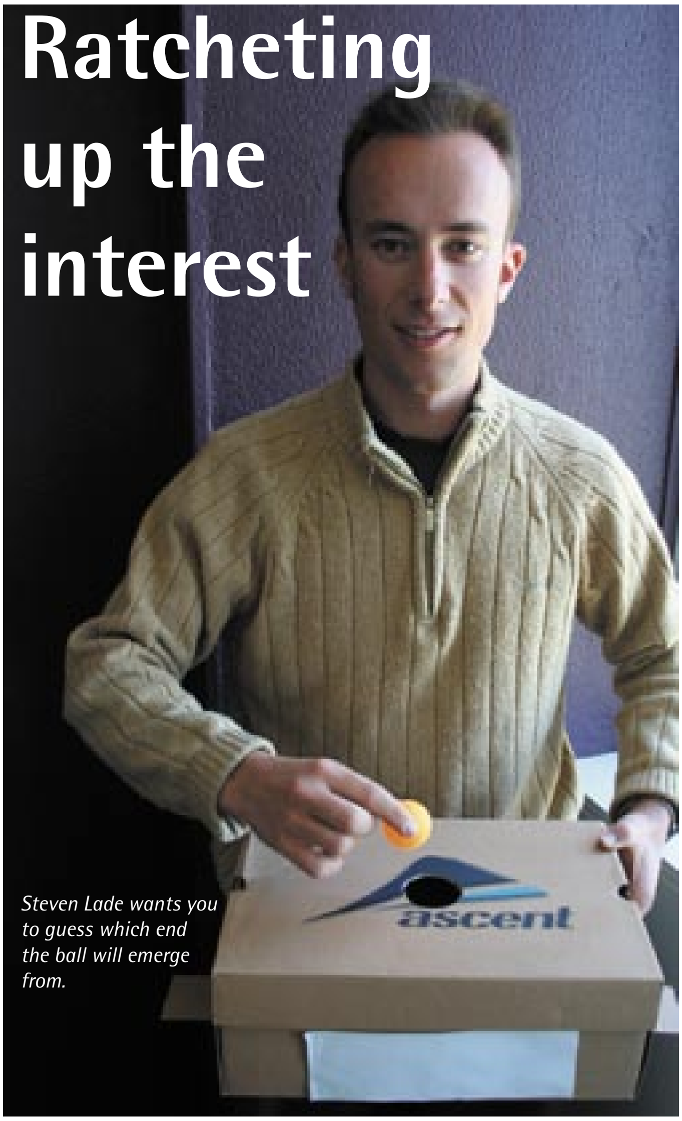
CSEM's
Materials Monthly
September 2007
Making materials matter
THE AUSTRALIAN NATIONAL UNIVERSITY

Ratcheting up the interest



Steven Lade wants you to guess which end the ball will emerge from.

The 'magician' held up a shoe box with a hole in the top and two openings at either end. He drops in a ping pong ball and then randomly shakes the box while asking the audience from which of the two ends the ball will emerge. Out pops the ball from one end and he puts it back in the top. "Which end this time?" he asks, and it comes out of the same end. He repeats the procedure and the ball again emerges from the same end. And then it happens again. Something's not quite right here.

So began Steven Lade's presentation to a university-wide audience of students, researchers and lecturers at the University's inaugural *Physics Students Uncovered* competition run as part of the National Science Week in August. The competition gives PhD students the opportunity to excite the world about their science, and, if they're good, win a bit of money and prestige in the process.

Steven's magic box was in fact a demonstration of a ratchet, a concept that most of us know in the form of a mechanical device such as on a bike or in a fishing reel. It rotates freely in one direction but not the other.

"A mechanical ratchet is a wheel with teeth that are not symmetrical, so they have one side steeper than the other," he explains. "This means that the ratchet wheel prefers to move in one direction.

"A mechanical ratchet is a good analogy for a particle ratchet, the area of science I'm interested in. With a particle ratchet you have a potential landscape acting on particles moving around. You can think of the potential as a series of asymmetric hills, maybe shaped like the teeth of a mechanical ratchet, and they serve to preferentially move the particle in one direction."

Steven's box is an example of a type of ratchet called a geometric ratchet, it contains interior fins which preferentially direct a randomly moving ball in one direction. Other types of particle ratchets include rocking ratchets and flashing ratchets.

"In a rocking ratchet you apply an oscillating force with a zero average. This could be an electric field on a charged particle or something more exotic," says Steven. "In terms of the potential landscape, you think of this as rocking the landscape back and forth, and you see that the particle will move more easily down one slope than the other so you get a net transport of particles in one direction.

"In a flashing ratchet the critical ingredient is that you flash the potential on and off. So, if the potential is an electric field you could do this just by turning the electric field on and off. There could be regular flashing between the two states, the on state and the off state, but you could also have a random flashing between the two states that could model something like transitions between various chemical states of a molecule."

In explaining ratchets, Steven engaged the audience with the science through the skillful deployment of a range of cardboard models and visual overheads. And, of course, this wasn't just about interesting science, it was just as much about the contestants capacity to communicate that science.

Steven, who is a first year PhD student working in the Nonlinear Physics Centre (RSPSE), was up against some tough competition: Toen Castle explained the value of novel knotted networks, Sarah Everett talked about plutonium fallout as a guide to soil erosion, Ramin Rafiei explored exotic neutron rich states of matter, and Matias Rodriguez spoke on attractive and repulsive forces in nuclear fusion.

However, at the end of the day the judges felt that Steven's riveting rave on ratchets earned him first place (and the $2000 prize money). They were impressed by his passion, inventiveness and the confidence with which he shared insights on a challenging area of physics.

"I enjoy the challenge of trying to communicate something clearly," says Steven. "Up until a couple of years ago, however, I was quite scared of getting up

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in front of people and talking; and I wasn't confident at all."

So, what's the secret of Steven's success?

"If you want to improve your communication skills, you have to work at it," urges Steven. "Give yourself plenty of opportunities; it's practice, practice, practice that counts. There are some formal avenues that you can use like the science communication course at the ANU Centre for Public Awareness of Science (CPAS) and Toastmasters. One great thing I got out of CPAS was that I had this perception that a good public speaker is able to wing it. That they can get up with a minimum of notes and preparation, and just to be able to make it up on the spot. However, that's simply not true. I've come to realise that you only get to that point after doing lots of practice. You should approach it like an actor does and work from a script. And this script is something that you carefully craft to make sure it's got the flow and all the ingredients that you want. You don't necessarily have to memorise the script word for word but you should have that script with you when you're practicing. It forms the base of your performance."

So, while the ball might seem to magically always come out of the same side of the box, as with Steven's performance, it's no magic at all, just excellent preparation and the appropriate use of ratchets.

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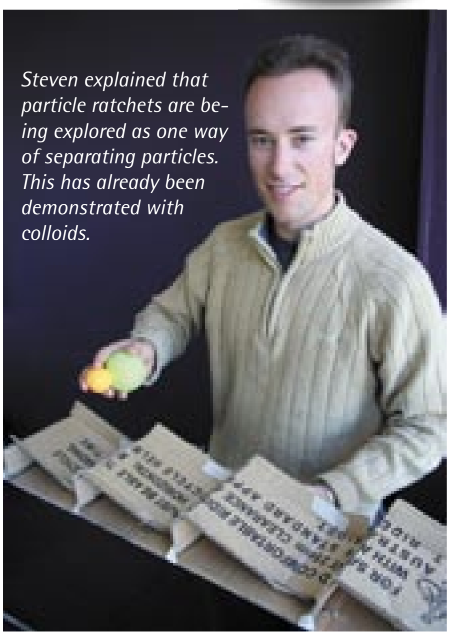

Steven explained that particle ratchets are being explored as one way of separating particles. This has already been demonstrated with colloids.

RAW science

Vince Craig and Erica Seccombe toast the opening of RAW.

As far as Canberra artist Erica Seccombe was concerned, this was science in the raw. That's how she summed up her experience as an artist-in-residence in the Department of Applied Maths in the second half of 2006.

"The researchers were looking at structures and materials in a variety of ways using a range of technologies," explains Ms Seccombe. "Then they would extract the essence of these structures in the form of ideas, schematics and models from which they would generate even more insights on how the world around us functions.

"What they were turning out came across to me as being raw science. And while I was based at Applied Maths I had the seed of an idea that it would be great to put their various outputs on the wall for everyone."

And from this seed of an idea a photo exhibit has grown. Titled 'RAW', the exhibit was opened to the public gaze throughout National Science Week in August at the Photospace (upstairs at the School of Art, in the Photomedia Workshop). Three of the works on display are presented here.

"What resulted was a wonderful collection of images, graphs, equations and photos that took the viewer on dizzying journey over multiple scales and time and space," says Ms Seccombe. "What makes the images so intriguing and engaging is that they encourage you to see different worlds through a filter of ideas.

"It's not unusual for an artist's work to be inspired by scientific concepts that attempt to describe the material structure of the universe and life itself. Artists and scientists have informed each other for centuries and the relationship is well documented, particularly in the last century where concepts of atomic and molecular science can be identified in the work of key artists.

Ms Seccombe's time at Applied Maths was supported by funding from artsACT (see the November 06 issue of Materials Monthly). Applied Maths has had a long history of interaction with the School of Art (for example, see the March 03 issue of Materials Monthly) and RAW signals that engagement is still growing strong.

"I'm hoping that RAW may possibly inspire fresh ideas and collaborations between the two disciplines," she says.

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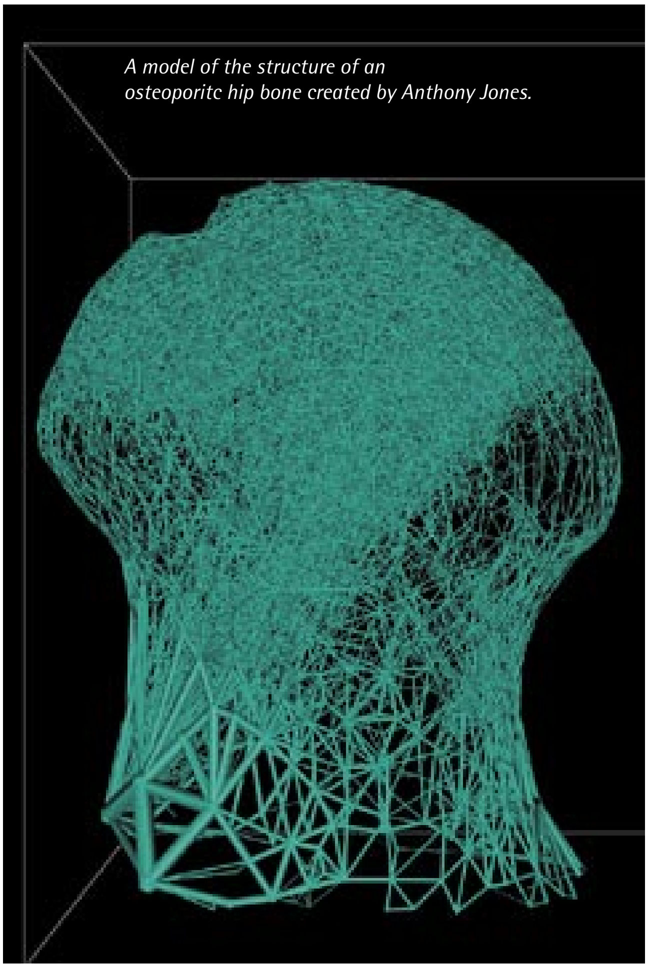
Evanescent waves

"When a laser beam is internally reflected at a glass surface, an 'evanescent wave' is created," says Christine Henry (pictured below). "This images shows the light pattern resulting when an evanescent wave is scattered by an object in its path - in this case, a 20micron diameter silica sphere attached to a V-shaped cantilever spring. Analysis of scattered light intensity can show the



A model of the structure of an osteoporitc hip bone created by Anthony Jones.

Boning up on networks

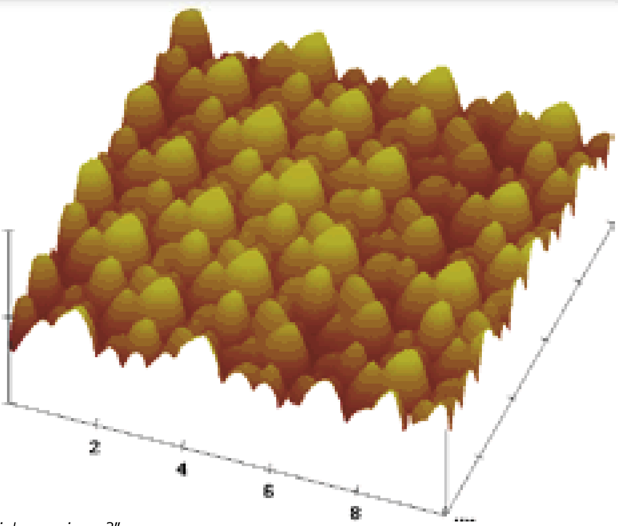
"Osteoporosis is a disease characterised by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk," says Mr Anthony Jones (pictured above).

"We have developed a method to model bone structure as a network of ball and sticks. This allows one to investigate the topological parameters of the underlying trabecular network. For example, one can look at the 'connectedness' of the trabeculae and how this relates to the bone mechanics. Recognition of the importance of structural components of bone strength is essential in understanding pathogenesis of bone fracture and in developing treatments. This method will allow researchers to investigate the weakest directions within the hip joint and determine the fragility associated with a particular fall direction."

Tips on particles

"We're interested in determining the roughness and sphericity of a range of ceramic particles," says Dr Vince Craig. "Now each particle is too small to directly image using the Atomic Force Microscope (AFM). However, we can learn a lot about the nature of the particle by using it as the tip probe on the AFM and run it over different known surfaces. It's a technique known as 'reverse imaging' and, in effect, the 'landscape' you see below is a set of high magnification multiple images of the single particle being used as the AFM tip.

"These force measurements allow us to determine how these particles will behave in solution. We can then answer questions such as: Will they be stable or will they settle out? Will they adhere or remain as individual particles? If we change the pH or salinity of the solution what will happen? What if we change the type of salt in the solution?"



"Yes, but which way is up?"

Dr Tim Senden (on the right) explains a visual conundrum to an artist at the opening of RAW.

Lean too

Simplicity leads to an elegant table solution

If you've wandered past the courtyard outside of the Wood & Furniture Workshop over at the ANU School of Art recently you will have noticed a new installation sitting under the winter-bare plane trees. Two bright green frames of steel support six majestic planks of red timber. It looks for all the world just like a table but it lacks any of the traditional fastenings or joints normally associated with a table.

Well, of course, it is a table, but this table's beguiling simplicity breaks with many of the traditional modes normally associated with this type of furniture.

"We've dubbed it the 'lean too' table," says Mr Frank Maconochie, a second year student in the Wood and Furniture Workshop. "And its simple design is quite a departure from the often complex, high-end furniture designed and produced in the workshop. And that's deliberate because this is a table for everyone and if we'd aimed at anything too elaborate it's unlikely it would ever have eventuated.

"The lean too was designed and built as a common resource for the woodwork community, and our neighbours in the Gold and Silver Workshop and the Sculpture Workshop. This is a very nice spot for a coffee and a chat, especially in summer when the trees are in full leaf, but we didn't have suitably appropriate table to sit around.

"So, Elliot Gorham, an Honours student in the Wood and Furniture Workshop, put out a call for a design of an outdoors piece of furniture. As it happened, I had purchased some hardwood timber to make the student work bench that we raffle off to raise money for the student exhibition, something we do every year. As it turned out, the wood wasn't appropriate for a bench. It's nice wood, but we have no idea of its provenance. In any case, it seemed to a good material for an outdoor table.

"We created the simplest possible design for the piece because no-one has the time to put into these things. We all struggle simply to finish our own projects for the course. So, we were after something both simple and durable for outdoors. And in keeping with an appropriate respect for the timber, we wanted a design that enables the reuse of the wood with a minimum of effort, should that be required at some point in the future.

The lean too - simple, strong and elegant.. Designed by Frank Maconochie (pictured) and Elliot Gorham, the table serves as a communal resource in the workshop area.

"And the lean too table is what has resulted. With this table there are no fastenings what so ever, it's all held in place by gravity. The locking mechanism are two sloping metal frames leaning in towards each other. They're a bit like a trestle on a trestle table but these frames are each one half of the trestle at either end of the table.

"Elliot fabricated the steel because he's had experience with this in his sculpture work. Then he prepared the planks so that they're all the same size, length and dimensions. We expect the wood will shrink and expand a bit, possibly with different pieces behaving in different ways. These planks were purchased as a mixed lot so we didn't expect a great match or how well they would dress up. However, the freedom of the design easily accommodates any variability."

The lean too table works because each metal frame has a post-box-type slot in the top through which the wood planks are slotted. The metal frames lean towards each other, hence the name, holding the timber in place. Each plank is held away from each

Concrete spacers hold the planks apart. The table needs none of the conventional fastenings or joints.

other by spacers made from expander foam strips (normally used between concrete slabs). The gaps easily accommodate any swelling or shrinkage.

The design is as simple as a table can be but the result is both elegant as it is functional. The top rail of the steel frame comes over the table at each end giving it a very distinctive appearance. It's strong, highlights the natural beauty of the timber beams (which are simply polished with oil to bring out their grain)and the whole structure simply pulls apart and can be flat packed for storage and transport.

"Elliot and Frank have created a wonderfully innovative design in timber and steel for the shared Commons outside the Workshop," says Dr Rodney Hayward, Head of the Wood and Furniture Workshop. "It is simple, yet very effective, and it shows a great human spirit deriving from the attitude of its creation."

Several people have asked Mr Maconochie if the design might have commercial applications.

"I'm sure it does," he says. "However, at this time the table has been more of a communal side project. The lean too's main value to us is as a place to meet and reflect on things."

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And if you needed this lovely timber for another project it's simply a matter of sliding it out of the metal slot that holds it together.

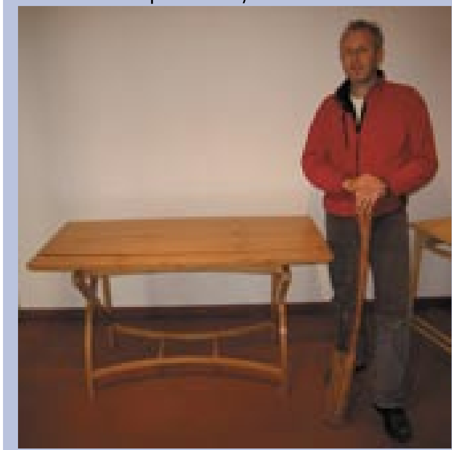
Clever table talk

The lean too follows in a long line of innovative designs for tables from the Wood and Furniture Workshop, and we've got the stories to prove it. This marks the fourth year in which Materials Monthly has featured a novel table design displaying the hallmarks of quality and innovative excellence.

Julie Kennett and the 'long now' table (held together with wooden butterfly joints).

In 2004 we discussed the work of Julie Kennett in creating the 'long now' table. Rather than rigidly fixing the boards of the table top to each other, they are held together (and apart) by wooden butterfly joints that can move with the wooden planks as they expand and shrink over time.

"This design doesn't require thick, premium-grade timbers which are becoming more and more uncommon." explains Ms Kennett. "The hope is we can explore the potential of a range of Australian timbers that previously have never been considered for this type of use, and construct furniture that corresponds to these timber qualities and the Australian climate. This includes plantation timbers and recycled timbers. It raises a number of exciting possibilities."



Peter Giles and his Mt Stromlo commemorative table crafted from burnt trees around the observatory.

In 2005, Peter Giles used a selection of timber oddments salvaged from the charred hulks of trees left around Mount Stromlo Observatory following the 2003 wildfires. Mr Giles was commissioned by the ANU to design and build a commemorative table for the Administration Building at the Observatory.

"The table's form incorporates a variety of curved lines and forms evoking the arcs and traces that are so common in astronomy and astronomical equipment, and the building in which it is housed" says Mr Giles.

Henri Wilson's 'force of nature' table used the flexing strength of beech to give his design legs.

Last year Materials Monthly featured Henry Wilson's 'Force of Nature' table. It uses beech wood in the trim and legs, and laminated styrofoam in the table top to keep the weight down. The supporting rail is flexed and inserted into a slot on the underside of the table where it's held under tension. When not in use the table can be pulled apart and stored. It's stylish to look at and requires no additional tools.

"I was striving for a simple design with no applied fastenings, a simple structure that's easy to assemble and transport," says Mr Wilson. "I particularly wanted to explore the properties of beech. It's a friendly and forgiving wood, especially resilient to bending, and is a plantation timber and therefore a renewable resource."

And now in 2007 we can add the 'lean too'. I wonder what the workshop has in store for us next year?

Frank Maconochie (pictured) and Elliot Gorham have continued the tradition of clever design with the lean too table.

An upgraded Instron

One of real workhorses of materials science and engineering at ANU, the Instron, is about to get an electronic face lift.

The Instron is a universal mechanical testing machine housed and operated by the Department of Engineering (Faculty of Engineering and Information Technology). It can be used to carry out tensile, compressive and flexure/bending tests.

"It's an incredibly versatile rig," says Dr Zbigniew Stachurski. "Tests can be carried out at speeds from 10^{-3} millimetres per minute through to 10^{2} millimetres per minute. And it has three load cells covering the range from 10 Newtons through to 100 kiloNewtons.

"And now we've obtained funds from the university to upgrade the facility with new software that will make the facility easier to use with greater functionality."

The Instron has tested the mechanical properties of a wide variety of materials over time. These include:

1. single graphite fibre testing (of around 8 micrometres diameter)

2. human hair test (undertaken for visiting students such as the National Youth Science Forum)

3. textile strength and drape test (with Lyneham High and Darramulan College)

4. tensile and bending tests on plant stems of arabidopsis (both wild and genetically modified) (in collaboration with Ensis)

5. compression and tensile tests on composite materials with nanotube reinforcement (in collaboration with RSPSE)

6. compression tests on fibre metal laminates (for example, Millie Styles)

Visiting students from the National Science Youth Forum have used the Instron on many occasions to measure the tensile strength of their hair.

Eileen Proctor used the Instron to test the ductility of various silver alloys..

7. compression tests on reinforced concrete bridge models (Darramulan bridge tests)

8. stress relaxation test at a range of temperatures (in collaboration with ETHZ Switzerland).

9. buckling tests on structural members for the Big Dish (with the Centre Sustainable Energy Systems)

10. Flexural tests on composite furniture elements (with Wood and Furniture Workshop)

"The ANU Instron is the only machine in the ACT equipped with the flexibility of features to undertake the range of tests listed here," says Dr Stachurski. "I think this is reflected by the diverse groups from within and outside of the university that have made use of the facility, from school students through to research institutions like Ensis.

"The new software upgrade, called Extend, will make the facility much easier to use. It will also provide us with feedback control that will allow close loop control for forces and extensions. This will enable time-dependent creep testing under constant load, something we haven't been able to do up till now."

The upgrade should be complete within a month.

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Amy Philbrook (above) is planning to use the Instron to test the mechanical strength of her test wood composite boards, and Millie Styles (below) used the Instron to measure deformation in aluminium foam composites.

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