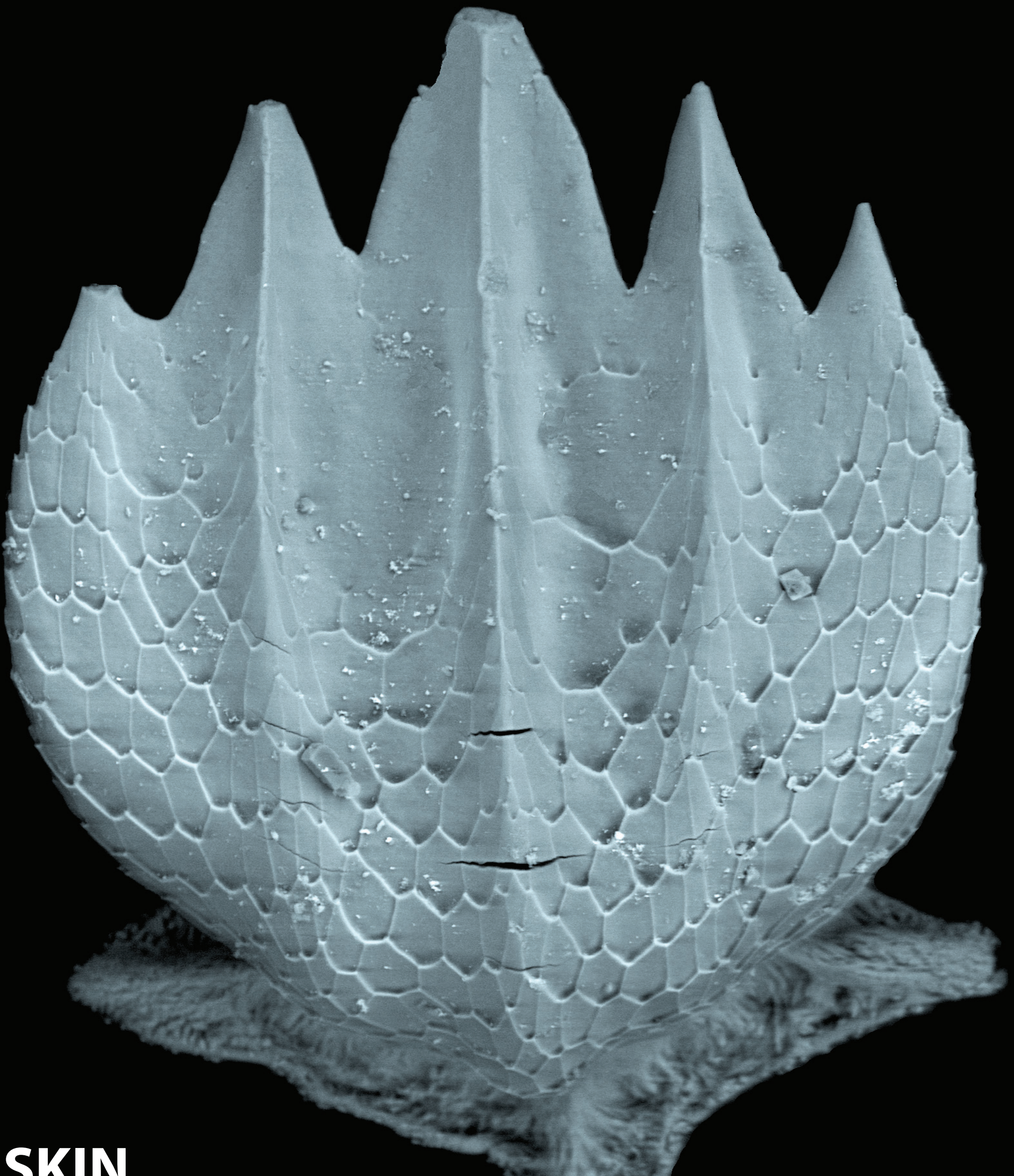
Australian Physics

VOLUME 59, NUMBER 4, OCT-DEC 2022



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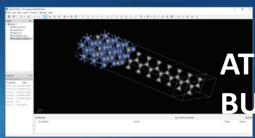
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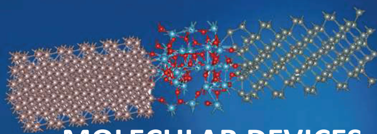
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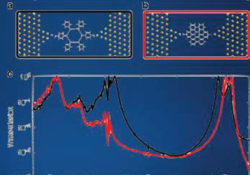
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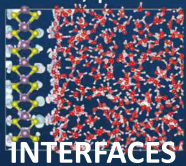
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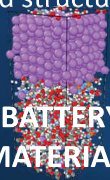
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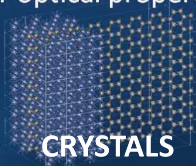
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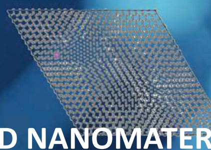
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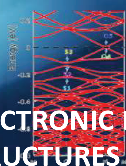
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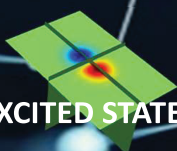
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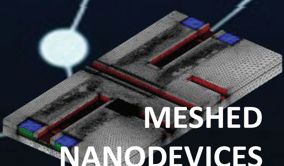
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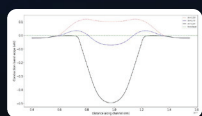
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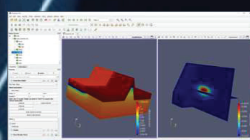
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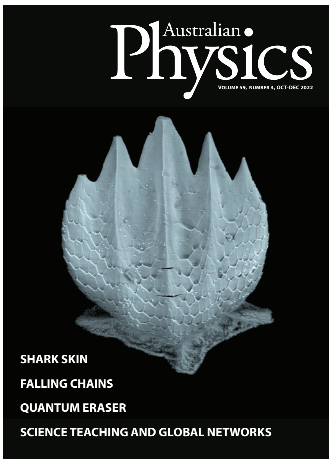

Cover image: Scanning Electron Microscopy image of a denticle (a scale) from a Hammerhead shark. Colour, sharpness, and exposure of the original image were adjusted for presentation purposes. Image kindly supplied by Erin Dillon (erinmdillon@ucsb.edu). See her breathtaking images and learn about her environmental work at https://erinmdillon.wordpress.com/

Australian Physics

A Publication of the Australian Institute of Physics

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Articles or other items for submission to Australian Physics should be sent by email to the Editors. Only MS Word files will be accepted; a template with further guidelines is available online at the AIP websites (www.aip.org.au).The Editors reserve the right to edit articles based on space requirements and editorial content.

ADVERTISING
Enquiries should be sent to the Editors.

Published four times a year.

Print Post approved PP 224960 / 00008
ISSN 1837-5375

PRODUCTION & PRINTING
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1/3B Newlands Road, Reservoir VIC 3073
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Editorial

Diversity in physics: past, present and future

In the final issue of *Australian Physics* for 2022, we highlight the secondary school teachers and students of the physics community by showcasing their Year 12 projects. The students should be proud of their achievement- the articles have been edited only for length and are of a very high standard. We received more articles than could fit in the print magazine, so more articles can be found in the *Australian Physics* section of the AIP website.

Continuing the theme of physics in schools, educators also share their perspectives on the 2022 CONASTA conference addressing scholarship of pedagogy and related issues. We encourage physics educators in schools and universities to share and collaborate.

As *Australian Physics* continues to evolve, we are looking for a co-editor to join the editorial team in 2023.

As the year comes to an end, we look forward to reporting AIP Congress highlights in the next issue. Also, with the Quantum Information special issue planned for the second quarter of 2023, please email your ideas to aip_editor@aip.org.au.

Finally, the Editors wish all our readers and their loved ones a safe, restful, and inspiring holiday season.

Best wishes,

David Hoxley, Clara Teniswood, Shermiyah Rienecker and Peter Kappen.

President's Column

About two years ago, I wrote my first column with this title, and it appears as topical now as it was in 2020. In terms of the acute medical impact, we are getting past COVID-19. However, there is still a massive impact on society in general, and the higher-education sector feels ongoing budget pressures, all the while even 2nd year students do not have the opportunity to experience normal campus life. On the upside, the pandemic teaches us about the benefits remote working/learning can have.

In the last two years, the AIP took the opportunity to speak up for members around the challenge of the Australian Research Council's (ARC) "loss of direction". In my opinion, the ARC is not "broken"; it means well but seems to have lost touch with the scientists it aims to support. For instance, banning pre-prints was well intentioned in order to focus on rigorous quality standards, but the measure missed the mark in terms of quick access to information firmly adopted by the physics community. Now, a full ARC review is underway and the AIP, together with other professional bodies that forged a united front in representing the scientific community, watches closely to comment on the recommendations.

The past two years have highlighted more than once the importance of science in response to significant global events (here, a pandemic). The Australian Government adopted an approach driven by data, and the public got used to seeing scientists in the media every day. Post-pandemic, a strong focus has been placed on employability and translation of research to applications to support build-up of the Australian economy. This focus was welcomed by the physics community at large, even though it also fuelled the focus on the National Interest Tests.

From my perspective, it is extremely important to showcase physics as a discipline synonymous with problem-solving, skills, employability, and a balanced research landscape from fundamental, via long-term applicable, to commercial outcomes. These skills and research translation are not merely aspirational; they have been part of the Australian technology success story. Talking to people who are not scientists, the discipline of physics is perceived as 'hard' and not readily connected to everyday problems. Yet, the Global Positioning System (GPS) started as a test of general relativity based on atomic clocks and was then developed into transformational technology. Try navigating a passenger jet from Sydney to London without GPS…. Articulating the relevance of physics to society is an important element of reversing the damage caused by the lack of JobKeeper for the tertiary education sector and the so-called "Job-Ready Graduates Package".

Generating public appreciation of physics requires all of us to effectively communicate and celebrate our excellent outcomes. To help achieve this in the best and most equitable way, the AIP reviewed its national awards, updated the criteria, and made them accessible online. In addition, two new awards were established this year for handing out at AIP Congress: the *Medal for Women in Leadership and the Communications Award*. Alongside awards, it is important to connect to all sectors of physics represented by the AIP, which includes universities, government and commercial research labs, and industry. Embracing our broad base, the AIP formed an Advisory Panel to the Executive and will deliver a corporate membership proposal to Council and implement a nationwide job fair next year.

With two years at the helm coming to a close, I am excited to hand over at the Council meeting next year to Prof Nicole Bell as President and Dr Stuart Midgley as Vice President. They are a team of highly regarded and talented physicists, one in theoretical particle physics and the other in a company delivering low-carbon footprint high-performance computing. It will be my honour to support them as Immediate Past President.

Enjoy the congress, and wishing you a peaceful holiday season!

Sven Rogge, AIP President

Connecting Teachers: The Value of Building Global and National Networks

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Teachers hold a special role in society, in that they develop and influence the directions of young people they work with and help shape the future landscape of industry, critical thinking, human ideas and search for new understanding. Crucially, this is a collective responsibility that requires input of a vast range of experiences, knowledge bases and approaches. Naturally, this demands teachers learn constantly and gain understanding through exposure to new perspectives and building networks with other diverse experts. Having the opportunity to communicate, analyse and apply ideas with an intellectual and practical focus is vital as an education practitioner and enhances one's ability to achieve outcomes with students. To express it succinctly,

"The most valuable resource that all teachers have is each other. Without collaboration our growth is limited to our own perspectives." - Robert John Meehan.

Attending conferences and other professional development activities can represent some of the most meaningful opportunities for teachers to connect with professionals, develop skills and ideas and establish valuable, ongoing links for the exchange of knowledge and experience. This is particularly so for teachers living and working in regional or more isolated locations. There are often fewer local opportunities to experience the broad array of expertise offered at large professional learning events. The COVID-19 pandemic and the broader use of technology and the internet has taught the world that most things can operate online and function at great distance through collaboration of parties situated all over the globe. However, this does not replace the benefits of face-to-face interaction, completing practical work in groups or the range of demonstrations and in-person interactions made possible when educated and like-minded individuals come together and communicate from within the same space. Personally, I have had two fantastic opportunities this year to experience the benefits and immense value of teacher focused networking and professional development.

I was privileged to be selected for CERN's International High School Teacher Programme, a two week intense learning experience in July on particle physics that brings physics teachers from around the world together at CERN's headquarters in Geneva, Switzerland. I owe considerable acknowledgement and appreciation to the Australian Nuclear Science and Technology Organisation (ANSTO) for facilitating and sponsoring my participation in this once in a lifetime opportunity.

Teachers at CERN's LEIR particle accelerator

After being delayed for two years (due to COVID-19 restrictions), this program collected 43 teachers from 34 countries, offering the opportunity to listen to and speak with academic experts, science communicators and industry professionals. Site visits of CERN facilities promoted real world applications of physics, broadening ideas about the significance of science and the need for collaboration across all fields to achieve goals and develop new technologies. Workshops presented new and innovative approaches to classroom discussion, teaching practice, and hands-on activities. Teacher participants were afforded time and space to discuss and share their own backgrounds, curriculums and teaching methodologies, culminating in group presentations that collected the best ideas for teaching aspects of particle physics.

These types of experiences lead to growth in teacher capacity and are then able to be taken back to classrooms around the world to inspire and motivate students and young people in their own pursuit of learning. The connections built with global colleagues during my CERN experience are lasting and give me ongoing opportunities to share my skills and learn from others. This informs my teaching practice, provides me with new ideas to implement, and affords highly educated, competent teaching professionals the ability to share knowledge on a global scale. CERN's program highlights the value of teachers as facilitators of learning, and enriches the knowledge and resources available to each educator so they are best equipped to empower future generations with the means to lead scientific change and advancement.

Later this year, I also attended CONASTA69 in Canberra, a major national science education conference held annually in September. Being awarded the 2022 Ruth Dircks Scholarship by the Australian Science Teachers Association (ASTA) gave me the opportunity to attend. The event provided a broad range of workshop options to address aspects of science teaching across many fields. As a physics teacher, this year's focus on physics and astronomy was of major interest to me. I was able to visit facilities such as the research centre at Mt Stromlo and the Canberra Deep Space Communication Complex. Workshops allowed me to learn how to access these centres in the classroom and engage students in current research these organisations are focused on. I was also exposed to a large range of educational companies and sponsors who provide fascinating programs and resources for school students.

Astronomy session at Mount Stromlo during CONASTA

In terms of professional networking, one of the hallmarks of CONASTA69 was the opportunity to meet and speak to many prominent individuals that I have previously only interacted with online through email, educational social media pages and Microsoft Teams groups. Meeting in person as well as developing new links with other teachers enhanced the ability to communicate, share ideas and build stronger connections with mutual benefits. My professional network links lead to greater opportunities for my students through successful outreach programs, excursion opportunities and online data collaborations.

A key aspect of professional learning events is the inbuilt time which allows participants to communicate with each other about their areas of expertise and experience and share ideas for improving pedagogy and student outcomes. As a high achieving professional, it is extremely motivating to engage with like-minded individuals who are cognizant of and engaged in educational practice and have high knowledge of academic content. My experiences have given me greater perspective and drive to improve my own abilities and share my skills with a larger and more diverse audience of educators and students. I am deeply grateful to have been given the opportunity to participate in unique, outstanding learning opportunities, where I have had the chance to form ties with other exceptional educators. Developing these national and international networks is key for promoting positive change and growth in knowledge, perspective and human outcomes. As a scientist and educator, I look forward to strengthening the connections I have formed into the future.

About the author

Koko Dove is a high school physics, chemistry and mathematics teacher who currently works in regional NSW. She has a broad range of subject qualifications and interests across many fields. Koko holds a Master of Education and a Master of Science (Astrophysics) and is commencing a PhD in Astrophysics at the Australian National University in 2023. As a teacher, Koko has an interest in promoting higher education for all students, women in STEM, opportunities for gifted and high potential students, and furthering professional knowledge and skills for herself and others.

Reflecting on the Australian Science Teachers Association's Conference

CONASTA is the Australian Science Teachers Association annual conference. This year's conference was originally scheduled for 2020, but was postponed due to Covid19. Here, two science educators reflect on their experiences at CONASTA69, which was held in Canberra during the recent school holidays.

CONASTA as a presenter, exhibitor and attendee

Jacob Strickling, Tiny Science Lab - jacobstrickling@gmail.com

Held in the heart of Canberra, minutes from the occasionally tranquil Lake Burley Griffin, CONASTA69 kicked off, where else, but Questacon. At this opening event, it was wonderful to meet some of the faces I previously associated with names in social media forums through which educators share teaching strategies and resources.

I witnessed some joyous reunions of teachers who hadn't seen each other since the last CONASTA (in 2019) and it became evident that this event is not just about improving educational techniques but actually reinvigorating the passion for science teaching.

At this year's CONASTA, I was able to wear all three hats of a participant: Attendee, Workshop Presenter and Exhibitor.

There was no shortage of hands-on workshops. Some prime examples were Paul Looyen's homemade cloud chambers, Stem Reactor's forensics, building toy solar cars, STEM on a Shoestring and exploring electrical circuits with lead pencils, batteries and LEDs. There were many more workshops suited to the more cognitive able than me and it was wonderful seeing packed rooms of colleagues sucking up the rarefied air.

A favourite definition of mine is that an Expert is simply a Drip under Pressure! Anyone can have a go at presenting a workshop. I called my workshop 'Simple DIY equipment to enhance your teaching' and brought in a bunch of junky bits of equipment I'd put together over the years. At the end of the workshop, I felt that I'd received more than I'd given in terms of helpful suggestions and enjoyment.

As an exhibitor, it was great to rub shoulders with so many of the big names in the Science game, for example Scientrific, Modern Teaching Aids, Stile, Education Perfect and the CSIRO to name but a few. It's a great thing to be able to talk face to face with the suppliers of equipment and educational resources. Asking questions and making suggestions is how we all improve. Exhibiting was such a great way to see so many new faces and strike up wonderful conversations.

So, is going to CONASTA worth it? Absolutely, positively it is! I'm so looking forward to seeing many of my fellow educators at CONASTA70 in Adelaide next year.

Connection, curiosity and conversation: the benefits of conferences as professional learning

Amy Dennis, ACT Education Directorate - Amy.Dennis@act.gov.au

After almost three years of participating in online professional development and staring into screens, it was quite a treat to attend a conference in-person. At CONASTA69, I was reminded how important it is to take the time to build my own teaching toolkit, despite the logistical challenges that can sometimes arise when planning these experiences. Over four days I was inspired by guest speakers, workshop facilitators and my peers, experienced first-hand some of Canberra's state-of-the-art science facilities and had the opportunity to be the curious learner I encourage my own students to be.

CONASTA provided the opportunity to explore new places, engage with some of the best scientists our country has on offer and go on excursions that I didn't have to plan! I was delighted to hear prominent scientists share their work, including their hopes for our students. A big takeaway was the focus on building skills and curious minds, an aspect that I strive for in my teaching every day. During a tour of the National Botanic Gardens, I had the opportunity to hear from real practising scientists and find new concepts to bring into my classroom.

I walked away from this conference a more informed teacher and was able to tap into my inner nerd again, something that can get lost during the cycles of reporting and assessing. The value of incidental conversations with colleagues can also not be underestimated. I took away many 'oh I hadn't thought of it like that' moments, coupled with the knowledge that I'm seen and heard with the struggles and challenges that I face in my teaching.

Most importantly, I was reminded what it was like to be a curious learner again, to be the student and to be inspired and learn from my peers. These moments all added up to rekindle the spark I have for sharing science with my students.

Opportunities to further our own development at conferences like CONASTA are well worth the effort. While we face many challenges in the current climate of teaching, ultimately, this experience reminded me of the bigger picture. I have shared so many of my new learnings with my students and have noticed my excitement is infectious. Thanks, CONASTA, for putting a little extra sparkle into my teaching this term.

About the authors

Jacob Strickling has taught high school science for the past 24 years. He now focuses on his new company Tiny Science Lab which produces innovative new science equipment for schools. Jacob enjoys running science incursions and presenting professional learning workshops for educators. If it's science and it's fun, you'll be sure to see him close by!

Amy Dennis is a high school science teacher. She is currently employed as Assistant Director in the ACT Education Directorate Academy of Future Skills Team, supporting STEM education in ACT public schools. She enjoys nothing more than getting excited about learning new things and sharing her love of finding stuff out with her students, big and small.

Investigating the weight of falling chains

Amlan Nag, Year 12 Student, Queensland Academy for Science, Mathematics and Technology
Anthony Swann, Teacher, Queensland Academy for Science, Mathematics and Technology - swan71@eq.edu.au

It is widely known in physics that all falling objects accelerate at the same rate, regardless of mass; however, chains are peculiar objects that are an exception to this rule. In this investigation, the relationship between a chain's flexibility and its freefall acceleration will be investigated.

The first documentation of a chain falling faster than g, was made in 1989 by Calkin and March [1]. In their correspondence, Calkin stated that in their experiment the chain consistently took 1.5% less time to fall than theoretically anticipated. Later in 2010, Hamm produced a holistic model for the falling chain. Hamm revealed that only the bead chain – which has geometric restrictions – experiences an additional "anomalous force" which causes it to accelerate faster than g [2]. To extend this body of work, I aim to validate Hamm's hypothesis regarding this "anomalous force" by comparing the impact force produced over time by the bead and jack chain.

When falling objects contact the ground, they produce a force that is equal to their rate of change of momentum. Similarly, using this and other principles from Newtonian mechanics the applied force of a falling chain can be modelled. To simplify the model, a few assumptions were made regarding the physical characteristics of the chains. The chains are assumed to be: i) inextensible; ii) perfectly flexible; and iii) have consistent linear density. The impact of these assumptions and how the chains individually deviate from these ideals will be discussed throughout the progression of the paper.

To construct a general model of the falling chain, it was assumed that the chain was contacting a flat surface. When the chain is released, the total applied force on the surface, F_T, will be the sum of the weight of the chain on the surface, F_{rest}, and the rate of change of momentum needed to stop the falling chain in motion, F_{stop} [3].

The force needed to stop the moving chain is defined by its rate of change in momentum [3]. As the mass of the chain in free fall is constantly changing; F_{stop} can be expressed as

$$F_{stop} = \frac{\Delta mv}{\Delta t}.$$

If x is the length of the fallen chain, and μ is its linear density, then this becomes

$$F_{stop} = \mu v^2.$$

Therefore, the total applied force is:

$$F_T = \mu g \Delta x + \mu v^2$$

This equation shows the force produced by a falling chain as a function of velocity. As this investigation measures the force over time, this equation should be expressed as a function with respect to time. Substituting $v = \sqrt{2gx}$ into the above equation gives:

$$F_T(x) = \mu g x + 2\mu g x = 3\mu g x$$

To find the force with respect to time, $x = \frac{gt^2}{2}$ was substituted into the previous equation to give:

$$F_T(t) = \frac{3\mu g^2 t^2}{2}$$

The maximum force will be recorded when the entire length of the chain has fallen on the force sensor, when x is equal to the length of the chain, L. Thus,

$$F_{max} = 3mg.$$

Along with the maximum force, the time at which this maximum force is exerted can be calculated by modifying the projectile motion formula $s = \frac{at^2}{2}$.

Therefore, $t = \sqrt{\frac{2x}{g}}$.

All the chains used in this experiment are dropped from a height of 2.5 m; therefore, they will spend 0.71 s in freefall. According to the proposed model, the total applied force of the chain will increase exponentially with respect to time, until it reaches a maximum force of 3 times its weight after spending 0.71 s in freefall.

Method

I modelled this experimental procedure based on Hamm's 2010 experiment; however, a few adjustments were made to account for the different equipment. A Pasco force sensor was used to measure the applied force, which is a load cell that converts a force into an electric signal [4]. I also noticed that while the chain was falling, the Pasco sensor tended to jerk vertically. To resolve this, I took three preventative measures: i) cotton was placed inside the cup to prevent the chain from rebounding off the surface of the container. This precaution was also taken by Hamm in his experiment, as he too observed this movement in the force sensor; ii) it was also observed the floor of the room was partially malleable, which encouraged the force sensor to bounce. Thus, a hard wooden board was placed between the Pasco sensor and the ground; and iii) an additional layer of cloth was inserted between the sensor and the wooden board to further dampen any movement.

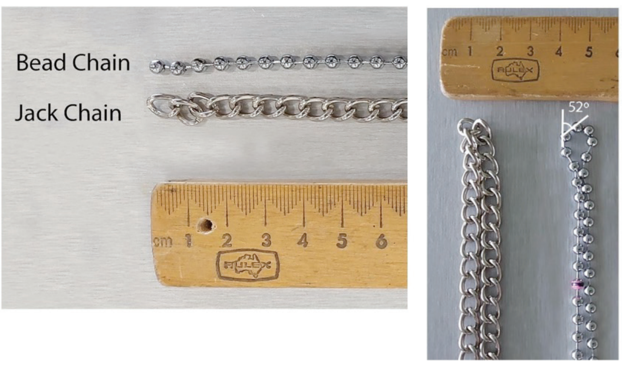

Figure 1: Bead and jack chains. The right image shows the minimum angle of bend.

Two different chains were used in this experiment: the bead chain and the jack chain (Fig. 1). The jack chain consists of individual links that are conjoined to each other, allowing the chain to have near 360° flexibility along its axis. In turn, the jack chain most closely resembles the ideal chain and the approximations made in the model. Meanwhile, the bead chain is similar to a ball-and-socket joint. Due to this geometric feature, when placed under tension, the bead chain has a maximum angle of bend of 52°.

The chains were dropped manually by suspending the chain above the force sensor until the open end of the chain just contacted the container of the Pasco sensor. This was a consistent way of ensuring that all the chains were dropped from 2.5 m, as they were all cut to this length prior to the trials. From this height, the chains were released onto the Pasco force sensor which was sampling at a rate of 200 Hz. Five trials were conducted.

Results

As shown in Figure 2, the jack chain fell consistently with homogeneous tension throughout its length. Particularly when contacting the surface, the jack chain behaved as anticipated by the theory; sequentially collapsing to form a pile as the chain continued to fall. This behaviour resembles an ideal chain and can largely be attributed to the jack chain's ability to bend along all degrees of freedom.

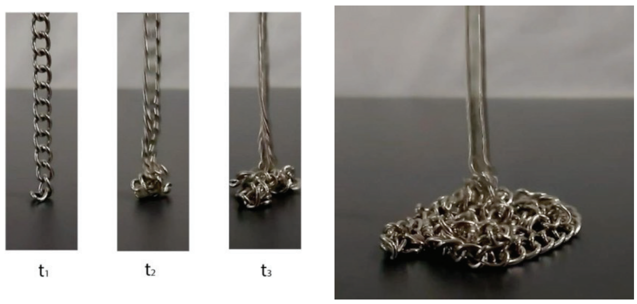

Figure 2: Jack chain falling behaviour when impacting a flat wooden board.

Unlike the jack chain, the bead chain did not fall homogeneously; instead, it tended to form a curve directly before contacting the ground. This curve formed when the chain initially made contact with the ground and persisted throughout the remainder of the fall, as shown in Figure 3. This arc is associated with the chain's maximum angle of bend, which restricts it from bending further than 52° (Fig. 1).

A low pass filter (Fourier transform) was applied using MATLAB to reduce noise that was evident in the raw data. This noise could be a result of the vibrations in the force sensor or unintended contact between the walls of the sensor contain and the falling chain. The data was then linearised to fit the designed model.

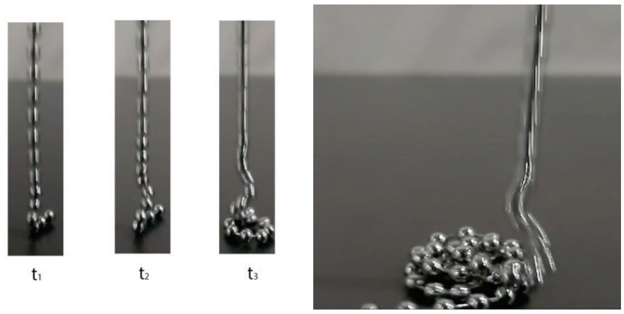

Figure 3: Bead chain falling behaviour when impacting a flat wooden board.

From this step forward, the exponentially rising segment of the graphs will be used as it is the only relevant segment for finding the experimental value of *g*. The exponential region is defined as the segment of the graph that stretches from the origin and the maximum recorded force value. All trials of the chains were separately linearized by plotting against t^2 (Fig. 4),

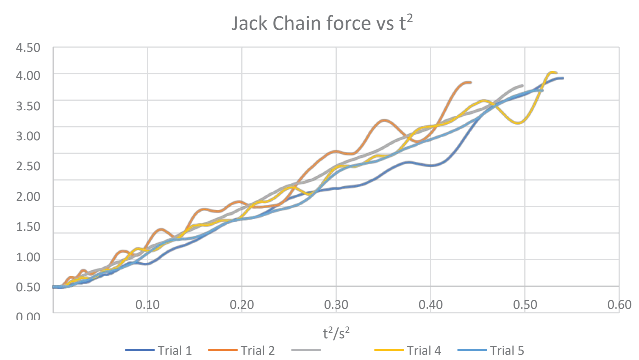

Figure 4: Linearised Force signal of the Jack chain, produced by plotting force against time squared.

from which 5 distinct gradients were calculated. The average of these gradients was then used to find *g*. The experimentally derived values for gravity, maximum force and time are shown in Table 1.

Discussion

Acceleration due to gravity was calculated to be 9.42 ± 0.73 m s^{-2} for the jack chain, which is slightly less than expected. As *g* is directly proportional to the gradient, an underestimation in the linearized gradient would result in a smaller *g* value. Thus, suggesting that the original force signal of the Jack chain did not increase as rapidly as expected. This is further supported by the F_{max} of the chain, which was lower than the literature value. However, as shown in Table 1, the jack chain spent 0.71 ± 0.04 s in free fall, which is −0.28% off the theoretical value. This indicates that the chain accelerated at a rate with is similar to *g*, suggesting that there is a systematic error in the F_{max} value rather than the jack chain falling more slowly.

In contrast, the bead chain recorded an experimental *g* value of 10.41 ± 0.50 ms^{-2}, which is significantly higher than the accepted value, 9.81 ms^{-2}. This suggests that the chain accelerated 5.8% faster than other objects in free fall. The high F_{max} is further indicative of the chain accelerating faster than gravity, as force is directly proportional to acceleration. In turn, the time taken for the bead chain to fall, 0.66 ± 0.01 s, was drastically lower as well. Although this may be evidence of a systematic error in the force and time axis, two other authors – [2] and [5] – came to the same conclusion regarding the tendencies of the bead chain. They concluded this behaviour was a result of the bead chain breaking an assumption made by the model: the chain is infinitely flexible along all degrees of freedom. In contrast, the bead chain has a maximum bending limit of 52^{o}, which raises an important question; how does the finite bending limit induce the chain to accelerate faster than gravity?

Many authors, including [6], have modelled the bead chain in free fall; however, the mathematical detail of

Table 1: Value of gravity, maximum force and time derived from each chain and their percentage discrepancy.

	Experimental value of *g* (ms^{-2})	Discrepancy from theoretical *g* (%)	Experimental F_{max} (N)	Discrepancy in F_{max} (%)	Experimental t_{max} (s)	Discrepancy in t_{max} (%)
Jack Chain	9.42±0.73	-4.00	3.84±0.16	-6.34	0.71±0.04	-0.28
Bead Chain	10.41±0.50	5.80	1.74±0.11	4.19	0.66±0.01	-7.57

this model is not necessary to gain a general understanding of why it accelerates faster than g.

As seen in Figure 5, the bead chain falls normally for the majority of its length; however, as the chain

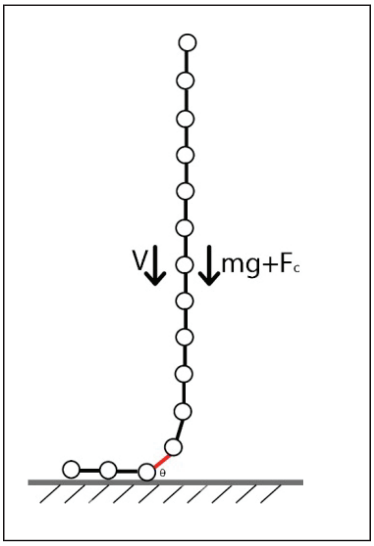

Figure 5: A simplified diagram of the falling bead chain, where *v* represents the chains speed and F_C represents the additional force that causes the chain to accelerate faster than gravity.

contacts the floor it bends creating an angle θ with the ground [2]. The bead chain has a maximum angle of bend of 52º, thus making θ ≤ 52º. In the diagram, the red line represents the bottom-most link, which is the next link of the chain that is in contact with the ground. Therefore, as the chain falls the link that contacts the ground constantly changes. To better understand this phenomenon, the bottom-most link was modelled as an isolated falling rod with no attachments (Figure 6).

As the rod falls at the angle θ, end-A strikes the ground first at a speed of v. In reaction end-B will pivot around the contact point of end-A and fall at a speed of v_B. The speed of the pivoting end, v_B, is greater than the initial falling speed ($v<v_B$) due to the conservation of angular momentum [6]. This effect can be observed by dropping a pen on a flat desk at an angle; the raised end of the pen will pivot at a speed that is greater than that of free fall. End-B, which is now travelling at a speed faster than free fall, is attached to the remaining length of the chain. Thus, it exerts an additional tension force, F_C, to the link above the collision point, resulting in the chain accelerating faster than gravity. As the v increases, the theoretical value of v_B increases in proportion, causing the magnitude of F_C to be higher.

In general, the experimental finding was consistent with the findings of other authors. The data of this experiment was highly precise, with the percentage uncertainty of the g values being 8% and 5% for the respective chains. In turn, this suggests the methodology and data processing of this experiment minimised the effect of random error.

Additionally, the accuracy of the Jack chain results was also high, indicated by the low discrepancy between the experimental and theoretical results. However, slight discrepancies can be explained by the limitations in the experimental setup. The percentage discrepancy of experimental g and F_{max} were calculated to be −4.00% and −6.34% respectively, suggesting the Jack chain produced a lower force on impact. It is assumed that this discrepancy is a result of the excessive wool used in the force sensor, which dampened the force exerted on impact, resulting in a lower magnitude being recorded. As this systematic error only affected the force input, the t_{max} values of the jack chain were still highly accurate with only a discrepancy of −0.28%. The jack chain closely resembles the assumptions

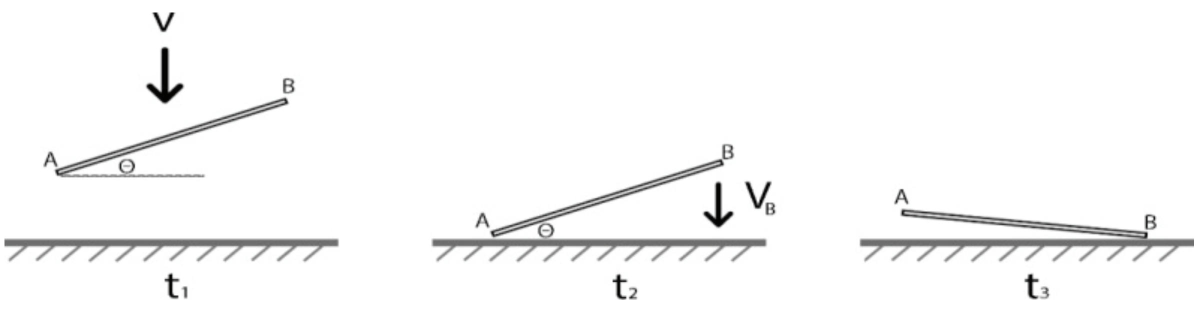

Figure 6: the last link represented as an isolated falling rod which is at an angle of theta to the ground. This figure was inspired by [6]

made in the model, explaining why it recorded results that were much more theoretically accurate than the bead chain.

Although the bead chain results were consistent with other papers, it is difficult to comment on the accuracy of the data due to the lack of theoretical values. Other studies used bead chains of different flexibility, thus making them not directly comparable to the one used in this investigation.

The bead chain experimental y-intercept was calculated to be –0.08 N, compared to the theoretical intercept of 0.00 N. This suggests the bead chain experimental data had low systematic error, which is an indicator of high accuracy. Thus, despite the lack of literature values, the bead chain is still consistent with the theory.

The force sensor tended to shake as the chains fell, resulting in significant noise in the data. Although this was remedied using a low pass filter, it introduced a different problem. In essence, the low pass filter removes noise and filters the data; however, there is no clear guideline regarding how much dampening is appropriate. In the data processing, I chose to filter the data as minimally as possible and kept the filtration consistent amongst all the trials. However, in future renditions of this experiment, it is recommended that a flatter force plate is used instead of a force sensor. This would result in less noise in the data, meaning less filtering would be necessary.

This experiment determined a link between the maximum angle of bend of a chain and its faster than g acceleration. As an extension, a future investigation could look at the relationship between the angle of bend and the magnitude of this anomalous force.

Conclusion

This research aimed to determine how the geometric restrictions of the bead chain result in it accelerating faster than gravity. Using a force sensor, the acceleration due to the gravity of the jack and bead chain was calculated to be 9.42 ± 0.73 ms^{-2} and 10.41 ± 0.50 ms^{-2} respectively. It was concluded that the Bead chain accelerates faster than gravity by contradicting the assumptions made in the model of the Jack chain. It does this by having a minimum angle of bend of 52°, which introduces an additional tension force in the chain resulting in it accelerating faster. In contrast, the jack chain does not demonstrate this property as it closely approximates the assumptions made in Hamm's chain model. Despite minor problems with accuracy, this research contributes to the present body of work by supporting the two current theoretical models of the Bead and Jack chains.

Acknowledgements

We would like to acknowledge the contribution of Aninda Saha, at University of Queensland, who assisted with the MATLAB code for the low pass filter.

About the author

Amlan Nag recently completed Year 12 International Baccalaureate Diploma Program at QASMT. He plans to study mathematics and finance at university. He hopes to one day become a financial analyst and start his own financial-technologies business.

Anthony Swann is an enthusiastic Physics and Mathematics teacher. He taught in regional Queensland at Tara Shire State College and Urangan State High School before moving to metropolitan Brisbane to teach International Baccalaureate Physics at QASMT. Every year he mentors students completing individual physics investigations for the IB extended essay.

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Analysis of the Quantum Eraser experiment

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In 1801, Thomas Young conducted an experiment known as the Quantum Eraser. Its goal was to demonstrate aspects of quantum mechanics including: interference, entanglement and complementarity. The Quantum Eraser experiment is a variation of another one of Young's experiments, the Double Slit Experiment. Still to this day no one has been able to fully comprehend the behaviour of the Quantum Eraser experiment.

The experiment

The methodology used starts with Young's double slit experiment where a laser passes through two closely spaced parallel slits in a screen and projects an inference pattern on a screen. This interference pattern is a number of dots and demonstrate that light behaves as a wave. When waves interfere, they either cancel each other out (no light) or superimpose (bright dot).

The Quantum Eraser experiment further develops this experiment to explore more about the nature of light. A spitting crystal is placed behind the two slits to create entanglement of particles. These particles are linked in such a way that if you do something to one it immediately affects the other particles, regardless of the distance that separates them. One half of the split particles have the same set up as the double slit experiment and the other half have 4 detectors, 3 half silvered mirrors and 2 full silvered mirrors (Fig. 1).

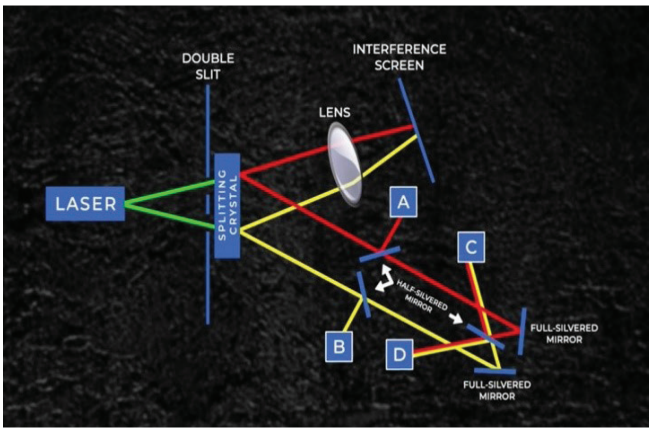

Figure 1: Quantum Eraser set up. Source: [1].

The detectors measure which slit the photons go through by measuring the cousin photons. The following table is a description of light models that appear on interference screen when detectors are turned OFF or ON.

Light Models	Detectors			
	A	B	C	D
Wave	OFF	OFF	OFF	OFF
Particle	ON	OFF	OFF	OFF
Particle	ON	ON	OFF	OFF
Particle	ON	ON	ON	OFF
Particle	ON	ON	ON	ON
Particle	OFF	ON	ON	ON
Wave	OFF	OFF	ON	ON
Wave	OFF	OFF	OFF	ON

These results show that time and location doesn't change the results. The results also showed measuring detectors erasing a wave model when turned on, unless the measuring detectors are unable to detect which photons come from which slit. This bizarre behaviour of interference, entanglement and measuring detectors remains unexplainable.

Analysis

Impact on our understanding of the nature of light

The Quantum Eraser has shown that light has both wave and particle models. However, when a device that measures the cousin slit tries to identify which photons have come from which slit then a wave model is 'cancelled'. These results have me questioning light properties including the wave model because there is an unexplainable reason why detectors erase photon information through interference which immediately changes the interference pattern to a particle pattern. There are lots of experiments that show light as a wave model and there is one experiment that shows particle form. However, the Quantum Eraser is the only experiment that can show both wave and particle patterns and change between models.

Comparison with Malus' Law experiment

I undertook the Malus' Law experiment prior to this analysis. Both experiments used polarised light and showed that light has a wave model. The Malus' Law experiment uses two polarising filters. However, the Quantum Eraser experiment uses one and splits the polarised light into half to create cousin photons. Malus' Law experiment observed light intensity and angle between polarisers. Contrastingly, the Quantum Eraser experiment observed the two quantum effects of interference and entanglement. The final comparison to add is that Malus' Law verifies only the wave model, however, the Quantum Eraser verifies both wave and particle models of light.

Conclusion

Thomas Young's experiment, the Quantum Eraser, demonstrated light as both a wave and particle pattern. The experiment, additionally, displayed peculiar properties that remain unexplainable by anyone who has ever tried to figure out the interference and entanglement of photons and the measuring detectors.

About the author

Anthea is a year 12 graduate from St John Paul College in Coffs Harbour. She has a passion for physics, mathematics and engineering and is now on a path to study civil engineering in 2023. Anthea has clear goals and is working hard to achieve them. In working on her HSC physics depth study, Anthea came across the quantum eraser effect and was enraptured. Though beyond the scope of the course, she was able to tie the effect comprehensively into her paper due to the links with Malus' law, polarisation and interference.

Nick is a Physics teacher and head of science at St John Paul College in Coffs Harbour. After starting out as a mechanical engineer he moved to teaching and found his calling. Nick and his family relocated to Coffs at the beginning of 2021, moving up from the outer east suburbs of Melbourne. Nick is passionate about sharing his love of science and providing our future scientists the best possible opportunities; in particular, supporting those with a love for physics to pursue their aspirations.

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An experimental investigation of drag and noise reduction properties of sharkskin in a low viscous aerodynamic environment

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John Gollan, Teacher, The Illawarra Grammar School, NSW

In the past decade, research into natural surfaces that outperform those created by humans has been on the rise, with potential applications in transportation, military and renewable energy. This present paper investigates the drag and noise reduction properties of an organic sharkskin denticle coating in a low viscous aerodynamic environment. An evaluation of current literature on the topic is provided along with discussion of the drag reduction mechanism, its effect and an understanding of the developments made in explaining the phenomenon. The drag and noise reduction properties were assessed by measuring the sound and speed of a small DC fan coated in cured organic sharkskin using a microphone and camera. The results indicated a statical difference in noise production ($p < 0.05$) with a maximum sound reduction of 10 dB seen in the fan with the coating. The rotational velocity remained unchanged due to an unforeseen flaw in the methods design ($p > 0.05$).

Introduction

In recent times, the use of biomimetic technologies has been explored to address issues with drag and noise such as sharkskin and its unique denticle-structured surface [1].

When sharks move through a fluid, the fluid exerts a force on the shark. This is known as a hydrodynamic force, or if the object is in air, an aerodynamic force [2]. The skin of sharks possess tiny rigid scales that delay the occurrence of chaotic fluid movement known as turbulence (green area in Figure 1) by maintaining constant fluid flow known as laminar flow (blue area in Figure 1).

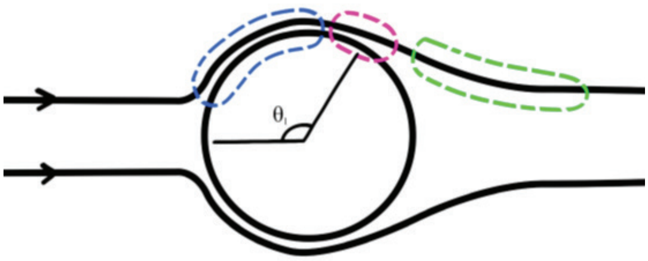

Figure 1: A circular object undergoing laminar flow. The blue region indicates the area of laminar flow, the pink area indicates the point of flow separation, and the green area indicates the turbulent flow.

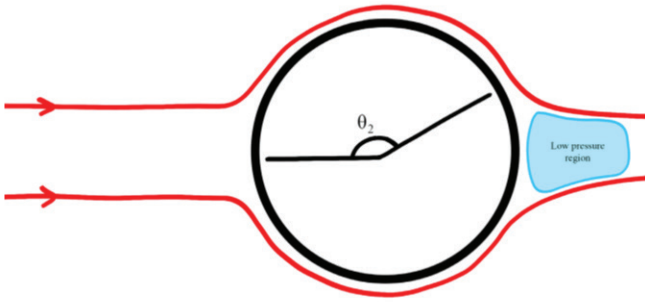

Figure 2: A circular object undergoing laminar flow with a reduced low-pressure region due to delayed flow separation. The blue region is the low-pressure region.

This transition from laminar to turbulent flow is called flow separation (pink area in Figure 1) which, when delayed (i.e. $Ø_2>Ø_1$ in Figures 2 and 1), reduces pressure drag caused by the low-pressure region near the trailing edge of the object.

This low-pressure region is also primarily responsible for sound generation as sound waves are unable to propagate effectively through the region.

Initial research into the drag reduction properties of sharkskin was conducted in 1985 when [3] used a force balance, wind tunnel and an organic sharkskin coating to demonstrate that the morphology of sharkskin scales reduce drag in some turbulent conditions. .

Since then, research has been focused on synthetically replicating this surface with testing results showing that the drag force can be reduced and manipulated, although the drag reduction mechanism of organic sharkskin is presently not well-understood [1]. However, there are still studies that have provided important conclusions about the properties of sharkskin and its drag reducing effect. For example, in 2000 Bechert et al. [4] investigated multiple biological surfaces with biomimicry potential. The drag reduction of sharkskin was investigated and experimentally proven, for both organic and synthetic sharkskin via a direct shear force measurement. The authors described this drag reduction via "sweeps" and "ejections". The strong exchange in momentum as the accelerating high-speed flow decelerates whilst approaching the surface (called a "sweep", A to B in Figure 3) and then accelerates whilst leaving the surface (called an "ejection", labelled C to D in Figure 3), reducing skin friction as the force applied to the surface is less. This increases the duration of laminar flow and as a result delays flow separation.

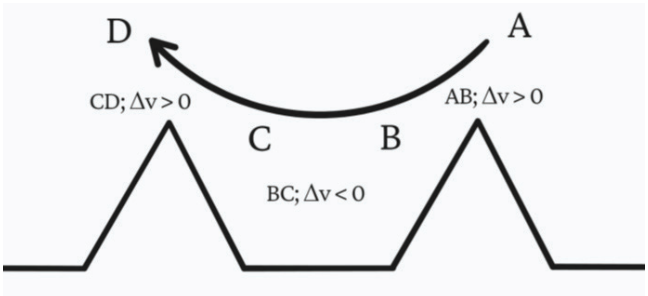

Figure 3: Graphical representation of the transfer in momentum [4].

Whilst literature exploring and manipulating the drag reduction potential of sharkskin is well established [1], its sound reduction potential is under-researched, specifically studies conducted in air.

Dang et al. used Computational Fluid Dynamics simulations to predict the hydrodynamic noise of an air foil [5]. This study determined a maximum noise reduction of 7.28 dB could be achieved and that the noise spectra of the biomimetic hydrofoil lacked the main peaks seen in the air foil void of modification. The authors attributed the reduction in noise to the 'secondary vortex', or what has previously been described as a short separation bubble, which maintained laminar flow and hindered the process of turbulence. This separation bubble was described as consuming the energy of the flow and weakening the intensity of turbulent burst (also known as flow separation).

The investigation presented here aims to answer the following question. Will adding sharkskin denticle coating aligned with the direction of laminar flow reduce the drag experienced and noise produced by an air foil? The hypothesis is that the application of an organic sharkskin coating to the upside of the air foils in a fan will result in a decrease in noise production compared to a fan void of any modification.

Methodology

The sound production and speed of the fan void of any sharkskin coating was initially tested as a baseline to compare to the fan with the sharkskin coating.

The specifications of the fan include its design speed of 1200 rpm, the individual air foil dimension being 5.5 cm by 3.4 cm, the propeller radius being 9.5 cm and the angle of attack for each propellor being 20±5° elevation perpendicular to the direction of flow.

The sound production was measured in 30 second intervals using an iPhone 13 microphone at 120 Hz, 15 cm from the base fan legs. The ambient noise was reduced by closing doors, windows and turning off devices that were creating noise (air conditioning) with the ambient noise initially being measured to ensure it was stable.

The rotational speed of the fan was measured using a 240-fps camera, determined by counting the frames in *Adobe Premiere* and calculated using the period formula (i.e., $f = 1/T$, where T is the period in seconds and f is the frequency in rotations/second).

The position of the recording device was crucial as the sound intensity varied with different positions. The microphone was positioned near the 'outside rim' of the fan, which is near the trailing edge of the fan blades, as this has been shown to produce the largest amount of noise [6].

Figure 4: Completed sharkskin adhesion.

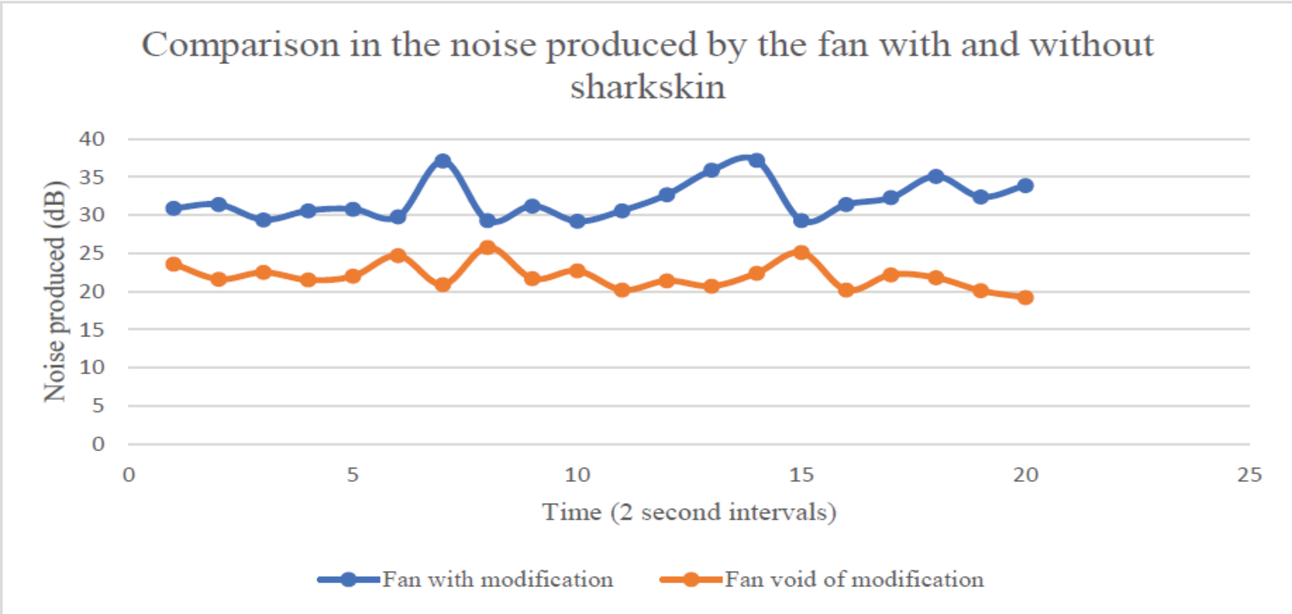

Figure 5: Comparison in the noise produced by the fan with and without sharkskin

Treatment of the sharkskin

Sharkskin was obtained in large strips of 30±10 cm from the scraps of a local fish store. The width and height were ensured to be larger than what was required as the treatment caused shrinking of 10±5% for both the width and height. The treatment method involved scraping the excess meat off the under-face of the skin using a scalpel followed by curing the skin on a ceramic smooth surface such as a plate for 1.5 to 2 hours in direct sunlight at noon until the skin was suitable to handle and rigid for attaching to the fan blades. The skin was then cut into 7 by 5 cm squares (to fit the blades with minimal off-cut) and 're-wetted' using a standard clothes iron, separated by baking paper to reduce contamination to form the skin onto the blade.

A thin layer of flexible contact adhesive *(Selley's Kwik Grip)* was applied to the fan blade. The skin was uniformly pressed onto the blade for 10 minutes, with the abrasive direction facing the same direction at the rotation and the opposite direction to the flow. The skin was left to dry on the blade for 12 hours.

Testing procedures for the fan with sharkskin followed the same protocols as testing the fan without sharkskin.

Statistical analysis

A two-tailed unpaired student's t-test of equal variances was undertaken to compare statistically the difference between the noise and speed of both fans. The standard deviation, mean, 95% confidence intervals and F-test were also determined for further analysis.

Using a two-tailed t-test compared to a one-tailed t-test for the noise and speed of both fans is justified since no literature could be found to support the initial claim and lack of certainty in whether the addition of the coating would cause an increase or decrease in noise production. The two data sets were compared using an F-test and determined to have similar variances ($p < 0.05$) and hence it's also justified to assume equal variances.

Results

Results from the experiment indicate a statistically significant decrease in sound production from the fan covered in the sharkskin and an almost non-existent change in speed (Figure 5).

As a result, the null hypothesis that the sound would not change or increase can be rejected as the p-value was less than 0.05 and the conclusion that there was a decrease in sound can be made. The decrease in sound on average was 10 dB with the 95% confidence interval of this difference being from 8.6 to 11.4 dB. The standard deviation of the fan void of any modification (2.49) was similar to the fan with the sharkskin coating (1.68).

There was, however, only a slight decrease in the rotational speed of the fan with the sharkskin but was considered not statistically significant as the p value was greater than 0. The mean rpm of the fan without the sharkskin was 1209 rpm and 1196 rpm for the fan with the sharkskin indicating a decrease of 13 rpm. The standard deviation of the speed of the fan with the sharkskin (0.64) and without the sharkskin (0.79) was significantly low indicating that both fans spun consistently at the same speed.

Discussion

Upon initial inspection, the results from this investigation clash as there is a reduction in noise from the addition of the coating but an unchanged rotational speed. This was simply due to a flaw in the experimental design of measuring the speed of the fan.

The essentially unaffected speed can be attributed to the design specifications of the fan, limiting the speed at which the fan can operate, which is an unforeseen limitation of this investigation.

The reduction in drag, as described previously, may be attributed to the denticle structured coating maintaining laminar flow and thus delaying flow separation. As a result, the extent to which the low-pressure region can interfere with surrounding air molecules is reduced and hence less noise is generated. This is also described as interactions with the turbulent boundary layer and is found to occur at the trailing edge of an object [6].

In the case of sharkskin, it is important to identify what type of drag is being reduced because there are other unavoidable sources of drag such as those seen in viscous energy losses [2]. The denticle structure of sharkskin is primarily responsible for minimising pressure drag by delaying the flow separation. It does this by forming a small separation bubble that consists of vortices. When the fluid collides with these vortices there is a transfer in momentum that favours the movement of the object, this is because the collision is highly elastic as the kinetic energy of the particle approaching the vortice is close to that of the kinetic energy of the particle leaving the vortice [2].

The sharkskin, as mentioned in the methodology, was only located on the upper surface of the air foil in support of Debisschop & Nieuwstadt's [7] conclusion that the sharkskin coating performed better in adverse pressure gradients. A limitation of this study was the lack of resources to produce a third fan model with a coating on both the top and the bottom of the air foil to test Debisschop & Nieuwstadt's conclusion. This would have provided greater insight into the properties of the surface and contributed to the accuracy of this design decision.

The method used, however, was able to validly indicate whether noise was produced by the microphones positioning which was supported by literature [6].

This investigation did not intend to experimentally prove that the lining of the blades with real sharkskin is a feasible commercial solution to reducing sound production in everyday life, however the findings presented in this paper do suggest that a synthetic denticle coating has the potential to reduce noise production.

Further research could involve synthetically replicating the sharkskin in a manner that is more suitable for an aerodynamic setting such as that experienced by a plane wing or helicopter blade. The results from this investigation thus act as a preliminary indication of this sound reduction for further research to use.

Conclusion

The results from this study indicate that the sharkskin denticle structure seen in sharks has the potential to reduce the noise produced by an object undergoing laminar flow. This is in-line theoretically with current literature as a drag reduction tends to lead to a reduction in noise production [2].

The methodology employed was flawed in its ability to measure the drag reduction due to the design specifications of the fan, however the measurement of noise was valid as it was able to differentiate and effectively compare the noise levels of the two fans.

In comparison to other studies, this paper lacked accuracy, however with the resources available it was successful in proving that sharkskin can reduce noise production. This paper acts as a basis for further study into the use of synthetic denticle coatings to reduce noise production.

Acknowledgements

I acknowledge the resources provided by the TIGS science faculty and am grateful to all those who I have had the pleasure of collaborating with on this project. I was especially like to thanks Dr J. Gollan, my teacher, and C. Harvey, for insight into aerodynamic equipment and methods.

About the authors

Casey is a Year 12 student at The Illawarra Grammar School. He enjoys the numerical and complex world of aerodynamics. Casey is excited for the journey ahead and is looking to pursue a degree in computer science.

John is a science teacher at The Illawarra Grammar School with a keen interest in applied science. He brings this to his classroom, with a goal that no student in front of him will ever ask 'Why am I learning this?' or 'Where will I ever need this?' Before beginning teaching in secondary schools in 2015, he lectured in geological processes at the University of Technology Sydney. Prior to this, he completed postdoctoral research on how climate variability influences species distributions, as well as leading several citizen science initiatives at the Australian Museum. John is always in search of engaging ways to equip his students with the skills and knowledge that might one day be used to solve the many challenges that society faces.

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Relationship between Supermassive Black Hole Mass and the Properties of Host Galaxies

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Albert Einstein's 1915 theory of general relativity proposes that gravity, instead of being an invisible force that attracts objects to one another, is a curving or warping of space. In 1916, Karl Schwarzschild, using Einstein's theory of general relativity, discovered that matter compressed to a point, a "singularity" where the curvature of spacetime was infinite, would be surrounded by a spherical region of space that anything, including light, would be obligated to fall towards. This discovery was not explored further at the time because there was no known object with such a high density in which this singularity would occur. It was not until 1967 that this was named a "black hole" by American Astronomer John Wheeler.

There are two main classes of black holes: stellar and supermassive. Stellar black holes, located throughout the universe, are formed when a star greater than 20 solar masses exhausts the nuclear fuel in its core and collapses in on itself with a gravitational pull so strong that nothing can escape [1]. Supermassive black holes, containing between 1 million to 1 billion times more mass than a stellar black hole, are found in the centre of elliptical and spiral galaxies [2].

There are three main types of galaxies that have been discovered thus far, elliptical, spiral and irregular. Every galaxy has particular features that contribute to its overall composition. These include: bulge mass, the mass of the tightly packed spheroidal group of stars concentrated in the centre of most spiral and elliptical galaxies; bulge luminosity, an absolute measure of the amount of electromagnetic energy emitted per unit of time by the bulge, and stellar velocity dispersion. Stellar velocity dispersion is the statistical dispersion or spread of the velocities about the mean velocity of the random motions of the stars within the bulge, due to the bulge's gravitational attraction [3].

I hypothesise that a direct correlation exists between the mass of supermassive black holes and the bulge mass, bulge luminosity and stellar velocity dispersion of their host galaxies.

Data

Bulge Mass

When black hole masses began to be measured in the late 1990s, it appeared as if the mass of the supermassive black hole was dependent on the mass of the bulge of the host galaxy. In a study "On the Black hole mass – bulge mass relation" [4], a sample of 30 galaxies with a range of bulge masses were examined. The galaxies included in the sample were selected based on the availability of a modelled bulge mass and the reliability of the data of the black hole mass.

It was found that the M_{bh} – M_{bulge} (mass of the black hole – mass of the bulge) relation was very tight, with the M_{bh} approximately = $M_{bulge}^{(1.12 \pm 0.06)}$. The mass of

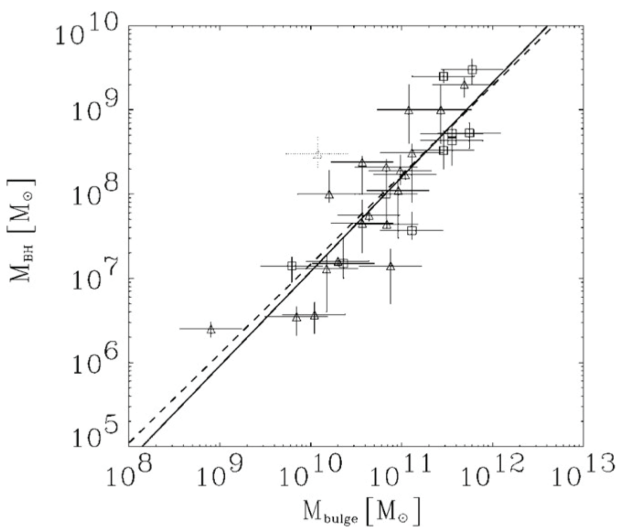

Figure 1: The Mbh – Mbulge (black hole mass – bulge mass) relation [4]

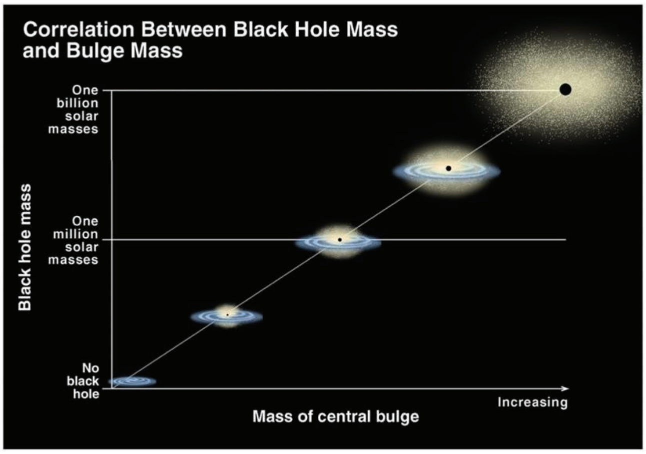

Figure 2: A visual representation of the M_{bh} – M_{bulge} relation [5]

the black hole was approximately equal to the bulge mass to the power of 1.12.

The graph for the M_{bh} – M_{bulge} relation for the 30 sample galaxies is shown in Figure 1. The solid line on the graph is the line of best fit, which has a gradient of 1.12 ± 0.06. Each square or triangle plotted on the graph represents a different galaxy and the horizontal and vertical lines around each plot show the possible uncertainty of the measurement. Figure 1 reveals a tight relation without distinctive outliers. Some of the plots' scatter can be credited to observational errors in black hole masses. For the galaxies included in the sample for this study, the median black hole mass is calculated to be 0.14% (±0.04%) of the bulge mass.

A simpler visual representation of this M_{bh} – M_{bulge} relation is shown in Figure 2. This graph clearly portrays that the larger a galaxy's bulge is, the larger we expect its central black hole to be [5].

Bulge Luminosity

McLure & Dunlop examined a large sample of 90 objects, consisting of 53 quasars (extremely luminous galactic nuclei) and 37 galaxies in a study on the black hole mass – bulge luminosity relation [6]. The reason for such a large sample size was to allow for a study of the bulge luminosity – black hole mass relationship over a wide range of differing masses and luminosities.

It was discovered that the M_{bh} – M_R(bulge) (mass of the black hole – measure of the intrinsic brightness of the bulge) relation was well correlated.

Shown in Figure 3 is the graph of the M_{bh} – L_{bulge} (black hole mass – bulge luminosity) relation for the sample of 90 objects. The solid line is the line of best fit for this relation. Each triangle plot represents an elliptical or spiral galaxy, each square represents a Type 1 Seyfer galaxy (a very bright source of visible light, ultraviolet light and X-rays) and each circle represents a quasar (distant, bright objects with central supermassive black holes). Figure 3 reveals the tight correlation of M_{bh} - L_{bulge}. It can be seen that the relation is equivalent to the scaling between black hole mass and bulge mass. Some of the scatter can be credited to observational errors in black hole masses.

Stellar velocity dispersion

Examining the correlation between the masses of super massive black holes and the velocity dispersions, "how strongly the bulge stars are gravitationally bound to each other", of the bulges in their host galaxies, a study by Kormendy & Gebhardt [2] comprised a sample of 37 galaxies. A strong correlation was uncovered for M_{bh} – σ_e (black hole mass – stellar velocity dispersion). This is almost equivalent to the M_{bh} – M_{bulge} relation represented in Figure 1.

The graph for the correlation between supermassive black hole mass (M•) and the stellar velocity dispersion (σ_e) for the 37 sample galaxies is shown in Figure 4. The solid line is the line of best fit. The circles, crosses and plus-sign plots represent different ways the data was obtained. The observed scatter may be caused by errors resulting from the different techniques used. These techniques are using dynamical models applied

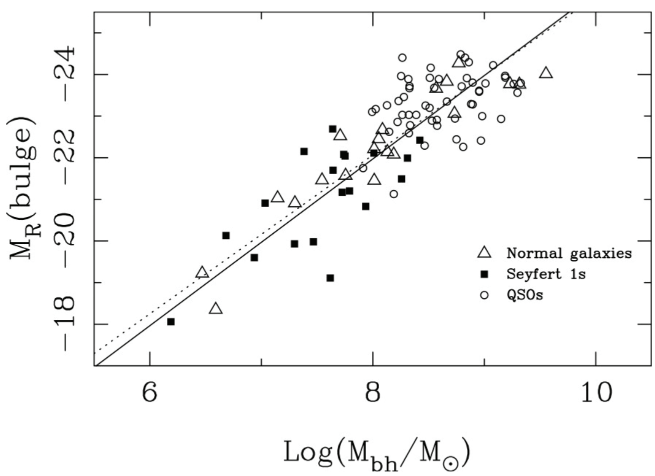

Figure 3: The M_{bh} – L_{bulge} relation [6]

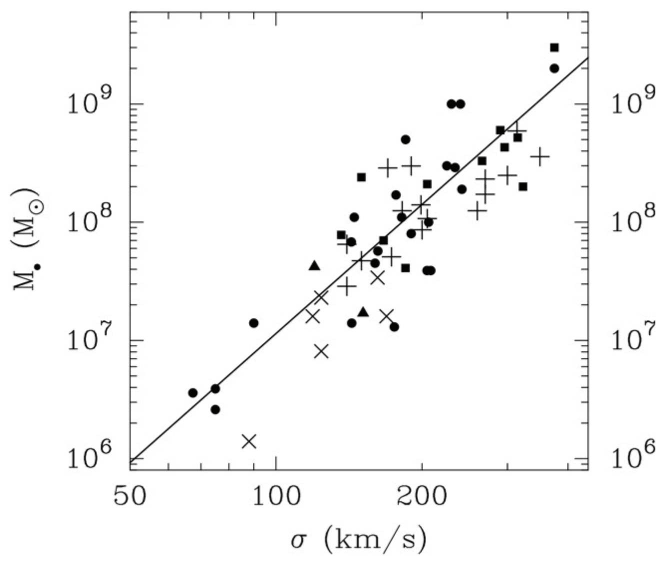

Figure 4: The supermassive black hole mass (M•) - stellar velocity dispersion (σ) relation [2]

to spatially resolved kinematics (represented by the black plots), reverberation mapping (represented by the crosses) and ionization models (represented by the plus signs). The strength of this correlation increases confidence that the observed black hole mass estimates are accurate.

Interpretation

Since revealing the strong correlations between supermassive black holes and their host galaxies, scientific research has moved on to exploring what regulates the formation and evolution of supermassive black holes. The tightness of the relations of supermassive black hole mass to bulge mass, bulge luminosity and stellar velocity dispersion suggests that the black hole mass is partially determined by the amount of available fuel within the host galaxy, which is connected to the total mass of the bulge. This strengthens the theoretical prediction that bulge formation and the growth of black holes are closely related [2].

This poses a new question in this field - how can we explain the relation between bulge formation and the growth of black holes? There are two possible answers, though neither have been proven correct thus far. The first explanation is that the relation is caused by the active galactic nucleus feedback. In this scenario, the jets and winds accreting the black holes can cause and halt star formation by expelling extra gas (star formation fuel) from the galaxy. This feedback causes the rate of star formation to roughly align with the rate of accretion of the black hole and therefore cause a relation between galactic bulge and black hole growth. The second explanation is that the correlation is caused by galaxy star formation and black hole growth both relying on the same fuel source. This shared fuel source causes the masses to correlate because black hole mass is partially determined by the amount of fuel available to the black hole, which corresponds to the total mass of the galactic bulge [7]. Therefore, it is natural to predict that black holes, bulges and quasars formed, grew or turned on as parts of the same process of evolution.

A further area of exploration investigated by scientists is how supermassive black holes influence and are influenced by their host galaxies. One means by which galaxies influence their supermassive black holes is by providing them with fuel. If galaxies provide black holes with fuel, where does this fuel come from? There is again no definite answer but there are two leading theories.

One possible source of fuel is the matter from the host galaxy. As a galaxy evolves, there is less interstellar matter in its central region than there was early in the galaxy's life because most of this matter has formed stars. This means that the number and luminosity of quasars decline with time and is the reason why today elliptical and spiral galaxy bulges have little interstellar matter left as a source of fuel for the supermassive black holes. This is also the reason why most of the supermassive black holes in our own and nearby galaxies are dark and relatively quiet [5]. Another possible, but less likely, source of fuel for the black hole is the collision of its host galaxy with another galaxy. This merging would push the interstellar gas and dust out of its orbit, and some may venture close enough to the supermassive black hole to become quasar fuel [5].

An additional question to ask is how do supermassive black holes influence their host galaxies? There are three possible answers to this question. The first is, through the winds of particles that manage to stream away from the accretion; the second, through radiation from the accretion disk; and the third, through the black hole's jets. These three processes can either promote star formation by compressing the surrounding gas and dust, or they can suppress star formation by heating the surrounded gas and shredding molecular clouds, thereby inviting or preventing star formation [5].

Therefore, there is sound evidence that galaxies and supermassive black holes can influence each other's evolution. The galaxy supplies fuel for the black hole and in return the quasar can either suppress or support star formation. A conclusion can be drawn that the balance of these processes is a factor in the correlation between black hole mass and bulge mass.

While there are various explanations and theories for the correlations between supermassive black hole mass and the properties of their host galaxies, no explanation has been proven correct. We are still unaware of how supermassive black holes form, whether they were formed before or after their host galaxies, and how they have evolved.

Conclusion

The hypothesis that a direct correlation exists between the mass of supermassive black holes and the bulge mass, bulge luminosity and stellar velocity dispersion of their host galaxies, was supported by the data presented. The $M_{bh} - M_{bulge}$, $M_{bh} - L_{bulge}$ and $M_{bh} - \sigma_e$ relations were found to be very tight and well correlated. These results suggest that supermassive black hole mass is partially determined by the amount of available fuel within the host galaxy.

About the author

Amira Kacser, who has just graduated Year 12 at Leibler Yavneh College, Melbourne, is interested in pursuing her studies of physics in the future. She plans to begin a double degree in Science and Engineering at Monash University in 2024.

Kimberley Bruce, former Head of Science at Leibler Yavneh College, is now working as the Curriculum Coordinator at Casey Tech School. She works to develop students STEAM skills and uses technology to enhance their understanding.

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#PhysicsGotMeHere

Dr Frederick Osman

Employer: Boston University Study Abroad Sydney

Job title and description: Associate Director (Academic) Boston University Program

Managing the development and operation of the academic and internship responsibilities for all programs with Boston University Study Abroad Sydney.

My career story so far:

Over 25 years' experience in education and management at the tertiary and secondary levels. I have managed and undertaken teaching and research projects independently and cross-functionally across the education, community and industry sectors.

Some awards and important roles, including physics-related roles:

- Fellow and President of the Australian College of Educators
- Fellow of the Royal Society of New South Wales
- Previous Chair of AIP NSW branch, 2008-2010 and 2018-2019
- Other AIP roles: Scientific Meeting Organiser from 2001 and Secretary of NSW committee from 2011-2017 and 2020-current.
- Current Chair of NSW Training Awards from 2017
- President and Fellow of the Teachers' Guild of New South Wales from 2016.

Selected Career Highlights:

Promoting Community Engagement: I developed and coordinated several cross-sectoral education teaching and research forums, workshops, and industry networks at the regional, national, and international levels.

Professional Enhancement: I have advocated for professional development to ensure academics, teachers, graduates, students can achieve knowledge and develop their skills. I have developed and implemented professional recognition programs, accreditation for education courses and award schemes, and mentoring forums, and linked highly accomplished teachers and new educators to the education profession. My governance roles have allowed me to address significant education issues.

Policy Development: My academic career has included policy development roles at School, College and University levels in academic curriculum, grading, program development, accreditation, evaluation policies and processes for local and international students.

Thought Leadership: I have organised major education conferences, forums, workshops, awards functions and industry network sessions for academics, teachers and students. This has provided successful partnerships and community involvement at the regional, national, and international levels. At the secondary tertiary education level, I helped design innovative curriculum opportunities to meet student needs.

Prof Tien Kieu

Where I work: Victorian Parliament

What I do: Ambassador for STEM Education and Member of the Legislative Council (South-Eastern Metropolitan Region)

In 2018, after a long career in academia and research, I took up an opportunity to run for the Victorian Parliament and was successfully elected to the Legislative Council.

At this stage of my life, I believed that I could contribute to the community at large on a different platform. Even though politics had not featured prominently in my life, having undergone the experience of growing up in a war-torn country, I was able to witness firsthand how important politics was, and how it could influence and determine the population's standard of life, and even death.

For this reason, I have been heavily involved in many human rights causes, volunteering and community

activities throughout my life - from my academia days until now.

Since entering Parliament, I have focused on multiculturalism, STEM and STEM education among other priorities. I formed Parliamentarians for STEM and was also appointed as the inaugural Victorian Government Ambassador for STEM Education.

Beyond these roles, I also serve as the Deputy Chair of the Legal and Social Issues Committee for the Legislative Council.

My physics background

In 1980, following the Vietnam War, I arrived in Australia on a humanitarian visa as a refugee after a perilous journey on sea and a restless stay in a refugee camp in Malaysia.

Upon settlement, I worked as a factory labourer before enrolling at the University of Queensland, where I commenced my academic career in theoretical physics.

My academic journey took me to the University of Edinburgh, Oxford University, the University of Melbourne, and Swinburne University; and my research in theoretical and computational physics extended to the fields of Lattice Gauge Theory, Quantum Field Theory, Fundamental Quantum Physics, Quantum Computation, and Econophysics.

I have also held visiting positions at MIT, the Princeton Institute for Advanced Study, and a Fulbright Fellowship at Columbia University.

My additional interest in machine learning and artificial intelligence also led to my engagement in consulting work for McKinsey & Co, and in quantitative and algorithmic financial trading for some private hedge funds.

In 2020, despite my demanding parliamentary duties, I managed to publish four papers in international journals on topics of fundamental quantum physics and adiabatic quantum algorithms.

This year, I submitted a paper on a quantum version of the central limit theorem, and its implications on time-dependent macroscopic entropies and on an emergence pathway for classicality from quantum mechanics.

How physics has helped me get to where I am

In addition to my life experience, I have found that my training in science, particularly in the area of problem solving, analytical thinking, collaboration and communication has assisted me greatly in performing my parliamentary duties to the best extent that I can.

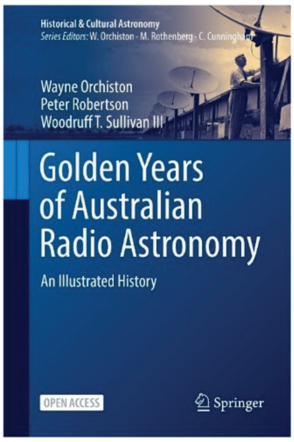
Maintaining some level of interest in physics in my parliamentary role is undoubtedly challenging; however, to engage in both sides simultaneously is extremely rewarding.

Exploring the History of Radio Astronomy – a book review

Golden Years of Australian Radio Astronomy: An Illustrated History

Wayne Orchiston, Peter Robertson and Woodruff T. Sullivan III, Springer, (2021), Hardback, 268 Pages; ISBN: 978-3-319-91841-9.

Reviewed by Harry Wendt, University of Southern Queensland, harry.wendt@gmail.com



The discovery of radio waves from cosmic origins, announced by Karl Jansky in 1932, opened a new window on the universe for the first time since the discovery of the telescope. However, it was not until after WWII and the advancement of radar electronics that the field truly blossomed. Serendipitously, Australia was well placed to explore this new field. It had a relatively large group of radio engineers and physicists who had honed their craft on the secret development of radar during the war and were now casting their net for new peacetime research opportunities. Reports of the wartime detection of radio waves from the sun sparked their interest. A confluence of the outstanding research leadership of Joe Pawsey and the entrepreneurial skills of Taffy Bowen, leader of the CSIR (later to become the CSIRO) Radiophysics group, saw Australia become a world leader in what would become the new field of Radio Astronomy. These events were even more remarkable as none of the original researchers had any training in astronomy.

The authors define the *Golden Years of Australian Radio Astronomy* as occurring from the first observations in 1945 through to 1960, just before the commissioning of the 64-m Parkes Radio Telescope (called *Murriyang*, in the indigenous Wiradjuri language), the first of the *"big science"* instruments in Australia. This period saw rapid instrument developments and discoveries from research conducted in various independent field stations in and around Sydney. The book has had a lengthy and somewhat tortuous genesis dating back to 2004, and the process of its development is described in detail in the preface, along with an overview of the first author's career. The 17-year wait for the book has been well worth it. Much of the book's content has been covered in earlier published individual scholarly papers. This work, however, brings together for the first time in a single volume a very detailed and thorough summary of the field stations, instruments, and research carried out in Australia during this period in an easily readable form that draws heavily on the resources of the CSIRO Radio Astronomy Image Archives.

The *Golden Years* begins with Jansky's first detection of radio emissions from the galaxy and then provides an overview and context of Australia's wartime radar development within the CSIR Division of Radiophysics and the subsequent development of radio astronomy in Australia. Three detailed chapters follow this summary. The first describes the ten main field stations operated by Radiophysics, with details of the instruments used, followed by two chapters describing the research outcomes of solar system research and then moving to galactic and extra-galactic research. Finally, the authors briefly overview selected developments in Australian radio astronomy post-1960.

The *Golden Years* represent a remarkable period in the history of Australian science. As Kellermann writes, *"…they not only made major discoveries that changed the course of astronomy, they also developed the new techniques of interferometry and synthesis imaging, the cross-type array later known as the Mills Cross, radio polarimetry, and the solar radiospectrograph, each of which became a basis for radio astronomy research for decades to come"* (p vii).

Besides using nearly 300 images to illustrate the text, there is extensive use of *"biobox"* entries that provide brief insights into the careers of each of the leading players during the period. In addition, each chapter has detailed references and an extensive bibliography of scholarly papers on early Australian Radio astronomy that appears as an appendix making the volume the perfect starting point for anyone wanting to explore this period in more detail. The text also benefits from the extensive use of quotes from the archive of the audio interviews prepared by Sullivan (2009) for his *Cosmic Noise* history that helps bring the story to life.

I only have some very minor quibbles with the content of this excellent work. It would have been helpful to include the image number of photos drawn from the CSIRO Radio Astronomy Image Archive (CRAIA) to make them easier to locate for other researchers. Also, some images, i.e., Fig 2.1, although referenced to CRAIA, I believe, have different sources. Annoyingly, the print quality of many images in the hardback version of the book I purchased was poor. I understand Springer has now addressed this issue in the printing, and the open-source online version did not suffer from this problem. There is a statement in the book that non-solar research began in September 1946 with an unsuccessful search for Cygnus A (P. 149), however, my reading of the archive record shows that exploration of galactic radio emission began almost in parallel with the first solar observations at Collaroy and North Head (Bluefish Point) in 1945. Payne-Scott (1945) described the cosmic radiation investigation in her internal laboratory report, *"It will be apparent that in addition to the radiation from the sun, there appears to be radiation from a more diffuse area centred approximately on the centre of the galaxy"*.

In conclusion, I highly recommend this book to anyone interested in exploring the development of Australian radio astronomy and, more broadly, scientific development in Australia. I am sure it will become a standard reference for this period.

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Physics around the world

Physics teachers inspire the next generation of scientists

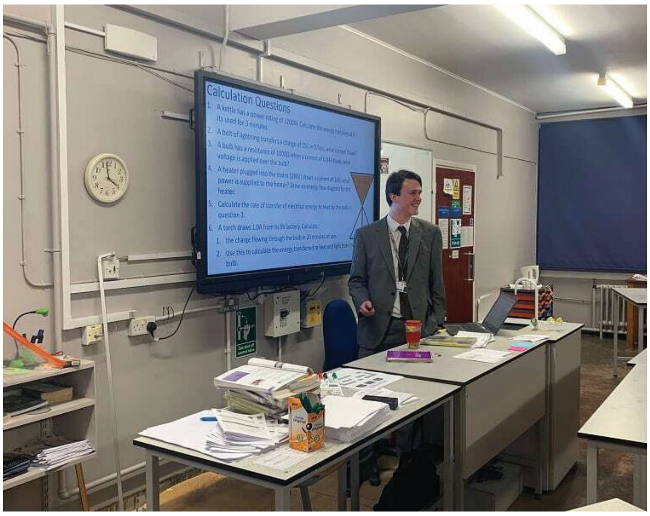
According to the latest annual survey of UK graduates by Prospects Luminate, secondary education is the third most popular professional career choice for physics graduates. Indeed, for anyone who enjoys discussing fundamental scientific concepts with young and curious minds, teaching physics at secondary school promises a fun, rewarding and varied work environment.

“I wanted a job that would make me happy,” says Oliver Alexander, who gave up the opportunity to pursue a lucrative career as a patent attorney to become a physics teacher. “I wanted to help and influence people, and teaching physics to secondary school students has the potential to change their whole lives.” Alexander admits to having some reservations about switching tack and taking an extra year to retrain – above all whether he would be good enough to communicate the beauty and complexity of physics to a classroom of teenagers. But now, in his first full year as a trained physics teacher, he has no regrets.

“I was miserable in a desk job and I knew I needed to do something else,” he says. “Being a teacher is crazy in a good way. I haven’t had a dull moment since I started.”

Part of that enjoyment is getting to know his students and classes, and seeing just how quickly they develop their scientific knowledge and skills. Aidan Reynolds, who has also just completed his first term as a physics teacher, can already sense the progress his students are making.

“During my training year I mainly taught A-level students, but now I have some classes who are just starting to tackle some GCSE topics,” he says. “They are newer to the subject, and you can really see them develop their understanding from one day to the next.” Reynolds and Alexander relish the opportunity to discuss and explore physics ideas with their students, and they work hard to devise different teaching approaches to help different age groups to properly understand fundamental physics phenomena. “It can be tricky to get some of the complex ideas across, particularly when you have studied them in such depth at university,” comments Reynolds. “It’s quite a fun challenge to take something that I know is very complicated, and making it simpler by breaking it down into its key component parts.”



Age of enlightenment: Oliver Alexander, who has just completed his first term as a physics teacher, can already see the impact that his teaching has had on his students: "They are already thinking more like physicists," he says. (Courtesy: O Alexander)

With physics teachers still in short supply, Reynolds often has the opportunity to cover more advanced topics with A-level groups to help them prepare for university admissions. “Tackling those harder questions keeps my physics brain ticking over,” he says.

For anyone thinking about becoming a physics teacher, both Alexander and Reynolds have a simple piece of advice: “Go for it!” Reynolds adds that it can be a good idea to try to spend a day or a week in a school to get a feeling for the environment. “I also did some tutoring, which makes you start thinking about how you would explain key concepts to different age groups,” he says. “When you go and observe some lessons you realize that it’s not as scary as it might seem from the outside.”

Both Alexander and Reynolds were supported through their postgraduate training year by the Institute of Physics (IOP), which runs a scholarship programme funded by the Department for Education for trainee secondary-school physics teachers in England.

The Teacher Training Scholarship scheme offers successful candidates tax-free funding of £26,000 to support them through their training year, as well as a structured programme of continuing professional development to help scholars develop more effective

Breaking it down: New physics teacher Aidan Reynolds enjoys finding new ways to explain complex scientific ideas to secondary-school students (Courtesy: A Reynolds)

approaches for teaching physics. Trainee teachers accepted onto the scheme also benefit from IOP membership during their training year, as well as access to a vibrant community of fellow scholars.

"My postgraduate training gave me lots of general teaching skills, but the IOP scholarship provided a more direct connection to the physics," says Reynolds. "The conferences and lectures organized by the IOP as part the scholarship helped me to apply the general techniques I learnt during my teacher training to physics. Talking to other teachers who are passionate about physics education also really helped me to develop my explanations, particularly for the younger age groups."

Making a connection

Both Reynolds and Alexander enjoy the social interactions with their classes and, after just a few weeks of teaching in their new schools, they are starting to make personal connections with their students. "They start talking to you about why they are interested in different subjects and what they want to do later on," says Alexander. "Today a student came to tell me that he'd applied to college, and I was really happy that he had wanted to share that success with me."

One term into his first academic year, and Alexander can already see the impact his teaching has had on his students. "At the start of year they didn't know how to go about solving a problem," he comments. "Now, when I ask a question on a new topic, they know how to approach it even if they don't get it right first time. They're thinking more like physicists, and that's so lovely to see."

Outside of the scholarship scheme, Reynolds still keeps in touch with a wider network of physics teachers through an e-mail group run by the IOP, the Physics Teaching News and Comment discussion forum (PTNC).

"There are so many teachers on the group who are sharing ideas and collaborating together to solve the same problems," he says. "It's absolutely amazing to be a part of that community and get that support, and I've found lots of resources on there that I've used myself or recommended to my students."

(extracted with permission from an item by Institute of Physics at physicsworld.com)

Where did all the calculus go?

Early in my teaching career, I had a rather uncomfortable exchange with a retired physicist. He challenged me to defend the A-level physics curriculum, which he thought had been "dumbed down" and lacked any solid, mathematical rigour. I regret not putting my thoughts across better at the time, but – with the benefit of almost 15 years teaching experience behind me – I now feel more prepared to respond.

I should add that this physicist's views were not a one-off. Since then, I have had many similar conversations with other university physics lecturers who mourn the lack of mathematical fluency in their first-year undergraduate students. I should point out that I am a huge advocate of mathematics in physics and believe that mathematics is in fact the more important subject, given that it is at the core of new discoveries.

I was surprised to discover that the inclusion of A-level maths content in physics specifications, or syllabuses, is a more recent affair than I had anticipated. It appears to have emerged in the mid-1980s in response to changes to the maths curriculum, which previously had not been standardized. Instead, there were small but significant variations between the A-level maths syllabuses offered by different exam boards. Unfortunately, attempts to remove the differences ended up having a knock-on effect for physics.

Back in the 1970s students benefited from studying some physics topics both in their maths A-level course and in their physics A-level. This gave students more opportunity to apply their learning as well as additional contact time with teachers to perfect these skills. Universities were therefore reluctant to accept physics students who had studied maths A-level courses that featured little or no physics. Admissions tutors instead preferred to accept students who had benefited from this "double study".

But when maths A-levels were standardized, physics content was removed to make way for other topics, such as probability and statistics, that are important in the social sciences. The reduction of physics content from the maths curriculum now meant there was less overlap between A-level physics and A-level maths. With less opportunity for those taking physics to refine their skills, physics specifications appear to have coped by increasing the onus on the student to study the material independently. Students studying the two subjects were simply no longer getting the rounded experience that they previously had received.

The uptake of physics A-level dropped over the next decade and physics went from being the most popular science to the least popular. One of the reasons suggested for the low uptake was the perception that physics was disproportionately difficult, which is supported by an analysis of student grades. Bright students performed worse in physics than they did in other subjects, which is off-putting when a student needs to strategically consider their subject choices for applying to university.

A good compromise

We need to accept that there are many other reasons to take physics A-level, besides the desire to study the subject at university. The skills it provides are useful to many other fields, which can lead to engaged, scientifically literate citizens. So it is in our interest to be as inclusive as possible. At A-level, teachers cater for a wide range of career paths, not just those progressing on to a physics degree. We deliver the subject in a way that is attractive and useful to both sets of students and accept that not all A-level physics students will be studying A-level maths. One consequence of adjusting for this balance can be a loss in mathematical rigour, particularly when it comes to notation.

It does not help either that when students get to university, lecturers often use a vastly different mathematical notation from what students were taught at school. In fact, lecturers often do not adjust their presentation of mathematics at all to accommodate students' varying experience. This can be incredibly intimidating, and I often wish that lecturers would adapt their teaching to be more inclusive.

Specialized A redesigned A-level maths could focus on the needs of physics and non-physics students. (Courtesy: iStock/SolStock)

Maths for physics

I believe that the solution lies in recombining A-level maths and physics, by redesigning maths A-level so that students can specialize in their second year. Students do not typically get much opportunity to choose their modules in A-level, which are decided by the exam board or school leaders. But if this were changed, then those wanting to do a physics degree could select "maths for physics" in their second year of maths A-level, allowing them to focus on concepts such as mechanics and applied calculus. Those wanting to specialize in other subject areas would be able to select more appropriate mathematics, such as probability and statistics. This would mean that those not studying maths can still do physics if they wish. Redesigning the maths course this way would reintroduce the overlap between the subjects and give students more opportunity to develop skills in class, not just for physics, but for every field.

I acknowledge that there are practical problems with this model, especially for small colleges that do not have the same staff numbers as larger ones, but I believe the potential benefits are worth it.

(extracted with permission from an item by Niki Bell at physicsworld.com)

PRODUCT NEWS

Coherent Scientific

Next Generation OPO

The next generation of the popular RADIANT series of OPO's from Opotek is here. The RADIANT tunable laser series utilises optical parametric oscillator technology to generate wavelengths over a broad range in the MIR. Integration of system components into one compact unit increases ruggedness, minimises misalignment and allows the user to reposition or relocate the system. Included verification hardware enables the user to confirm that beam paths are preserved after shipment or relocation. Hermetically sealed modules protect sensitive optical materials from the environment. A built-in red laser diode is aligned to overlap with the mid-IR output for beam guidance. Wavelength tuning is motorised and computer controlled.

New Raman Edge Filters

The new Verona long-pass optical filters from Semrock provide industry-best solutions for deep blocking close to the laser line for Raman applications. Verona is just the beginning of their evolving Raman product line to match the rapidly developing Raman market. Semrock's understanding of how crucial flat transmission is for the maximal collection of weak Raman signals is why they offer a filter with both low ripple and improved steepness from our RazorEdge™ series, making the Verona family the new gold standard for Raman analysis. Push the limits of what you can see with your Raman system with Verona Raman filters.

New EBSD Camera

Introducing the Velocity™ Ultra from EDAX - the fastest EBSD camera in the world, offering high-speed EBSD mapping with the highest indexing performance on real-world materials.

Powered by a CMOS sensor optimised for high-speed EBSD, the Velocity Ultra joins the Velocity EBSD Camera Series, combining indexing speeds up to 6,700 indexed points per second (ipps) with indexing success rates of 99% or better. This image resolution, combined with the proven Triplet Indexing routine, provides orientation precision values of less than 0.1°.

The Velocity EBSD Camera Series now includes four cameras tailored to specific EBSD analysis applications:

- **Velocity Ultra** – Collection speeds up to 6,700 ipps
- **Velocity Super** – Collection speeds up to 4,500 ipps
- **Velocity Plus** – Collection speeds up to 3,000 ipps
- **Velocity Pro** – Collection speeds up to 2,000 ipps

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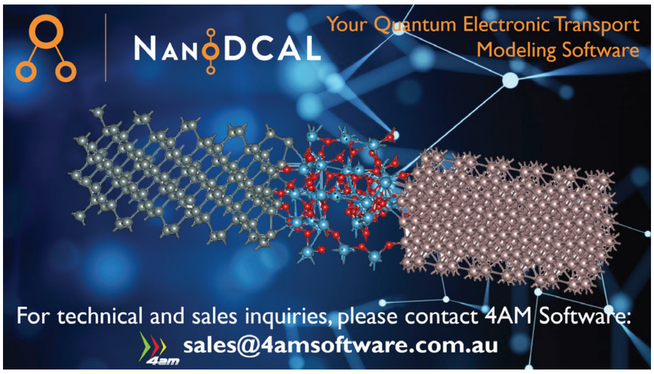
NANOACADEMIC Technologies

NanoDCAL

NanoDCAL offers reliable and powerful quantum transport simulation features to model nanostructures or nanodevices. It is an atomic orbital implementation of NEGF-DFT. It computes the Hamiltonian of materials and devices from first principles (i.e., without external parameters) using density functional theory (DFT) and simulates quantum transport phenomena within the Keldysh non-equilibrium Green function formalism (NEGF). NanoDCAL includes a large suite of methods for calculating important transport properties of your materials. NanoDCAL was used in hundreds of peer-reviewed papers in domains as varied as molecular electronics, nanotubes, topological insulators, batteries, magnetic tunnel junctions, metal grain boundaries (crystallites) and more: all of them can be found referenced on our website, under Technical Insights menu. It has demonstrated efficiency, so why not test it? Unleash the full power and functionality of NanoDCAL by obtaining a parallel license and use it at its full potential.



Main NanoDCAL features are the following:

- Written in MATLAB and C
- Focus on molecular and nanoscale electronics (small to large scale 1k+ atom systems)
- Spintronics (collinear / non-collinear / spin-orbit coupling)
- Semiconductor nanoelectronics (I-V curve)
- Several features such as total energy, force, scattering states and phonons calculations are part of NanoDCAL suite
- Study molecules, crystals, one-probe and two-probe systems
- Force, stress, structure optimization
- Electron-phonon coupling
- Atomic orbital basis optimizer
- Photocurrent
- Thermal transport coefficients

We offer licenses for single users and research groups and some options such as the HPC (parallel version) and advanced training and support services.

A free trial version is available for testing. Create your free user account today and start using our advanced atomistic tool, today!

RESCU

RESCU – Real space Electronic Structure CalcUlator – is a powerful MATLAB-based density functional theory (DFT) and DFPT (perturbation theory) solver. It can predict the electronic structure and derived properties of bulk materials, material surfaces and molecules. RESCU calculates the ground-state density using a basis of numerical atomic orbitals, plane-waves or real space grids, or a combination of them. Written with the objective of solving systems comprising up to a few tens of thousands of atoms, RESCU is carefully parallelized and exploits libraries such as MPI, ScaLAPACK and CUBLAS. It includes many state-of-the-art analysis tools such as density of states (DOS), projected density of states (PDOS), local density of states (LDOS, PLDOS), finite-displacement phonon and band structure. It has some unique features that most if not all other commercial codes on the market do not have.

Main RESCU features are the following:

- Written in MATLAB and C
- Focus on large scale systems (up to 20k atoms)
- DFPT implementation (e.g., dielectric tensor, dynamical matrix)

- Optical properties (e.g., dielectric permittivity, refractive index)
- Raman tools (e.g., tensor, spectrum, intensities)
- Advanced functional treatment such as DFT + EXX (hybrid) and DFT + U (Hubbard)
- Common analysis tools like DOS, PDOS, LDOS, PLDOS, band structure, band-unfolding, charge analysis
- Non-linear optical susceptibility
- Spintronics (collinear / non-collinear / SOC)
- Phonon tools (finite-difference-based)
- Large scale CFSI solver

We offer licenses for single users and research groups and some options such as the HPC (parallel version) and advanced training and support services.

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QTCAD

Nanoacademic Technologies Inc.'s QTCAD newly released software is unique on the market and enables to study arbitrary gated quantum dot configurations in semiconductors including for example advanced III-V alloys such as GaN and AlN (Nitride) materials, but all semiconductors can be studied. QTCAD is the only commercially available computer-aided design software with all the features needed to model spin qubits in gated quantum dot devices, namely, device electrostatics at cryogenic temperature, single-particle Schrödinger solvers for electrons and holes within k.p theory, and quantum-mechanical many-body solvers accounting for Coulomb interactions within the gated quantum dots. QTCAD simulations have recently been used in the interpretation of experiments with industrially fabricated gated quantum dot devices such as FD SOI architectures.

Main QTCAD features are the following:

- An interface with our large scale DFT software RESCU (k·p theory)
- An electrostatics tool that solves the confining potential of quantum dots in semiconductor
- A valley-splitting calculation tool;
- An exact diagonalization tool / many-body Schrödinger solver for electrons and holes;
- A master equation solver for quantum transport calculations in the sequential tunneling regime

enabling treatment of Coulomb blockade and predicting charge stability diagrams;

- Quantum-mechanical treatment of magnetism (orbital and Zeeman effects);
- Linear spin-orbit coupling from arbitrary user-defined Hamiltonians;
- Our electric-dipole spin resonance module interfaces with QuTiP for time-dependent simulations of quantum control;
- Works at cryogenic (sub-K) temperatures in many practical designs of solid-state spin qubits, which is a notoriously difficult problem to solve with available TCAD software;
- Arbitrary 1D, 2D and 3D device geometries are defined via Gmsh using our adaptive meshing technique to avoid time-consuming manual mesh refinements. Simulations are launched using our user-friendly Python API.

Many more features are in the works to extend the reach of QTCAD over quantum technologies and more physics phenomena. We offer licenses for single users and research groups and optional advanced training and support services.

QTCAD is now commercially available for academic users, a Professional version will launch soon (companies: please contact us for more information on info@ nanoacademic.com).

A free trial version is available for testing. Create your free user account today and start using our advanced quantum modeling tool, today!

Contact Us

Visit us for more technical descriptions on our website www. nanoacademic.com and linked documentation: https://docs. nanoacademic.com/.

For any commercial inquiries, please contact our ANZ Partner 4AM Software on sales@4amsoftware.com.au

Lastek

Photon Force Single-Photon Sensitive Cameras and Sensors

Photon Force offers a range of products and services all aimed at the acceleration of scientific and commercial research that incorporates single-photon counting and timing. Their camera range currently includes the PF32-500k as an entry-level unit, whilst the PF32-1M offers extreme speed for applications that require flexibility in readout modalities. The Photon Force PF32 cameras are the highest throughput SPAD array cameras on the market today.

- 32x32 TCSPC pixel array
- 55 picosecond resolution
- Two modes; TCSPC and photon counting
- Up to 500,000,000 photons timestamped per second

Where are Photon Force technologies used?

Photon Force products are used across a wide range of sectors to enable ultrafast, Time-Correlated Single Photon Counting with the ability to timestamp half a billion photons per second. Our cameras and sensors are primarily used in the fields of photonics, quantum optics and other scientific research to enable next generation technologies and products in a wide range of industries, spanning neuroscience, energy, communications, automotive, and beyond.

High Finesse WS8-2 High End Wavemeter

The High Finesse WS8-2 is the unsurpassed high-end instrument for wavelength measurement of pulsed or continuous laser sources. It delivers superb absolute and relative accuracy required by cutting-edge scientific research, as well as industrial and medical applications.

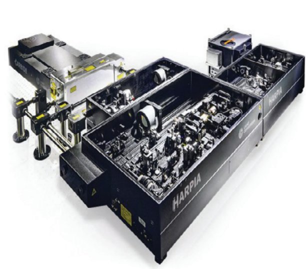
The unmatched precision of the WS8 series demonstrates the world leadership of High Finesse wavelength meters.

The photonic fiber switch at the input offers endlessly singlemode operation, making it possible to measure lasers at wavelengths across the entire spectrum with the full accuracy of the wavelength meter.

Typical Applications

The WS8-2 is the highest-end solution for wavelength monitoring and control with an absolute accuracy of 2 MHz and a wavelength deviation sensitivity of 0.2 MHz. The WS8-2 is subject to the most stringent production, testing and certification procedures and therefore offers the maximum accuracy with state-of-the-art technology.

Light Conversion HARPIA: Comprehensive Spectroscopy System



The Light Conversion HARPIA comprehensive spectroscopy system performs a variety of sophisticated time-resolved spectroscopic measurements in a compact footprint. It offers an intuitive user experience and easy day-to-day maintenance meeting the needs of today's scientific applications. Extension modules and customization options tailor the HARPIA system to specific measurement needs.

The system is built around the HARPIA-TA transient absorption spectrometer and can be expanded using time-correlated single-photon counting and fluorescence upconversion (HARPIA-TF), third beam delivery (HARPIA-TB), and microscopy (HARPIA-MM) modules. HARPIA is designed for easy switching between measurement modes and comes with dedicated data acquisition and analysis software. Each module is contained in a monolithic aluminium body ensuring excellent optical stability and minimal optical path lengths. For a single-supplier solution, the HARPIA spectroscopy system is combined with a PHAROS or a CARBIDE laser together with ORPHEUS series OPAs. HARPIA also supports Ti:sapphire lasers with TOPAS series OPAs.

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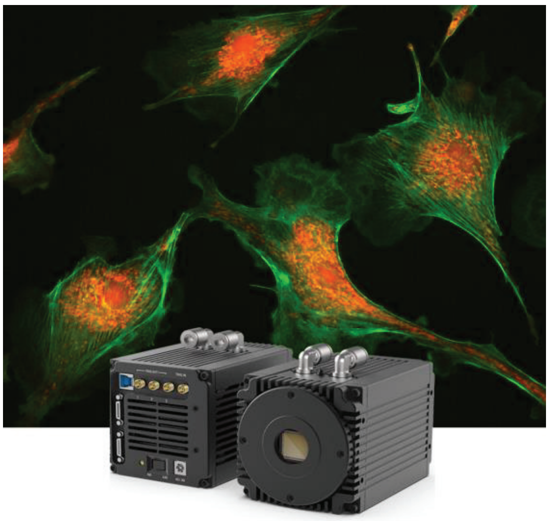
- <50e- Readout Noise



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