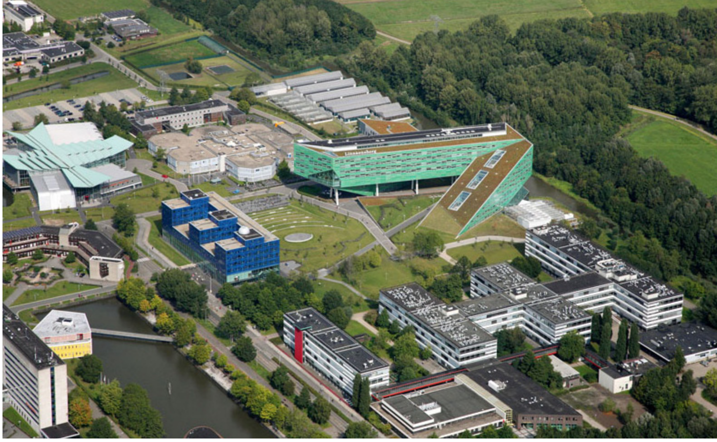
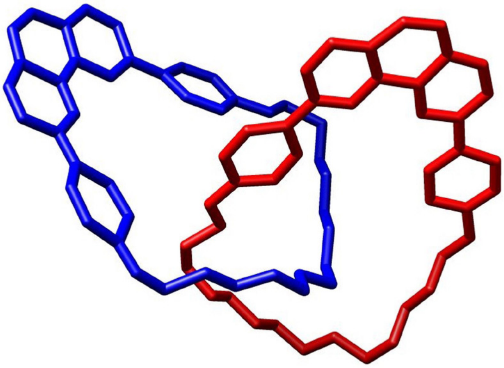
perio*diek

Recurring FMF magazine volume 2016 number 3

6 - From the Frontiers of Knowledge

In the Periodiek's new recurring section 'From the Frontiers of Knowledge', researchers from the various institutes affiliated with the RUG in the fields of physics, mathematics, astronomy, computing science, and artificial intelligence report on the cutting edge science that is conducted there. In this issue, the KVI-CART and the VSI are presented.





10 - Molecular Machines

Recently, the Nobel prize in Chemistry was awarded for Molecular Machines. One of the Laureates was the RUG's own Ben Feringa. In this article, Eva Dijkman tells us what it's all about.

Do you have a question for a professor?

Do you want to know something and don't know who to ask?

Mail us at perio@fmf.nl **and we'll try to find an answer!**

16 - The Sky is the Limit

For the first-year course Physics Laboratory 2, Joey Richardson and his group members launched a weather balloon to an altitude of 25 km to measure cosmic rays.

In this Periodiek

From the Editor in Chief

Dear Periodiek reader, we are very proud to present to you the first Periodiek created by us, the new Periodiek committee. Making it has been a new and exciting experience for all of us, and we hope you will enjoy reading it.

I'm writing this on a Saturday, during the so-called 'Perio weekend'. Last night most of us were at a party, so we're all a bit tired, but spirits are still high. This is the first time I'm at the university in the weekend, and if you would've told me a year ago that I had to be here on a Saturday, I'd think you were joking. But with some nice music and a couple of great articles, it isn't that bad.

Now that we're in the final stages of making this magazine, I can say that it takes a lot of effort and I would like to thank the previous committee for doing it last year.

When this Periodiek reaches you, it may already be 2017, and it's probably still cold outside, so in this edition you can find some recipes for hot chocolate and tasty coffee.

On behalf of the editors, happy new year!

— *Rick Vinke*

Editors
Rick Vinke,
Thomas Swarts,
Jasper Somsen,
Carolien Feenstra,
Sander Vermeulen

Authors
Ad M. van den Berg,
Carolien Feenstra,
Joey Richardson,
Steven Hoekstra,
Sietse Buijsman,
Wouter Roos,
Eva Dijkman,
Jan Bakker

Advertisers
KxA (p.9),
Philips (p.19),
Schut (p. 24)

Advertise? Contact us at bestuur@fmf.nl.

Print run 1100 pieces

Press PostNL

ISSN 1875-4546

The Periodiek
is a magazine from the Fysisch-Mathematische Faculteitsvereniging and appears three times per year. Previous issues can be found at perio.fmf.nl. The board of editors can be reached at perio@fmf.nl.

In the News

Supercluster revealed in the Zone of Avoidance

A new study reported the presence of a potential supercluster in the constellation of Vela. An international team of astronomers measured the redshift of 4500 galaxies in the Zone of Avoidance to map the galaxies. The data shows a galaxy overdensity in the Zone of Avoidance. Indeed, this region on the sky is often avoided by astronomers due to attenuation, interstellar dust and stars of the Milky Way that cause obstruction of light coming from beyond the Milky Way.

The new spectroscopic data was made with the SALT, the South African Large Telescope, and the Anglo-Australian Telescope. The mass of the newly discovered Vela Supercluster (VESC) pulls the Local Group, of which our very own Milky Way is a member, with approximately 50 kilometers per second towards itself. No worries, during the time the Local Group is closing in on the Vela Supercluster the Milky Way will have collided with the Andromeda galaxy already.

NASA, Science

Drones inspired by dragonflies

Besides being pretty, dragonflies are also an inspiration for engineers. UK scientists and engineers are currently working on the SKEETER, a dragonfly unmanned aerial vehicle. The dragonfly has a superior mobility above other insects due to its wings that can flap independently. It can even turn the flapping off and on.

British military are currently using drones inspired by hornets: The Black Hornets. The drones are efficient but only at certain speeds. A drone with flapping wing propulsion instead of a propellor has the ability to perform better over a larger range of velocities and can glide in case of failure. The prospect of the dragonfly drone will open up other functions besides surveillance such as safe delivery of packages and a new vehicle for Ant-Man.

The Engineer

€7 million to research electric dipoles, quantum gravity and skyrmions

The Van Swinderen Institute and the Zernike Institute for Advanced Materials in Groningen were awarded with seven million euros by the Stichting voor Fundamenteel Onderzoek der Materie (FOM) for upcoming research.

The Van Swinderen Institute will continue their measurements of the electric dipole of electrons, led by prof. dr. Steven Hoekstra. With the knowledge of internal quantum state control and decelerating and cooling molecules the researchers of the Van Swinderen Institute will look beyond the Standard Model.

Prof. dr. Eric Bergshoeff of the theory group of the Van Swinderen institute was awarded part of the grant together with other colleagues of the university of Amsterdam, Utrecht and Leiden to research quantum gravity. The research aims to obtain the mathematical laws of quantum gravity and to gain insight in the gravitational force when quantum mechanical effects are studied as an isolated system, such as in the very early Universe.

The Zernike Institute for Advanced Materials was awarded their part of the grant to investigate magnetic skyrmions. A skyrmion is a topological defect with a spiral structure for which the magnetic moment in the middle is opposite to the magnetic moment of the outer ring. Prof. dr. Maxim Mostovoy of the Zernike Institute for Advanced Materials and his colleagues in Delft want to obtain electric control on skyrmion dynamics to make efficient magnetic memories.

RUG

Bacteria catalyses silicon-carbon bonds

What seems to be complicated for chemical engineers is a natural business for bacteria: bonding silicon atoms with carbon atoms. Chemical engineers in California made a discovery that could provide a large boost to the pharmaceutical industry. By extracting the cytochrome c from a bacterium, *Rhodothermus marinus*, found in hot springs, the bonding between a silicon atom and a carbon atom can be catalysed.

The cytochrome c molecule is an electron carrier protein that is found in the mitochondria of these bacteria. When carbon molecules with two unshared valence electrons are inserted into silicon-hydrogen bonds, the process is sped up by adding the cytochrome c protein. On top of that, by mutating the protein, the reaction is sped up 15 times. Hence, the bacteria makes an efficient contribution to organosilicon chemistry.

Science

AUTHOR: STEVEN HOEKSTRA

From the Frontiers of Knowledge

The Van Swinderen Institute for Particle Physics and Gravity

In this article we will introduce you to the Van Swinderen Institute (VSI). You probably already know some of our staff members from the courses we teach throughout the physics curriculum, especially in the Quantum Universe specialisation. Here we would like to familiarise you with our research. This information can be helpful if you are interested in doing a bachelor or a master project in one of our research groups.

The VSI is a young institute; we held our kick-off symposium in March 2015. The institute was formed in the fusion of the former Centre for Theoretical Physics (CTN) and members from both the theoretical and experimental groups at the Kernfysisch Versneller Instituut (KVI, since then KVI-CART). The VSI currently consists of thirteen scientific staff members, two technicians and three part-time secretaries, and our director is Prof. Eric Bergshoeff. Since 2016 the VSI represents the University of Groningen in the national institute for subatomic physics, Nikhef. Through this and other collaborations our research is firmly connected on a national and international scale.

Our research mission

The aim of the VSI is to study the fundamental forces of nature with implications for our universe. These investigations connect through close similarities in physics from Planck-scale physics (quantum gravity) via sub-atomic scales (particle physics) to cosmic dimensions. We combine both theoretical and experimental efforts, working together on three research frontiers: the high energy frontier, the precision frontier and the cosmic frontier. Here we will give you a brief overview of the research we perform at each of these three frontiers. In a series of future Periodiek articles we will describe the research at each frontier in more detail.

High energy frontier

The Standard Model of elementary particle physics provides a near perfect description of subatomic physics. Nevertheless, there are multiple reasons to believe that there must exist new physics beyond the Standard Model. The highest energy scales currently available for experimental searches are many orders of magnitude below the Planck scale, i.e. the scale where the quantum effects of gravity become relevant. This large unexplored energy range may harbour many surprises and forms the research objective at the high-energy frontier.

Our scientists participate in the LHCb experiment at CERN. This experiment aims to explore what happened after the Big Bang that allowed matter to survive and to build the universe we inhabit today, by studying the properties and behavior of elementary particles at highest possible energies. From the theoretical perspective, we investigate the properties of the fundamental forces in nature at the smallest distance scales, within the framework of the microscopic theory of the strong and electroweak interactions, the Standard Model of particle physics, and possible extensions of it. Research topics include electroweak symmetry breaking and the Higgs sector, the family structure of the Standard Model, strongly coupled theories Beyond the Standard Model (BSM), conformal symmetry in gauge theories and AdS/CFT, Lorentz and CPT symmetry violation, new heavy gauge bosons, and 'dark photons'.

Precision frontier

Complementary and competitive to the research carried out at high energy particle colliders, we can search for physics beyond the standard model in low energy precision experiments. We do this by placing a sensitive well-known system (which can be a molecule, ion, atom or other particle) in a completely controlled environment, so that its properties can be precisely measured. From a comparison with the accurately predicted properties of this system we can learn about the completeness of the underlying physics: the fundamental interactions and symmetries. Deviations between experiment and theory could indicate detection of new physics. Researchers in our institute are running such experiments on cold molecules and on ions, while from the theory side high accuracy calculations of various atomic and molecular properties are performed.

Cosmic frontier

The research at the cosmic frontier aims at solving some fundamental physical questions, such as the nature of dark matter and dark energy and the origin of the universe. Scientists at the VSI attempt to gain a deeper understanding of the gravitational force, in particular in the quantum realm, in the very early universe and in connection with dark energy, focusing on three themes: branes, holography and string cosmology. Due to the expanding nature of our Universe, these problems are interrelated in an intriguing and challenging way. String theory is by far the most promising candidate theory of quantum gravity; on the other hand, modified gravity models such as Massive Gravity change the workings of gravity at large distance scales and are candidates to solve the dark energy mystery.

Very recently (November 2016) two large FOM grants have been awarded to the institute members. The first program will make an experiment possible to measure the electric dipole moment of the electron using cold molecules. The second program is aimed at studying the general principles and mathematical laws behind quantum gravity and its consequences for the physics of black holes and cosmology. These awards will allow us to expand our research activities and infrastructure and to bring more PhD students to the institute. If you are intrigued by this research and would like to know more, just drop by or send one of us an email! •

AUTHOR: AD M. VAN DEN BERG

From the Frontiers of Knowledge

Matter under extreme conditions studied at KVI-CART

At the KVI-Center for Advanced Radiation Technology extreme conditions in Nature are explored to obtain better insights into the fundamental forces in Nature and to improve techniques which can modify or damage materials in a well-controlled and well-verifiable way.

Our common theme is the development of complex instrumentation to study these conditions and the design and application of smart analysis and data-viewing tools based on advanced algorithms. The largest in-house piece of instrumentation of our center is the superconducting cyclotron AGOR, which can accelerate particle beams to energies of hundreds of MeV or even GeV, depending on the ion species, which range from very light (hydrogen and helium nuclei), to very heavy (lead nuclei) ions.

The main theme for research at this cyclotron facility is the interaction of these high-velocity particles with matter, and how to create and to control the damages we inflict on materials. One of the outstanding applications is the treatment of cancer using precision irradiation by particle beams. This research is performed in close collaboration with the Groningen University Medical Center, which is currently constructing a new facility for radiation therapy based on accelerated particles.

To make further improvements on this technology, researchers in Groningen advance the current methods through the development of new instruments and through new irradiation strategies, which require substantial research activities before they can be ported to the clinical environment. An example which might lead to increased targeting quality is the combination of imaging techniques made by magnetic resonance scanners while the irradiation of ionising particles takes place.

At the Facility of Antiproton and Ion Research in Darmstadt (Germany), the particle beams reach even higher energies. At this facility, which is also under construction, we will explore in large international collaborations extreme conditions of nuclear matter, similar to the conditions occurring prior and during supernova explosions, where we need to understand properties of nuclei relevant under extreme conditions in stellar environments. With the antiproton beams at this facility, we will study very short-lived exotic particles made from a mixture of quarks. These studies will reveal the true nature of the origin of mass of the atomic building blocks: the protons and the neutrons. For these studies we also design, construct, assemble and operate complex instruments.

At the far end of the accelerator scale, i.e. far beyond the energies achievable by human-made accelerators, we investigate the origin of particles created during the most extreme conditions in the Universe; acceleration near supermassive black holes in remote galaxies. This research is taking place at research infrastructures nearby (LOFAR in Drenthe) or at more remote places like South America.

As a spin-off of this work, we are currently investigating the mechanisms behind the ignition of lightning, which we, even after the studies of Benjamin Franklin almost 250 years ago, still poorly understand. Again, we combine our expertise on the creation of radiation under extreme conditions with advanced analysis techniques to tackle this problem •

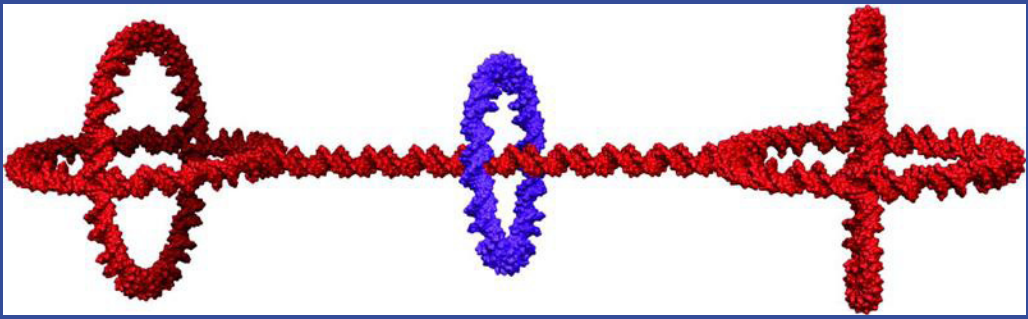


FIGURE 2

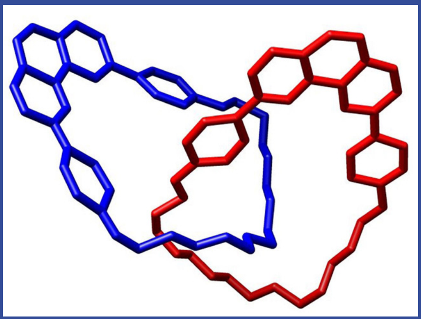
AUTHOR: **EVA DIJKMAN**

Molecular Machines

On your bike on your way to class in the freezing morning cold you have probably seen the huge banners around Zernike. Or the near life-sized poster near the Nijenborgh canteen. Or even the big banner near the bus stop. Or the flyers. In fact it has been hard to miss Ben Feringa's face this past month. So it is probably no news to you that Ben Feringa, professor at the RUG since 1988 [1], received the 2016 Nobel prize in Chemistry together with Jean-Pierre Sauvage and Sir J. Fraser Stoddart.

Curiously it was Richard Feynman, the Nobel prize laureate in physics of 1965, who was perhaps the first inspiration of the topic of this Nobel prize in chemistry which was awarded 'for the design and synthesis of molecular machines' [2]. In the 1950's, Richard Feynman already drew attention to the possibility of building small machines from atoms [3], something that already existed in nature in for example bacterial flagella. This gave scientists something to dream about in much the same way as pointing out flying birds did for the Wright brothers.

FIGURE 1



Around the time of Richard Feynman's visionary lectures, chemists were busy trying to create molecules that were held together by mechanical bonds. Contrary to covalent bonds, in which atoms of the molecules share electrons, this would provide a way of linking molecules without their atoms interacting with each other. It wasn't until the 1960s that such structures could be successfully synthesised and isolated [4]. However, yields remained extremely low and the methods were so complex that practical use was very limited. Two types of structures that were first synthesised in this period are catenanes, compounds with one or more rings that are interlocked and can thus form chains (figure 1), and rotaxanes, based on a ring threaded over an axle with stoppers at each end (figure 2).

In 1983, the field took a giant leap forward when Jean Pierre Sauvage and his colleagues introduced a specific synthesis method, called template synthesis, which used metal coordination to form catenanes [4]. The success of this simpler synthesis method marked a breakthrough and invigorated the research. Subsequently, many different shapes of interlinking molecules were successfully synthesised, such as trefoil knots and Solomon links. Based on the varied catenanes that were formed, Sauvage and his co-workers discovered that the structures were capable of translational isomerism, in which a compound moves relative to the other compounds in the structure.

The field took another big leap forward in 1991 when Sir James Fraser Stoddart and his colleagues showed clear translational isomerism in rotaxanes. The ring of the rotaxane could be shown to move between the two ends of the axle. Following this discovery, in 1994 both Sauvage's and Stoddart's research groups showed translational and rotational movement that could be externally controlled. This was done in both cases by introducing asymmetries in the structures. These asymmetries result in a most favourable position of the compounds relative to each other, which shifts as circumstances change. This means movement can be controlled by changing these circumstances, for instance the pH or applied electric current.

These mechanically interlinked structures do lack a classic component of a standard motor: a turning axle. And this is where Ben Feringa reappears. Normally when molecules spin their spin is random. But in 1999 Ben Feringa was the first to design a molecule that would only spin in a particular direction. The molecule was composed of something that can be likened to two small rotor blades, two flat chemical structures that were joined with a double bond between two carbon atoms (figure 3). When the molecule was exposed to a pulse of ultraviolet light, one rotor blade jumped 180 degrees around the central double bond [3]. This design represented a giant leap forward in the design of molecular machinery, and is seen as the first molecular motor. These three developments together formed the start of a small revolution. As stated in the press release of the Nobel committee: 'In a sense, we are at the dawn of a new industrial revolution of the twenty-first century, and the future will show how molecular machinery can become an integral part of our lives.' The Feringa group was able to improve its nanoscale motor to a speed of 12 million revs per second in 2014. Already in 2011 they built a four-wheel drive nanosized car. And perhaps most impressively, Ben Feringa's research group has used molecular motors to spin a 28 micrometre long glass cylinder (10,000 times bigger than the molecular motors) [3].

In interviews prof. Feringa often refers to the brothers Wright. "The first time the Wright brothers took flight they made it 37 meters. Now, a hundred years later, we have airbuses, helicopters and even drones. Travel by air has become a normal part of life. Only time can tell what shape a the nano-equivalent of a Boeing 727 will take, but perhaps in the future molecular robotics will have become a normal part of everyday life as well" •

References

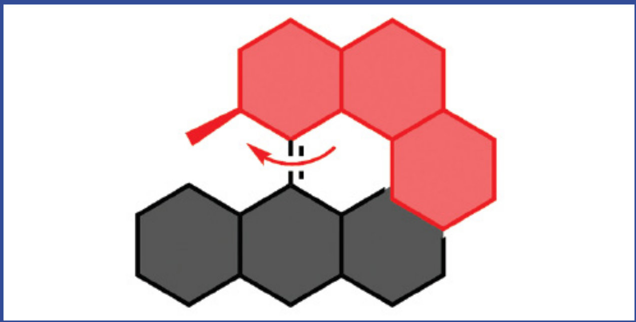
[1] http://www.rug.nl/news/2016/10/nobelprijs-scheikunde-voor-ben-feringa

[2] https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/

[3] https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/popular-chemistryprize2016.pdf

[4] https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/advanced-chemistryprize2016.pdf

FIGURE 3



3D Printing Mouthpieces

AUTHOR: **JAN BAKKER**

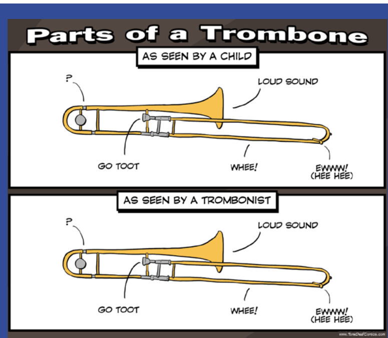
Some people say that you should separate work from private affairs, but if I look back on the different projects I did during the time I studied in Groningen, the ones I enjoyed most are the ones where I failed miserably at making this distinction. Even though these projects often end up without too much hard core physics (or maybe because of that), they tend to be very rewarding and fun to tell people about, hence this article.

The project involved some theory, measurements, computer drawings, printing, testing and commercialisation. I'll touch on some of these, in this order.

In all brass instruments, sound is produced by buzzing the lips against the mouthpiece. So whenever you read trombone in this article, you can substitute trumpet or whichever other brass instrument. This mouthpiece is a detachable part of the trombone (figure 1). The shape of the mouthpiece is key in the timbre and intonation of the instrument. Since material properties are only of secondary influence, and people have different preferences for their mouthpiece, I saw an opportunity for printing them in plastic with a 3D printer, offering unlimited customisation options.

A primary function of the mouthpiece is bringing the pitch of the different overtones of the instrument together in a desirable overtone sequence, where each whole multiple of the fundamental mode is present. This is the case in for example a violin string. In its essence though, the brass instrument is a half open tube, with the mouthpiece side acting as the closed

FIGURE 1



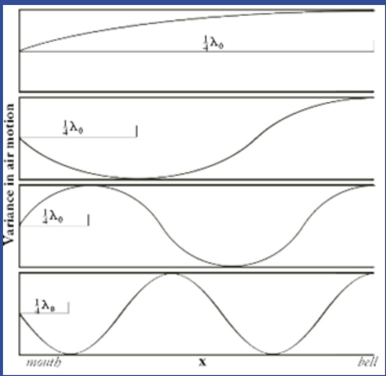


FIGURE 2 closed (or open) tube resonances

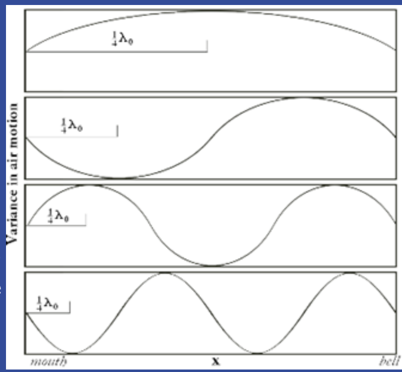


FIGURE 3 half open tube resonances.

end, whose overtones would be only the odd multiples of the fundamental (figures 2 & 3).

The flare at the bell side of the trombone mainly influences low frequency waves with a wavelength larger than the radius of curvature of the bell. These waves 'feel' like they are outside the instrument before they are at the bell side and hence 'see' a shorter instrument, raising their frequency. On the other end, these waves only 'see' the length of the mouthpiece whereas the higher frequency waves 'see' the whole volume of the mouthpiece, lowering those resonances in frequency. The combined effect closely resembles a closed tube with the corresponding overtones (figure 4).

When one plays on the instrument, it is not just one overtone that sounds. The spectrum of overtones provides a fingerprint for the timbre of the instrument, which can be obtained by Fourier transforming a recording of the sound (figure 5). Generally, a tone with only the first couple of overtones strongly present is perceived as a warmer sound, whereas more higher overtones give a brighter sound.

Measurements

One of the trickiest bits of the research turned out to be getting accurate drawings of the mouthpieces. Since no manufacturer was willing to provide them, I had to measure them up myself. 3D scanners are generally not accurate enough. In the end, I made precise casts using silicon casting material and photographed these and the outside of the mouthpieces. I then zoomed in from a couple of meters to prevent parallax distortion. This provides sufficient information because of the cylindrical symmetry of the mouthpieces (figure 7).

Testing

To print the mouthpieces, I used an Ultimaker 2+ 3D printer that was made available to me by Katja Loos' chemistry group. The mouthpieces were made from the least toxic material available, the plastic polylactic acid. After countless tries, the quality of the printed mouthpieces got to a level that I could start testing. To do this, I compared the Fourier spectra of mouthpieces with identical shapes made from different materials. I could not find significant differences (figure 6).

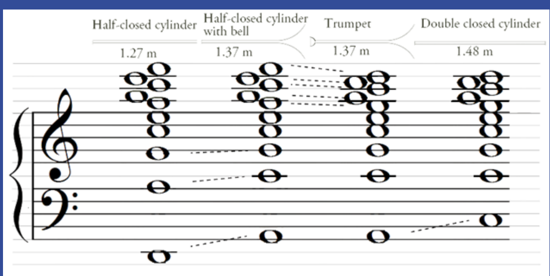


FIGURE 4 The effect of bell and mouthpiece. You can see that the trumpet (or trombone) acts effectively as a double closed cylinder, except for the lowest (unused) resonance. If you are not familiar with this notation, you can just view the height of the note as the frequency of the note.

But a sound is more than the real part of its Fourier spectrum; among other things, the start and end of the tone are also important for the character of the instrument. I also did a panel test where some musicians tried to hear which mouthpieces were the same and which ones different. Unfortunately, they were able to identify clearly which mouthpieces were made of plastic and which from metal.

Follow up

To improve on this, a finer printing technique could be used, resulting in a smoother surface. In addition, heavier materials that have the same density as brass, and therefore maybe the same sound, could be used. One could also try a hybrid approach, where a custom plastic cup is screwed onto a metal tube such that the contact between mouthpiece and instrument is metal on metal.

Even as it is, the project has potential. There are already some plastic mouthpieces on the market, which are injection moulded instead of 3D printed. Some target groups include children and musicians playing in cold weather. My panel test showed me that I can compete with these mouthpieces and provide much more flexibility in design. I already sold some to friends, and, shameless plug, set up a little website to spread the news, www.ppmouthpieces.com. Whether it stops there, or grows into a real business, to me it was a great project to work on because of the diverse skills I needed and the satisfaction of actually being able to use the results •

The HTSM program

The High Tech Systems and Materials program is offered to all students at our faculty. Its aim is to connect hardcore science with industry. The participants come from all kinds of majors, something I really enjoyed. The program consists of three parts: in the first year of the program, starting somewhere around november, the students get lectures on bèta topics (polymers, material science, etc.) and soft skills (giving feedback, brainstorming, etc.) and write a project plan for the second part of the program, a summer school (in our year at Philips). During this summerschool, we developed our own product proposal at Philips Drachten. In the final part you show what you've learned, through a project of your choosing, which for me was the one described in this article.

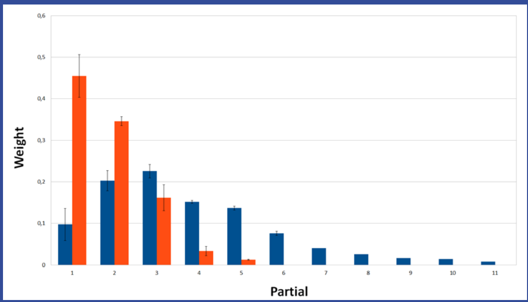


FIGURE 5 A spectrum of the overtones present in a middle C played on a trombone (red) and a euphonium (blue), which is a more mellow sounding instrument

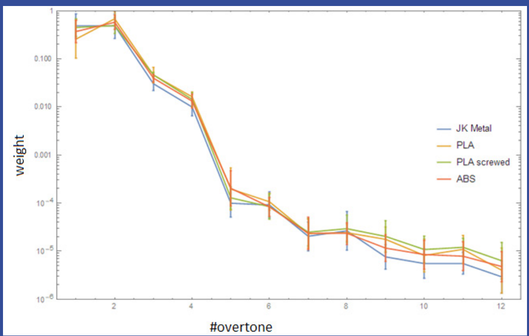


FIGURE 6 One of the graphs comparing a middle C on the original metal mouthpiece and three 3D printed alternatives.

FIGURE 7

AUTHOR: **SIETSE BUIJSMAN**

Introducing the New FMF Board

If you have visited the FMF members room in the past half-year, you have likely encountered one of us already. Still, we would like to introduce ourselves properly by telling something about us.

Our board consists of Berend Mintjes, the chairman, Sander Vermeulen, the vice-chairman and commissioner of education, Sietse Buijsman, the secretary and author of this article, Tobias Vos, the treasurer, Thomas Swarts, the commissioner of external affairs and finally Harmjan de Vries, commissioner of internal affairs.

I have known Sander and Berend for a few years now as we started our bachelor of physics in the same year and we have been hanging out together since. We applied for the FMF board together, but only after Berend tricked Sander and me into doing so, by telling both of us that the other was going to apply as well. Thus, under the influence of heavy peer pressure, we applied and shortly after we received the news that we were (likely) going to be on the next board. Do not worry, none of us have any regrets about this decision whatsoever.

We have officially been installed as the 58th board on the 22nd of September, but we have been slowly learning and taking over tasks from the 57th board since July. By the beginning of September, we practically had full responsibility for organising activities and keeping everything else running. We had a bit of an unusual start, as Harmjan only joined us shortly before the academic year started. As a consequence, he only had a very short period of time to be shown the ropes by his predecessor, Nick Lutjes. For the rest of us, however, it was a huge relief, as this meant we did not have to distribute his tasks among ourselves.

Our first month was incredibly busy, as there were a lot of things we needed to take care of ourselves. We had to write our policy plan, register about 150 new members, find people to join our committees and organise our own activities, as said committees were not ready to do so yet. By October, most of these things had been taken care of and we could slowly start focussing on actually fulfilling our tasks as a board. As October progressed, I noticed that all of us got more capable and efficient in performing our own tasks as well as in working together.

What I believe is very unique about our board, is that every single one of us got the function they applied for and I think that everyone is very good at it. However, more importantly, I feel that we get along really well. Right from the first time we met each other, we had a great evening and a lot of fun. Everytime we would meet up, we would come up with new jokes. So far, we have never been bored [board --Ed.] when we were together. I think this is very unique and that it greatly contributes to our motivation and drive.

Only two months have passed, which means that we will have to stick together for ten more months. No one knows what lies ahead, but judging from the time we had together so far I am confident that these ten months will be great and filled with amazing experiences •

FIGURE 1 The new board just after installation.

AUTHOR: **JOEY RICHARDSON**

The sky is the limit

During the course Physics Laboratory 2, in the final block of first year Physics, groups of students are asked to prepare an experiment, collect data and write a report on it. Our group consisted of four students from different backgrounds: Jelle Bijlsma from the Netherlands; Joey Richardson from England; Jonathan Hamann from Germany and Marcello Capasso from Italy.

After much discussion, we decided on the topic of our experiment – an investigation into how the cosmic rays flux depend on height. In particular the two main hypotheses were that the count rate increases with height up to ~18 km to then sharply decrease. This would imply that the source of radiation is extraterrestrial and is caused by single high energy particles colliding with the atmosphere to create showers of secondary particles .

Now, proving this is no easy task. While climbing the Martini Church with a Geiger Counter provides a very nice view of Groningen, it would not have helped our investigation. The solution was to send a weather balloon up to ~25 km.

With a plan set in mind, we first had to find a sponsor to our expensive project. To solve this issue we decided to email IBM, who gave us an appointment with their manager. After the meeting the four of us walked out smiling with a funding organisation supporting us. Our apparatus included a Geiger counter to measure count rate, a temperature sensor and a pressure sensor to measure pressure, which we then used to calculate height. Everything was connected to an Arduino Due, a small computing device used to save the data on an SD card. We also purchased some cameras, which were then mounted on the payload pointing downward and sideways. To our dismay, we did not see a secret NSA base in the clouds or Santa Claus flying through the sky, but at least it looks really pretty up there (see photo above).

We worked hard during the preparations of the equipment, which included a long day of testing at the KVI-cart, which almost broke our spirits. As the launch date came closer, we were increasingly confident of success thanks to thorough preparation and helpful advice from members of the university staff such as Ad van den Berg and Huilin Chen.

Finally, the day came. We got in the car and road tripped all the way to Espel in Flevoland. Upon arrival, we checked our flight predictor tool, as setting off with the wrong wind in the wrong location could have led the balloon to fly into the North Sea, or worse: Germany. The preparation of the balloon took around an hour, a large portion of which involved filling the balloon with the 3.5 cubic meters of helium.

At last, the time had come. We let go of the balloon and waved it goodbye from the ground. We then took a group selfie and got back into the car to drive to the expected landing zone. After around two minutes, the GPS on the equipment box lost signal, so for the almost two hour flight time, we were left in the dark. To our relief, once the equipment box got close enough to the ground, we started to receive its GPS coordinates. We recovered the box, celebrated wildly, and took the equipment home to begin investigating the measurements.

To our delight, our measurements confirmed both of our hypotheses: the count rate increases up to the expected peak at 18 km, to then decrease sharply as the balloon keeps rising.

The peak is due to the rarefaction of the air as you go further from earth. At 18 km the likelihood of a primary particle to have collided is at its maximum, as you go higher the chance of primary particles to collide with air molecules decreases and as you go lower the probability that it already collided increases.

Because of the success of last year's project, this year the group is preparing a new experiment involving the measurement of the thermal neutrons' flux in the troposphere. The radiocarbon (14C) content of atmospheric CO2 is useful in understanding the processes of the global carbon cycle, due to the fact that various carbon sources contain distinct 14C signatures. Radiocarbon is primarily produced in the upper atmosphere through reactions of nitrogen nuclei with thermal neutrons that are induced by cosmic rays. To this end, observing the vertical profile of cosmic rays could provide us a promising tracer to understand the natural production of 14C, and thus contribute to our understanding of the global carbon cycle •

AUTHOR: CAROLIEN FEENSTRA

A Minor in Nanophysics

The choice of minor in a bachelor can make a significant change. The minor is a chance to look beyond your bachelor and take a 'break' from your regular curriculum, by going abroad or pursuing a University Minor at the RUG. The minor can also be an opportunity to explore a field more deeply by choosing a minor within your own programme or an internship.

Robert Fery follows a minor in nanophysics at the RUG while studying physics at the Technical University of Berlin. Universities in Germany only have 'plain physics', Robert points out, with no specific bachelor in applied or theoretical physics. Specialising within the bachelor is done by choosing optional courses to your preference.

To explore nanoscience and nanotechnology, Robert chose to follow a minor in nanophysics within the ERASMUS+ programme. Since the University of Glasgow ended its partnership with the EU programme, Robert ended up with his second choice: Rijksuniversiteit Groningen. His self-composed minor in nanophysics contains courses in Programming in C/C++, Solid State Physics, Subatomic Physics, Modern Developments in Nanophysics, and Nanophysics and Nanotechnology. He enjoys the nanophysics track, and he would like to continue this study in his master's.

At the Technical University of Berlin a physics bachelor contains 1.5 years of basic laboratory courses followed by half a year of extensive project practicals. Within the nanophysics minor, Robert followed Physics Laboratory 4, but decided to drop the course after realising he had already performed most of the experiments in Berlin, as part of his basic laboratory courses. One of the main differences between the labs at the TU Berlin and here at Zernike is the lab structure, Robert explains. "Here, there are predetermined structures." He found that the setup of practicals at the RUG allows for less student input and freedom to set your own experimental goals and methods. However, the equipment at the RUG is more advanced. Another large difference between the RUG and the TU Berlin is the examination. To pass a course students are obliged to make assignments in order to do a written pre-examination. Upon successful completion, the final exam is conducted orally with a professor. Students are given three chances to pass the oral exam. If the student does not pass at the third chance, the course is not available to the student anymore. This of course poses a considerable difficulty if the subject is compulsory.

A minor in nanophysics has inspired Robert to pursue his study within nanophysics. For his bachelor research Robert would like to work on semiconductors at the Fraunhofer Institute of Applied Solid State Physics, and perhaps pursue his career with a PhD to become a researcher for institutes and companies •

Fraunhofer IAF

One of the business units at the Fraunhofer Institute of Applied Solid State Physics is developing tunable semiconductor lasers with wavelengths in the infrared spectrum, ranging from 2 to 11 μm. Besides the semiconductor lasers the business unit is developing LED modules for the ultraviolet and visible spectrum. The goal of the business unit is to make light sources based on semiconductors applicable beyond solid state lighting. 'Photobiosense' is one of the applications. Fraunhofer IAF develops a Quantum Cascade Laser in the mid-infrared range for a sensing system that measures the concentrations of the component gases in biogas.

Fraunhofer IAF

PHILIPS

AUTHOR: **WOUTER ROOS**

Mechanics of viral nanoparticles

On November 1st, Wouter Roos started as Associate Professor in Molecular Biophysics at the RUG, having previously worked at the VU Amsterdam. His group will address interactions between viruses and cells, the interplay between nucleic acids and cellular proteins, and will -together with an indusctrial partner- develop High speed AFM technology to probe vescicle dynamics. In light of his move to Groningen, he introduces one of his research projects here. -Editors

Viruses are a remarkable example of how a highly efficient and successful self-assembly process of natural building blocks lead to the construction of hierarchically structured complexes. its simplest form, viruses form from a large number of identical proteins that assemble around the viral genome in a closed, geometric shell. From a physical point of view, it is intriguing to elucidate the material properties of these particles and therefore we have set out to characterise their mechanics. To characterise viral nanoparticles in a biologically relevant environment one has to study the particles in liquid. Given the length scale of these particles (~30 – 100 nm), and the fact that we want to work in salt solutions, Atomic Force Microscopy (AFM) is the ideal technique to perform the measurements. After imaging of the viruses, the nanoparticles are indented one by one and a force curve is recorded. Figure 1 shows the principle of the force measurements including the resulting force-distance curves. From the linear part of the indentation curve the spring constant of the particle can be extracted, and the drop in the force is associated with irreversible failure of the particle.

This nanoindentation method has been used to study the physics of a wide variety of viruses [1]. Here a few examples will be given. Norovirus is a virus encountered by many of us, as it is associated with gastroenteritis, also called stomach flu. Next to this very annoying characteristic of Norovirus, it also has a fascinating side and that is its structure. The protein shell that surrounds the viral RNA has an intriguing structure including arch-like protrusions. It was hypothesised that these arches had a mechanical

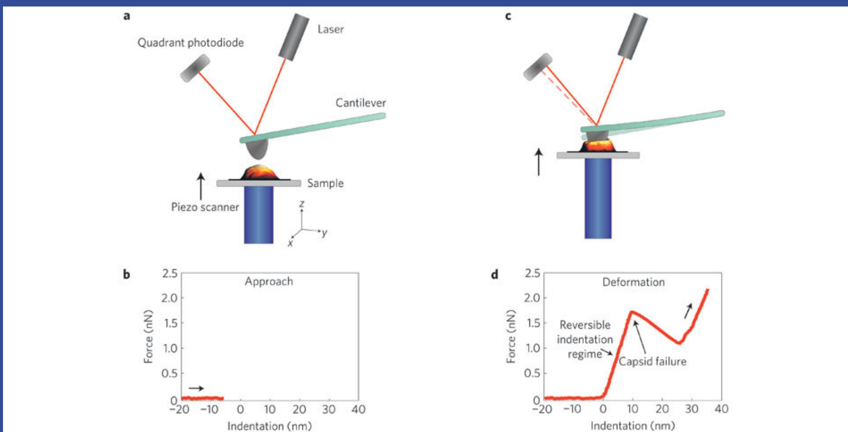


FIGURE 1 Nanoindentation on a virus. a) Side view of AFM set-up with one viral nanoparticle on the surface. b) Force-indentation curve, before indentation has started. c) The particle is indented. d) The curve shows after the initial linear deformation that the nanoparticle has broken. Reprinted from ref. [1] with permission from Nature publishing group.

stabilizing effect. Using mutants without the arches and comparing the mechanical properties of these particles with the normal viral particles, we tested this hypothesis, which turned out to be true: just like in prestressed concrete, these arches play a stabilizing role by putting the virus under tension [2]. This resulted in a remarkable strengthening of the virus which could help these nanoparticles to survive in hostile, harsh environments. Figure 2 depicts AFM images and reconstructions of the virus. Prestress in viruses turns out to be a more common method of stabilization of the shell than previously thought. Next to Norovirus, for instance, also Herpes Simplex turns out to use prestress to stabilize the protein shell that surrounds its DNA [3]. Interestingly, in the case of Herpes it is not an isotropic increase in strength, but an increase that is specifically localized at the vertices of the icosahedral particles.

Next to prestress that can reinforce the viral structure, the viral genome can also have a stabilising effect on viruses. Nanoindentation experiments on the Triatoma virus (which infects insects) have revealed how the viral genome can have antagonistic effects on the particle stability [4]. At neutral pH the RNA stabilises the viral shell, which can be concluded from the high spring constant of the particles and the breaking force. Interestingly at alkaline pH, the RNA plays a destabilizing role, likely due to charge inversion resulting in a low spring constant and a low breaking force. This result can be explained in view of the viral life cycle: during infection the virus passes through the mildly acidic gut of the insect where it should stay stable. After passing the gut the pH rises and the virus arrives in an alkaline environment where the host cells will be infected. A pre-destabilisation will help in the final uncoating process in which the viral RNA is delivered to the cell.

Above I have shown a few examples on how the mechanical measurements on viruses can reveal fundamental physical properties of these natural nanoparticles. This not only gives us insight into the fascinating design principles of genomic protein containers, it can also provide handles for the rational design of synthetic nanoparticles in electronics, physics, chemistry and medicine •

References

[1] Roos WH et al Nature Physics, 2010, Vol. 6, 733
[2] Baclayon M et al Nano Letters, 2011, Vol. 11, 4865
[3] Klug WS et al Phys Rev Lett, 2012, Vol. 109, 168104
[4] Snijder J et al Nature Chemistry, 2013, Vol. 5, 502

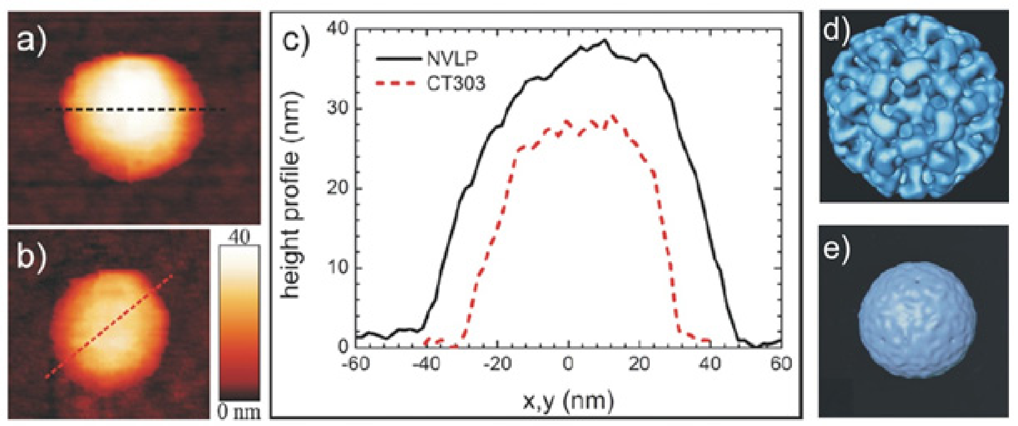


FIGURE 2 Norovirus. a) AFM image of Norovirus. b) AFM image of the CT303 mutant that lacks the protruding arches. c) Height profile of the virus (NVLP) and the CT303 mutant. d) Reconstruction of the NVLP. e) Reconstruction of the mutant showing the absence of the protrusions. Adapted from ref. [3] with permission from the American Chemical Society.

Hot Winter Drinks

AUTHOR: CAROLIEN FEENSTRA

With temperatures around 273 Kelvin it's about time to melt cocoa butter crystals in warm milk. A process better known as making hot chocolate. If spiced hot chocolate alone is not enough to keep warm there is the Spanish barraquito with its 4 separated liquids.

Hot chocolate

Ingredients:

- 300 mL milk
- 50 g dark chocolate (cut in pieces)
- 1 tablespoon of cocoa powder
- 100 mL whipped cream
- 1.5 tablespoons of sugar
- 4 pinches of chili powder (or more), optional
- a pinch of salt
- marshmallows, optional

Heat up the milk in a small pan. Once the milk is hot, add the chocolate and cocoa powder. Stir until the chocolate is dissolved and add the chili powder. Turn off the heat and whip the cream with the sugar until frothy. Pour the hot chocolate in a mug, put a tiny pinch of salt on top and add the whipped cream with marshmallows.

* For a different flavour, replace the chili and the whipped cream with a bit of (vanilla) liqueur and a pinch of cinnamon.

Barraquito

Ingredients:

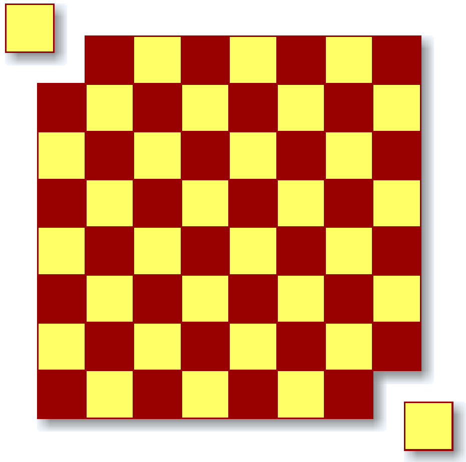
- 1 cup of strong coffee or espresso
- 100 mL of milk
- 2 tablespoons of sweetened condensed milk
- a shot of vanilla liqueur such as Licor 43, or replace by a teaspoon of vanilla extract.
- a lime
- a pinch of cinnamon

Put the condensed milk [can be found in supermarkets near the Asian cuisine section] in a glass. Pour the Licor 43 slowly on top of the milk. Rasp some peal of the lime and add it to the liqueur. Heat up the milk in a small pan and whisk up a foam. Spoon 5-10 spoons of the foam on top of the liqueur. Now take a spoon, hold it closely to the frothed milk and pour the coffee over the convex side of the spoon into the glass. Cover up any signs of coffee in the milk foam with more milk foam and sprinkle some cinnamon on top.

Previous Brainworks

1 GERECHT
2 MELK
3 BOTER
4 KAAS
5 KOK
6 POMPOEN
7 ONTBIJT
8 DINEREN
9 FRUIT
10 KIPPENSOEP
11 VERBRANDEN
12 OBER
13 PEPER
14 BROOD
15 BESTEK
16 OVEN
17 EIEREN
18 GROENTE
19 RUND
20 BIER
21 BRADEN

The solution for the rebus out of 2016-1 is given on the left. The solution of the previous brainwork is as follows: since every domino covers a black and a white square of the chessboard, and two white squares are removed, you can never cover the full chess board with dominoes.



New Brainwork

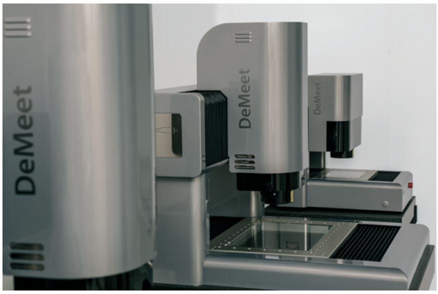
The Praeses

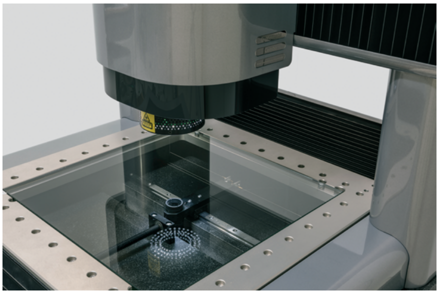
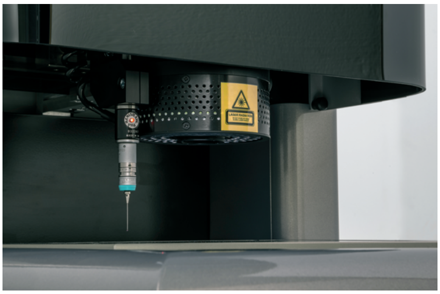
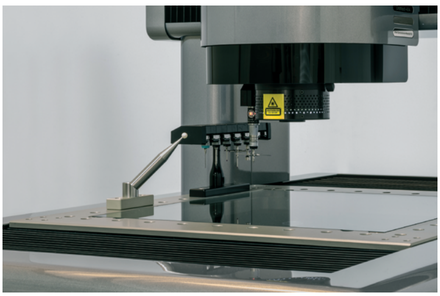
You are the chairman of the FMF and there will be a borrel tonight. It will be a Lustrumborrel, so it is paramount that all goes well. You have 2000 pints of beer (pints were chosen in an effort to improve the FMF's intercultural competence) that you were planning to offer to the members, but you find out one of them has been roofied (spiked with rohypnol).

The effects of the drug become apparent after an hour. You have just over 90 minutes to find the roofied pint, as it would of course be unacceptable to drug the members. You have some arts students who are trying to crash the Lustrumborrel at your disposal.

What is the smallest number of art students you need to drink from the pints to find the roofied pint within 90 minutes?

You can send in your answer until February 18th 2017 at perio@fmf.nl



Schut Geometrische Meettechniek is een internationale organisatie met vijf vestigingen in Europa en de hoofdvestiging in Groningen. Het bedrijf is ISO 9001 gecertificeerd en gespecialiseerd in de ontwikkeling, productie, verkoop en service van precisie meetinstrumenten en -systemen.

Aangezien we onze activiteiten uitbreiden, zijn we continu op zoek naar enthousiaste medewerkers om ons team te versterken. Als jij wilt werken in een bedrijf dat mensen met ideeën en initiatief waardeert, dan is Schut Geometrische Meettechniek de plaats. De bedrijfsstructuur is overzichtelijk en de sfeer is informeel met een “no nonsense” karakter.

Op onze afdelingen voor de technische verkoop, software support en ontwikkeling van onze 3D meetmachines werken mensen met een academische achtergrond. Hierbij gaat het om functies zoals ***Sales Engineer***, ***Software Support Engineer***, ***Software Developer (C++)***, ***Electronics Developer*** en ***Mechanical Engineer***.

Je bent bij ons van harte welkom voor een oriënterend gesprek of een open sollicitatiegesprek of overleg over de mogelijkheden van een **stage-** of **afstudeerproject**. Wij raken graag in contact met gemotiveerde en talentvolle studenten.

Voor meer informatie kijk op www.Schut.com en Vacatures.Schut.com, of stuur een e-mail naar Sollicitatie@Schut.com.

APPROVE for DeMeet