the place of one or more technical electives, such as the upper-level classes that provide the student with specific "up to date" information, which often suffers from obsolescence soon after its presentation or which may be assimilated with greater ease through on-the-job training. This loss of "icing on the cake" would appear to be an adequate sacrifice for an introduction to another basic science that can serve as a substantial foundation for the further accumulation of knowledge.

Nevertheless, one may wonder whether the additional knowledge gained from the study of biology would be of any practical use to the engineer. While this approach certainly will not immediately solve all current engineering enigmas, an appreciation of biology may aid the engineer by encouraging him to seek solutions to engineering problems through the observation of nature. Indeed, centuries ago, initial interest in optics was stimulated by the observation that concave water droplets on leaves refract light in such a manner as to produce magnification. Flora and fauna provide excellent examples of useful structures, systems, and processes which the engineer may be able to adapt for his special purposes. Our own bones are fine examples of civil engineering, as their internal structural arrangement provide a relatively low density material that can withstand greater tensile, compressive, and shear stresses per unit weight than granite or concrete. The joint arrangement in the appendages of the grasshopper was suggested as a basis for the landing gear of the British Harrier jet. Researchers in the field of computer science might find the cell a fascinating playground, as the DNA present in the nucleus acts as a premier example of compact data storage, providing 45 million storage positions, each capable of taking on one of four values, held in a roughly spherical volume with a radius on the order of the width of a human hair. In addition, through the process of evolution, "nature's designs" have been field-tested and optimized over millions of years to allow the organism to efficiently interact with its environment.

In order to expose engineers to this wide variety of natural phenomena which could serve as a springboard to further creative thought, perhaps a specialized biology sequence could be designed which would emphasize concepts of utility to the engineer. Certain topics of lesser interest, such as plant biology, could be removed from this technical survey of the life sciences (although the method by which trees transport water from roots to leaves, generating 300 atmospheres of pressure in the process, calls into play considerable hydraulics). However, since the development of such a class would demand considerable time and toil and may not be feasible in the immediate future, perhaps professors teaching physical science courses could devote more attention to biological phenomena pertinent to their subject matter. The extensive coverage given to the eye by the physics department during a unit on optics offers a fine example of this spirit, and the hydrodynamics of capillary action, the dynamics of limb movement, the thermodynamics of metabolism, and the RC circuit properties of neurons offer further material that can be developed in a similar vein. Such an exposure to biology could act as a catalyst for further interest and study of the subject by students (and staff), as engineers discover just how much Mother Nature can offer to their chosen profession.

Scott C. Brun

***Illinois Technograph* invites letters in response to its articles and editorials, or any other items of interest to its readership. Articles, photographs, and other contributions are also welcomed. Letters must be signed, but names will be withheld upon request.**

technovations

Inside-Out Delivery

Doctors in the future may explore the body's ducts using catheters that actually turn themselves inside out as they travel through the body. Daniel R. Shook, a biomedical engineer at the biomedical engineering and instrumentation branch of the National Institutes of Health in Bethesda, Maryland, described the everting catheter in a recent American Society of Mechanical Engineers journal.

Essentially, the everting catheter is a flexible catheter inside of a rigid catheter. The rigid outside catheter is inserted into the body similar to a conventional catheter. The doctor then pushes the flexible inner catheter out, causing it to unfold and turn inside-out along the walls of the duct.

Because of the everting catheter's flexible design, it can follow extremely complicated vessels, yet there is little friction against duct walls, according to Shook. In addition, only the tip, rather than all of the catheter, moves through the vessels.

As with conventional catheters, everting catheters can deliver drugs and instruments to many different parts of the body. An everting catheter, however, can negotiate extremely twisted vessels, such as those in the brain. According to Shook, the catheter can easily navigate through these vessels and deliver drugs to tumors without delivering the drugs to surrounding tissues.

Two companies already hold licenses to manufacture the catheter, but they are not currently marketing it. The main problem with the everting catheter is that a doctor cannot easily control the direction that the catheter takes once it reaches a branch in a vessel. Shook stated that further development was needed to solve this problem.

CD River Data

During the past few years, compact disk read only memories (CD-ROMs) have promised to replace many of the dusty reference volumes used by engineers and scientists. One company that has done much work in this area is U S WEST Knowledge Engineering, Inc. of Denver, CO. It recently introduced two products that put a century of river flow data on the portable disks.

The first product, introduced last spring, is called Hydrodata and compiles more than 100 years of water quality and river flow data. The second product, Hydropeak, was introduced in September and contains flood flow information for the entire United States.

Normally, hydrologists, civil engineers, and planners must access this information from large mainframe computers. With the Hydrodata and Hydropeak CD-ROMs, the data is accessible on their personal computers.

CD-ROMs are essentially identical to standard audio compact disks, except the data encoded on them represents text or graphics, rather than music.

Because of their large capacity, much more information can be included on the CD-ROMs than in conventional formats. The results of some common calculations, such as standard deviations and other overall figures, have also been included on the CD-ROMs to better utilize their capabilities.

Each product comes with a software package that allows the planners not only to access and print the data, but also to transfer the data to other programs, such as spreadsheets and word processors. Professionals can thus not only retrieve the data, but also quickly put it to use.

Light Meets Electricity

Communications technology is rapidly moving toward fiber optics because of the extreme speed with which they carry data. One problem this transition presents is that of converting the light pulses carried by optical fibers to electrical pulses used by computers. International Business Machines Corporation recently announced the development of an experimental computer chip to convert light pulses back to electrical pulses.

The new chip is made of gallium arsenide (GaAs) rather than conventional silicon. Not only can a GaAs chip convert signals faster than its silicon equivalent, it also does it more efficiently.

The primary problem with creating fast photodetectors is the interference conventional electronic circuitry causes. Long wires from photodetectors to their electronic amplifiers make the detectors very susceptible to noise. To reduce this noise, the photodetectors must be built on chips alongside other electronics.

IBM scientists chose GaAs as the base material for the new chips, but encountered new problems because of the choice. The high-temperature annealing process used to create transistors changed the photodetector's characteristics. They found that adding small quantities of certain other materials ("doping") allowed the detector to maintain its characteristics during high-temperature processes.

Overall, the IBM scientists believe that the new chips are as much as two times faster than any previous designs.

University Scientists Supervise Superconductivity Research

Scott M. Heydinger

Since last spring's discoveries in superconductivity, the University of Illinois has been pursuing superconductor research more actively than ever.

The University of Illinois, Urbana-Champaign has been very active in superconductor research since the recent discoveries of higher temperature superconducting materials. Earlier this year, it was found that certain ceramics could be made to lose their resistance to the flow of electricity, or superconduct, at relatively high temperatures. These discoveries have sparked intense research around the world.

In February, Myron Salamon, professor of physics and assistant director of the Materials Research Laboratory, began trying to obtain funds. He applied for funding from the National Science Foundation to allow University scientists to conduct new studies in superconductivity. Other funding was obtained from the Department of Energy and the Department of Defense. Faculty members were also redirected to superconductor research. "It's still a struggle," Salamon explains, because more University scientists are interested in the field than can be supported.

Currently, the University is collaborating with companies such as IBM and DuPont. Also, Salamon says he looks forward to the University joining the proposed Illinois Superconducting Institute. This organization would tie together university and industrial knowledge within the state.

Initially, graduate students were asked to put their thesis work on hold and begin studying the new materials. The students were enthusiastic about studying the new field, Salamon said. At present, the list of professors and students is still growing.

Professor Emeritus John Bardeen is one University researcher who has been previously involved in superconductivity research. Bardeen shared the 1972 Nobel Prize in Physics for a theory explaining how conventional superconductors work. Last May, he discussed possible ways of understanding the new superconducting phenomena at a conference in Berkeley, CA.

Donald Ginsberg, professor of physics and a co-leader of the thrust group for high temperature superconductivity research, has been experimenting on superconductivity since he came to the University in 1959. His interest began as a graduate student in 1956. Ginsberg also wrote the article on superconductivity in the 1974 edition of *Encyclopedia Britannica*.

Bardeen says he is impressed with the rapid pace of discovery. He also says he believes that the University is now well equipped for the work. He admits that the University does not have the largest superconductivity research center. However, he says the University has been at the forefront of the field since the program began. Ginsberg agrees: "The total effort here is one of the most extensive in this area at any university."

University researchers have been working to achieve a better understanding of the science of superconductivity. By controlling and optimizing the parameters involved in the production of superconducting compounds, researchers can obtain valuable information about the electronic interactions which are responsible for supercondutivity. Eventually, it is hoped that this understanding will aid the search for even higher temperature superconductors.

The University produces almost all of the superconducting samples it needs for research. Mark Reeves, graduate student in physics, explained how superconducting pellets are made at the Materials Research Laboratory. Yttrium, barium, and copper oxide powders are mixed together. The powder compound is then pressed into pellets with 2000 pounds of force applied over the quarter inch-diameter sample. The pellets are then sintered, or heated, in an oxygen atmosphere. This hardens the sample and allows it to absorb oxygen, the key to producing a good sample. The resulting compounds are then characterized and distributed to other groups on campus for experiments.

University researchers are working to produce larger single crystal samples. Since the magnetic properties of superconductors depends on the orientation of crystals within the sample, it is better to have a sample that consists of one large crystal rather than many smaller, randomly arranged crystals. Joe Rice, graduate student in physics, has grown thin single crystals which are about 2 mm square. Making a sample large enough for certain

Mark Reeves, graduate student in physics, patiently tills a dewar flask with liquid helium in order to carry out low-temperature calorimetry experiments on superconducting materials (Photo by Dan Powers).

experiments is a challenge, though. "That's the trick," says Bardeen. P. Han and David Payne, professors of ceramic engineering, are also trying to grow bigger and thicker single crystals.

Payne is also head of the materials science and engineering department, which was recently formed by combining the ceramics and metallurgy departments. His own work involves rapidly solidifying a superconducting compound and producing an amorphous solid. The solid is then melted and slowly solidified, enabling him and his students to find out how a superconductor achieves its structure.

Another experiment involves taking measurements with SQUID, the superconducting quantum interference device. Brian Pazol, graduate student in physics, considers it a sensitive voltmeter. Since the concentrated research program began earlier in the year, those researchers involved in high critical temperature (or high T_c) research have managed to keep the machine booked solid, said Sue Inderhees, graduate student in physics.

One of the major pure science aspects of superconductivity being studied at the University is the heat capacity of superconducting materials. Reeves, who is studying this property, says that results of this research will help theorists gain a better understanding of the mechanisms behind superconductivity.

To carry out his experiment, Reeves uses a sophisticated calorimeter which was designed and fabricated at the University. The instrument is not very common, making the University one of the few places able to conduct this type of study, Reeves said.

The device consists of two insulating dewar flasks, one inside the other. The outer one contains liquid nitrogen to cool the inner dewar flask, which is filled with liquid helium or liquid nitrogen. Inside the inner flask is an evacuated probe that contains the superconducting sample. Measurements are taken under computer control. The volume inside the probe, where the actual measurements are taken, is gradually heated by a resistor. By determining the amount of energy needed to raise the temperature of the sample one degree, its heat capacity can be found.

The results of this experiment included an unexpected phenomenon below 10 K. Ginsberg presented the findings at the March meeting of the American Physical Society in New York.

Relva C. Buchanan, professor of ceramic engineering, is producing thin films of superconducting compounds. A solution of organometallic carboxylates is concentrated by heating. The solution is then spun onto a substrate, where it forms a solid film about one micron thick upon heating. He says it is important to look into this matter because, "this is the only form in which the carrying of higher density currents has been achieved to date." He says he also intends to look into improved methods of producing pellets and possibly wires.

Other researchers at the University are attempting to create better compounds by studying the absorption of oxygen during the sintering process. About ten theoretical physicists are devoting substantial amounts of their time to the field. George Kordas, associate professor of ceramic engineering, has recently developed a process for developing superconducting compounds at 1100° F instead of 1750° F. Numerous other aspects of superconductivity are being investigated; undoubtedly the list of achievements in this field will continue to grow.

Bardeen says he sees a bright future for the field. He predicts that as a result of all the data now being generated, "things will begin to shake down in the next few months," and the correct theoretical approach could be chosen from among the many theories that currently exist. Considering the amount of research taking place in Urbana-Champaign, the next big superconducting discovery may well come from the laboratories of the University.

tech visions

A Centripetal Celebration

Engineers can have a field day computing the amount of centripetal force required to navigate the curves on this twenty-four foot long skateboard ramp built by Urbana resident Randy Gawlik. The product of a week's worth of intensive labor, the ramp is extensively used by daring high school and college students.

A Liberal Look at Engineering

Mary J. Winters

By taking advantage of a program offered by the Colleges of Engineering and LAS, some students are gaining the benefits of a broader education as well as greater desirability by employers in their chosen engineering field.

"All engineers ever think about is calculus and slide rules." "An engineer can't study literature; he's too busy solving equations." "Everyone knows that engineers are geniuses who wear glasses and go around quoting Einstein and Copernicus."

Generalizations like this are quoted and believed by many people. The thought that an engineer can know anything besides engineering seems to surprise people. Of course, they believe that engineers are people, too, but they think that studying for an engineering degree leaves little time for anything else.

The engineering curriculum at the University of Illinois, Urbana-Champaign does leave little room for electives. Although eighteen hours of social science and humanities courses are required, other technical electives can easily fill up a four-year schedule. However, there is a way for engineering students to get a more rounded education, and more and more students are taking advantage of this opportunity.

For over twenty years, there has been a program at the University which allows students to receive degrees from the College of Liberal Arts and Sciences and the College of Engineering in five years. This program "permits a student to earn a Bachelor of Science degree in a field of engineering from the College of Engineering and a Bachelor of Arts or a Bachelor of Science degree from the College of Liberal Arts and Sciences". (*1985-87 Undergraduate Programs*)

Originally, the program was intended just for students with a wide range of interests. Twenty years ago, there was not as much emphasis placed on careers as there is today. Students who wanted to take some extra courses were able to do so, and the program let them earn an extra degree at the same time.

According to the Undergraduate Programs guide, the five-year program allows students to prepare for interdisciplinary careers. It also enables students to develop a well-rounded cultural education in addition to their engineering specialty. "It gives students an opportunity to get some breadth in their education that is formally recognized," says Harry Wenzel, assistant dean of engineering. Bruce Hinely, assistant dean in Liberal Arts and Sciences, agrees with this assessment of the program's primary thrust. "In my opinion, the main purpose is to combine the scientific and technical knowledge which the engineering curriculum provides with the broader, more rounded education that the LAS curriculum provides."

This does not mean, however, that students can take shortcuts in either college when they decide to study for two degrees. All admission and graduation requirements for both colleges must be met.

Wenzel and Hinely agree that many students enter the program after their freshman year. Wenzel says that many transfer students who already have a significant number of credit hours in either or both colleges enter the program when they transfer. Dean Hinely estimates that only about half of the students who enter the program do so as freshmen.

Students enter the program for many reasons. Some engineers simply enjoy taking liberal arts classes. Others have a more specific purpose. Hinely says that several students are studying computer engineering and psychology with the intention of applying their knowledge to artificial intelligence. "By selecting an appropriate liberal arts and sciences major in combination with the desired engineering curriculum, it is possible for students to qualify for new and unique careers in industry, business or government". (*1985-87 Undergraduate Programs*)

There are currently 138 students registered in the program. According to Dean Hinely, enrollment has grown considerably in the last three or four years. About five years ago there was only a handful of students in the program, he says.

Students in the program usually spend their first year in the College of Engineering. The following two years are spent in LAS, and the final two years are spent in the College of Engineering. This does not mean that a student can only take engineering courses while in the College of Engineering and liberal arts classes in LAS. Usually, a student mixes his engineering and LAS courses. The transfers do allow each college to hold the student's records for a time.

When a student decides to enter the program, he obtains a five-year program form. Because the program assumes that a student will take courses which can fulfill requirements in both colleges, the student

must carefully choose his classes. He then organizes his classes and completes the form. However, this proposed schedule does not need to be followed strictly. It is possible to switch courses between semesters or to take courses during the summer.

After the student has filled out the form, he must see his engineering advisor, who reviews the form and makes sure all the required engineering courses are listed. After the engineering advisor signs the form, the student takes the form to his LAS advisor for the same reason. Then the student brings the form to the engineering college office and a copy to the LAS office. After that, a student only needs to complete the five years of classes, which may require taking eighteen or nineteen hours of classes in a semester.

Apparently, most students who enter the program believe the work is worthwhile. "I haven't seen that many (students) drop out," Wenzel says. However some students do drop out because they decide that a secondary degree would not be as beneficial as originally supposed or that the program does not satisfy their specific needs. For example, some students decide to get their Bachelor's degree in one major and then attend graduate school to receive a Master's in another area. Many students are interested in receiving joint degrees in engineering and business. However, there is currently no joint program between the College of Engineering and the College of Commerce and Business Administration.

There are many ways to combine engineering and LAS degrees. As previously mentioned, computer engineering and psychology is one popular choice. Some others are: computer engineering and rhetoric, computer science in engineering and a foreign language, and general engineering and English. It would even be possible for a student to study computer engineering and computer science/math.

Some students in the program believe that the program will help their careers. Engineers with a more liberal education are desired by employers. "It's a good thing to have on your resumé," says Dean Wenzel.

It is even possible for members of R.O.T.C. to join the program. However, R.O.T.C. scholarships sometimes require a student to finish the program in four years instead of five. This plan is difficult or perhaps impossible without having a significant amount of credit before coming to the University. One student is following this plan with studies in computer science and Spanish. He says he believes it will be an advantage in his intended military intelligence career.

The five year LAS / engineering program is a great opportunity for students at the University. The benefits and rewards of the program are worth the extra time and work required. If you are tired of exclusively taking math and science classes, this program is definitely worth considering.

Although no plans presently exist to replace Foellinger Auditorium with Engineering Hall, a large number of engineering students are taking the trek "south of Green" in order to engage in studies over and above their technical courses (Photo by Peter Lei).

Michael W. Lind

tech teasers

1. If one third and one fourth of a piece of cloth are black and the remaining eight yards are gray, how long is the bolt?

2. Three men are playing a game where the loser doubles the other two players' money. Each man loses one game in their set of three. How much did each start with?

3.

Complete I am hard
Behead am sound
Behead me again
Then a number is found

4. What monosyllable of five letters will make two monosyllables?

(answers on page 12)

tech notes

Testing Your Cleverness

Do you enjoy spending hours on tricky mathematical problems? If so, then the National Putnam Exam may be for you. This exam, given to approximately 2000 undergraduate students each year, will test your ability to solve many different types of mathematical problems.

The exam consists of 12 problems. given in two three-hour sessions. Topics range from calculus and geometry to more advanced topics, and the exam emphasizes both technique and cleverness, according to Harold Diamond, professor in mathematics. Students work as individuals, but three are selected to determine the University's national ranking. Last year, David Secrest, senior in physics, placed 35th out of a field of 2094, helping the University place 15th overall, Diamond said.

The exam will be held on Saturday, December 5. To help prepare for this year's exam, Diamond is holding weekly study sessions on Wednesdays from 4:00 to 5:00 pm in 143 Altgeld Hall. For more information, contact Harold Diamond at 333-0379.

Overseas Business Tips

Anyone doing business overseas must learn to accept the local customs and be as flexible as possible, according to a publication by the International and Domestic Negotiating Institute in Red Bluff, California. Many times, business people do not realize that things are done differently than they are in the United States.

"American businessmen and businesswomen need to start from scratch and act as if they are preparing to deal with someone from another planet!" said Eugene Mendosa of the Institute. He believes that for people to make successful deals, they must not maintain a traditional viewpoint.

Mendosa recommends several things to help people survive in the international business world. Business people should not get upset just because foreigners do not conduct business as Americans do. They should also not rush immediately into a transaction, and they should avoid being individualistic, according to Mendosa.

To increase the chances of success, Americans should study the etiquette of other cultures, learn all they can about the country's business practices, and be patient, according to Mendosa.

More information is available in a free pamphlet from IDNI by contacting Cynthia Williams, Dept. 5026, International and Domestic Negotiating Institute, P.O. Box 882, Red Bluff, CA 96080.

The Debut of Automotive Ceramics

Alex Magnus

Although difficulties still exist, extensive efforts are being made to further the transition of ceramic materials "from teacups to turbines", because ceramic components allow engines to operate with greater efficiency.

A ceramic car engine? Why would anyone want the material of teacups and bathroom wall tiles to be the engine housing of our cars? Ceramic materials possess properties that have many advantages over the superalloy materials currently being used. Superalloys are materials that exhibit greater strength at high temperatures, 1500° F to 2000° F, than do conventional alloys. If ceramics have so many advantages, then why are they not in production and use now? Ceramics, although highly promising, do suffer from problems in manufacturing and implementation. Governments, private companies, and university professors, such as Professor Dennis Assanis, assistant professor of mechanical engineering at the University of Illinois, are working to overcome some of the major drawbacks that have yet to be resolved. Ceramics is currently one of the most scrutinized technological material science areas. "Solving the fundamental problem is now just (a matter of) time," says Kent Bowen, professor of engineering at Massachusetts Institute of Technology.

Ceramic structural parts have significant advantages over conventional parts. Compared to superalloys, ceramics are lighter and made from cheaper raw materials. They require no lubrication and resist corrosion. Because of their strength at high temperatures and excellent thermal conductivity characteristics, ceramic parts and coatings allow engines to run hotter, allowing for significant fuel savings. According to Professor Assanis, the fuel savings will come from two areas. One is insulating the combustion chamber to conserve heat, and the second is to preserve the exhaust heat by venting it through a turbocharger and back to the engine.

Ceramics can be exposed to temperatures as high as 2500° F without distorting or melting. At 2500° F engines can achieve maximum fuel efficiency. Current parts only run at 2200° F, yielding a 25% decrease in efficiency. Running the engine at higher temperatures will allow the use of alternative energy sources, such as methanol mixed with gasoline. Although this fuel is presently in use, Assanis says that the use of ceramics will make it more feasible.

Gas turbine and diesel engines respond well to higher operating temperatures. The hotter these engines run, the more efficient they become. Since heat is poorly conducted in silicon nitride, heat conventionally wasted in the cooling system could be kept in the cylinder and converted to work. In theory, the thermal efficiency of such a diesel engine could be increased by 30%. In actuality, Professor Assanis has found that an intercooled turbocompound engine derives a modest 4.3% thermal efficiency improvement at a 60% reduction in heat loss.

Turbo chargers can also utilize energy from the engine exhaust. Ceramics could be used to make particularly efficient turbine rotors. Ceramics have a third of the density of steel, and their lower thermal expansion allows for more efficient operation at smaller clearances. The lower inertial mass of the rotor cuts the moment of inertia by 45%. This feature reduces the amount of energy needed to accelerate the turbocharger. It reduces turbocharger lag and ensures agile engine response. Nissan has already developed a silicon nitride rotor and is currently using it in Japan in their 300ZX.

Other companies are also making ceramic engine parts. Ford Motor Co. has successfully tested structural ceramics components, including cylinders, pistons, and pins for over 100 hours in a single cylinder engine. The engine showed potential for up to an 11% improvement in fuel economy, with minimum wear and

Graduate student Joe Grindley coats engine components with ceramic materials at the Plasma Spray Booth in the Ceramic Engineering Building (Photo by Eric Smith).

low friction. Companies that are funding Assanis's $300,000 ceramic research budget are Caterpillar, General Motors, Chrysler, Amoco, and government agencies.

Porsche has introduced a ceramic-lined exhaust port system in their 944 model. The system insulates the head from the heat in the exhaust system, protects electronic components, and channels more heat to the turbocharger system. It allows for a more efficient engine and a smaller radiator because less heat must be dissipated by the cooling system.

The Department of Defense is also enthusiastic about ceramic engines. Because ceramic engines require less cooling, cooling systems could be eliminated on tanks. This would reduce weight and maintenance costs.

Ceramics research is not new, especially for the silicon nitride family which includes Syalon, a material used to manufacture engine components. Syalon is named after the chemical names of its elements which are: silicon, aluminum, oxygen, and nitrogen (Si-Al-O-N). The secret of this alloy is the alteration of the silicon nitride crystal lattice. Aluminum atoms replace some of the silicon atoms in the structure; oxygen atoms replace some of the nitrogen atoms.

While silicon nitride could be used for making monolithic parts such as a piston head or valve, present research centers on ceramic coatings. Professor Assanis coats pistons, combustion chambers, cylinder heads, and spark ignition components with zirconia of a thickness of 0.5 to 3.0 mm. A thicker coating would increase the chance of failure and diminish the performance parameters. Assanis plans to use this procedure on a one cylnder engine which he received from Australia for $100,000. After coating the pistons, cylinder pads, cylinder head and liner, he may also place a fully ceramic valve in the engine.

Assanis utilizes the facilities of the department of ceramic engineering at the University in manufacturing the coatings for the engine components he uses in his research. As a result, he can better control the process and can measure the properties of the materials himself.

Perhaps the most serious problem with ceramic parts is their tendency to fracture or shatter under stress. Their brittleness presents a serious technical challenge to both ceramic parts producers and ceramic engine designers. Flaws on the order of 5 to 10 microns can lead to failure of ceramic parts. However, at higher operating temperatures, the stress concentrations surrounding a flaw can actually decrease.

Another major problem area is reliability. There are still many unknowns about ceramics and their long term use. Ceramists have difficulty understanding material properties because not enough ceramic auto engine parts are being produced to provide the necessary volume for study.

Processing methods such as injection molding, slip casting, and hot isostatic pressing create more uniform ceramic parts with fewer flaws. Another method of manufacturing is slip casting, a technique based on a powder slurry. It could be used to create thin-walled parts such as cylinder liners. Uniaxial pressing is a third way to manufacture ceramics. The ceramic powder, laced with an organic binder, is compacted in dies under an intense pressure of up to 30,000 psi. It is then sintered at 3772° F in a nitrogen atmosphere, making it tougher than silicon nitride. It can then be diamond ground to precise dimensions.

Reliability may also be hindered by inherent frictional resistance between parts. This property can be controlled at the atomic level. The process involves implanting metal ions into the surface of ceramics in order to provide the lubricants needed to improve engine performance at elevated temperatures. The process adds the desired lubricating quality by bombarding ceramic specimens with metallic ions, atoms or groups of metals. A very thin layer of metal-ceramic alloy with unusual and extremely desirable properties is created. The ion implanted layers, which are metal-ceramic oxides, appear to become quasi-liquid at very high temperatures and thus serve as their own sacrificial lubricant. Materials used include partially stabilized zirconia and hot pressed silicon nitride. This is one processing method that can reduce some of the existing problems that are inherent in ceramic engine component mating.

Whether the payoffs come next year, in 1990, or in the year 2000, many engineers are convinced that ceramics offer valuable weight, wear, and insulation advantages. The problem now is the arduous task of finding the best ceramic material for the job, improving reliability, and then improving the manufacturing process. If advanced ceramics are developed to their potential, it will have a significant impact on the auto industry, car owners, and the nation.

BIBLIOGRAPHY

Dizard, John W. "The Amazing Ceramic Engine Draws Closer", Fortune 25, July 1983, pp. 76-9.

Scott, David. "Syalon-super strong ceramic for engines, tools", Popular Science, April 1985, p. 89.

Nobbe, Thomas A. "Hot prospects for non-metallic engines", Machine Design 26, June 1986, p. 66.

Tech Teasers Answers

1. 19.2 yards

2. $39, $21, and $12

3. The word *stone* beheaded is *tone*, beheaded again is *one*.

4. Just a few of the monosyllables that will make two monosyllables are heart (hear and art) and stone (tone and one) and Spain (spa and pain). How many more can you name? Write them down and mail them to:

Illinois Technograph
302 Engineering Hall
1308 W. Green St.
Urbana, IL 61801

We will publish the answers we receive i a future issue.

tech profiles

Jim Lefter, visiting professor of civil engineering, has had a challenging and exciting career. After receiving an M.S. degree in civil engineering from the University of Maryland and an M.A. degree in government from Washington University, Lefter worked as a consultant for Bethlehem Steel Company and other industrial and private consulting firms. Later, he worked for the U.S. General Services Administration and as a contracting officer for the Veteran's Administration.

Within his field, Lefter has had many accomplishments: from supervising the construction of hospitals, to restoring a fire—damaged computer room in the Pentagon. With the help of Mete Sozen, professor of civil engineering, and other consultants, he developed new and now widely imitated designs to ensure the safety of buildings during earthquakes. He has also written a book, *A Micro-Based Primer On Structural Behavior*, the result of his love for computers and their uses as engineering tools.

Lefter is now retired from federal service and is teaching as a visiting professor at the University. Lefter is very grateful for this opportunity, as he has always wanted to teach at this campus. Lefter's students get to share in his experience and enthusiasm for his field, which he conveys quite easily, by studying cost estimation in Civil Engineering 318, and design, structural failures, and legal aspects of construction in Civil Engineering 398/498.

Lefter says his wife and children, along with his work, keep him busy. Any hobbies he has time for, such as writing, are work-related. His motto is: "We're always looking for a better way."

Steve Kropp

Tschangho John Kim, professor of urban and regional planning and civil engineering, as well as associate director of international programs and studies, is certainly a world class educator. Originally from Korea, he earned a B.S. in architectural engineering at Hanyang University in 1967. He went on to study urban design at the Vienna Graduate School of Art and proceeded to earn an M.S. in urban planning at the Pratt Institute in New York in 1973. Majoring in transportation, he eventually acquired both an M.S. and a PhD. in urban planning at Princeton University.

Professor Kim usually teaches Urban Planning 407, Planning Evaluation, which studies the economic aspects of planning and transportation policies. However, Kim is currently occupied with a variety of research projects.

He is working on two operations for the National Science Foundation which involve developing efficient algorithms to solve non-linear programming problems. He is also assisting the U.S. Army Corps of Engineers Research Laboratories in the development of the Expert System of Site Selection, which involves artificial intelligence and the creation of new computer software.

Moreover, Kim is engaged in research for the State of Illinois on the economic feasibility of transporting Illinois coal to Asian markets.

Of special interest to Kim is his current position as associate director of international programs and studies (IPS). The objective of IPS is to enable and encourage University staff, faculty, and students to expand research and development of ideas into international forums. Kim is particularly enthusiastic about the study abroad program for undergraduates in which University students work and study in foreign countries. Professor Kim invites all students and especially engineers to "experience study abroad and broaden their horizons."

Among Professor Kim's non-academic goals is the improvement of the University through the creation of a campus-wide bus system for students' safety and convenience. The proposed bus system would enormously assist those living in residence halls and apartments far from campus. In addition, the buses would provide a safe mode of transportation, helping to prevent crime on campus.

Whenever Professor Kim finally does get time off, he likes to relax with sports. He has an intense passion for golf and Kim says, "I never, never, ever skip skiing in the winter."

Ashish Mayenkar