Fall 2024 | Volume Two • Issue One

THE WELCOME ISSUE

- The Andrew MacRae Op-Ed
- Academic Advice
- Cipher Scavenger Hunt
- And more!

PHASE SHIFT

A *Phasers* publication

Photo by Iain Rosen

WELCOME!

Phasers, the University of Victoria's Undergraduate Physics and Astronomy Students' Events and Recreation Society, is proud to publish a new volume of the student-run newsletter, *Phase Shift*. Whether you're new to UVic or returning for another academic term, enrolled in the department or not, a student or faculty member or even just curious about physics and astronomy, we think there's something here for you.

Within the pages of this issue, you'll find an interview with senior lab instructor, professor and head of the UVAMO Lab, Dr. Andrew MacRae; an advice column on tips, tricks and anecdotes for new and seasoned students; a look at the goings-on in the world of physics and astronomy with an update on the Artemis project; a brief explanation of the names behind the newsletter and course union as well as a crossword puzzle and an interactive scavenger hunt. Lastly, on the next page you'll find various dates of note, ranging from historical and astronomical events to Phasers events and important academic dates. We hope this collection of articles helps show that astronomy and physics go beyond the classroom and can be accessible to everyone.

Best of luck in this academic year and happy reading!

- The 2024-2025 Phase Shift Publishing Team

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We hope you thoroughly enjoy this newsletter's contents and if you have any questions or comments, or if you're an undergraduate student at UVic hoping to submit or be involved, please feel free to write to ***uvicphasers.newsletter@gmail.com***

October to December Important Dates:

- Academic Date
- Pħasers Event
- Astronomical Event
- Historical Event

Hear from a different physics or astronomy professor every month at Pħasers' Night With A Prof talks. These are announced on social media and on Elliott notice boards. Find more Pħasers info and links at https://linktr.ee/uvicphasers

Oct 24-29, 1927: 5th Solvay Conference
Oct 30: Spookacular Science Showdown Trivia Night
Oct 31: Course drop deadline
Oct 31: Sci-Fi Halloween Party
Nov 5: Grad School Info Night Session
Nov 11-13: Reading break
Nov 15: NWAP with Michele Lefebvre
Nov 30: Goldstream Park Trip
Dec 4: Fall classes end
Dec 7: Final exams begin
Dec 7: Jupiter at opposition
Dec 11-14, 1972: Apollo 17 crew are the last humans to visit the moon
Dec 20: Last day of final exams. Be free!

Academic Advice

by Amith Valath

It is your first day at the University of Victoria, your first class. You walk in and sit down at a spot, which you know is *the* spot. Excited to be a part of the grand illusion called University, you begin to listen to your professor. Somewhere along the way you realize you're confused, and have a doubt. What do you do? Some of the options are...

(a) ChatGPT (b) Ask your friends (c) Ask your prof (d) Ignore the doubt completely

A little down the road, one more option pops up: drinks from Fel's. My advice is to combine this with option (b), and it becomes a "healthier thing".

Working in the Pħasers lounge, on the 4th floor of Elliott. Can you spot Pete?

Jokes aside, while using ChatGPT or ignoring the doubt may seem easier, approaching your professor and/or discussing it with your friends can be a game changer. While both the internet and your professor can give the same answer, talking with your professor or peers helps you establish a good social connection to people with similar interests. This may help you gain a new perspective on things you know, or learn things that have escaped your knowledge. You may feel hesitant to approach professors, keep in mind they are normal people who are more than glad to help. The Physics Aid Service is a good alternative is you're having trouble understanding assignment problems. The Math and Stats Assistance Centre is another resource that students should keep in mind. Additionally, course unions, like Pħasers, have official Discord servers with channels set up to discuss specific classes. Sometimes, no matter how hard you try to do assignments, you might feel yourself getting nowhere. In times like these, try taking a break. UVic is a beautiful campus and offers nice paths to take a walk. Or you can hang out in the Pħasers lounge, which is located on the fourth floor of the Elliott building, and talk to Pete the Problem Duck, which is completely normal. For those needing coffee, the lounge also has a coffee maker!

On a final note, I haven't tried all the advice I have given. Maybe I'm a hypocrite, or a theorist. But I encourage you all to become experimentalists and test my theories for yourself! ◘

TECHNICAL TERMINOLOGY

Pħasers? Phase Shift? What the heck does it all mean?

by Kyle Brown

Some readers may be curious about the meaning of a 'phase shift', for which the newsletter is named, or about the physics behind the 'Pħasers' acronym. Others may think they know all there is to know about these two terms. Whichever the case, this brief article should help to explain both terms to newcomers and highlight new information to those already familiar.

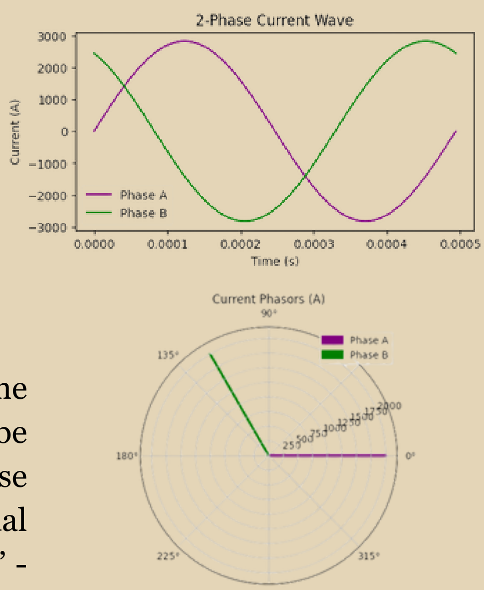
Let's start with the Pħasers logo. Our newest logo, designed by Erin Clease, features a depiction of one end of a wormhole, which is a theoretical structure that warps spacetime to connect two points that would otherwise be separate. Wormholes have never yet been observed, despite persistent media hype implying otherwise.

Now for the acronym logo, designed by Spencer Plovie with ideas inspired by Aaron Banister. Each letter relates to a different aspect of physics or astronomy, from galactic astronomy and planetary science to quantum physics and relativity.

Beginning with the 'S' on the right, we have a barred spiral galaxy, which is a subclass of spiral galaxies that includes our own. The 'R', represented by the uppercase Greek letter gamma with super-and-subscripts, is the Christoffel symbols of the second kind which describe, for some coordinate system, the change in basis vector α in the direction of γ for an infinitesimal displacement in direction β. Christoffel symbols often come up in general relativity.

Next, standing in for an 'E' is a modified version of the astronomical symbol for Earth - it would typically have a complete outer ring. After this are sine waves of various periods and amplitudes, which appear throughout physics, followed by another Greek alpha which commonly denotes helium nuclei - that is, alpha particles. Continuing, ħ is referred to as "h bar", the "Dirac constant", or the "rationalized Planck constant". It is equal to Planck's constant h divided by 2 times pi, $h/(2\pi)$, and is used in quantum mechanics in formulae relating to quantized energies.

Lastly, we have the Physics and Astronomy course union's eponymous phaser of Star Trek fame. In said sci-fi world, phaser is short for PHASed Energy Rectification, and phasers are handheld energy weapons. While Star Trek phaser technology doesn't exist in reality, in the world of physics the homophonic phasor (from PHASe vectOR) is an analytical tool that describes a sinusoidally changing quantity, often represented in "phasor diagrams".



Plot of phase shifted wave function and its corresponding phasor diagram

A sinusoidal function is one where some quantity is proportional to the sine of another so that its value is periodic. Phase angle is used to describe the location of a point on a sinusoid relative to its total period. A phase shift is then defined as a difference in phase angle between two sinusoidal functions, and can either be positive - a leftward shift and a "phase lead" - or negative - a rightward shift and a "phase lag".

Now you're all caught up! ▫

the Andrew MacRae Op-ed

by Ash Samra

Some may know him as the instructor of PHYS 229 or PHYS 325. Others may know him as the lab coordinator for upper level physics courses. But in the basement of the Elliott Building in ELL 014, he's the principal investigator of the Atomic, Molecular and Optical Laboratory, or UVAMO.

Andrew MacRae is an adjunct assistant professor and senior lab coordinator in the department of Physics and Astronomy, having graduated from UVic with a Bachelors in Honours Physics in 2005, and completed his doctorate in Physics at the University of Calgary in 2012, after which he did a postdoctoral fellowship at the University of Berkeley. Finally, before joining the UVic faculty, Andrew worked in industry at Polaris Motion as a software engineer, where he developed control systems and software for high precision machines.

Phase Shift sat down with Dr. MacRae to interview him about his research, school, life, and everything in-between.

Ash: What led you to pursuing your career path? Did you always know what you wanted to do, or was it more of a journey in figuring that out?

Andrew: I did not plan on being a physicist. I didn't have a major plan, I was just interested in things. I had an epiphany that no one's going to stop me if I sign up for university. I ended up taking a night course in physics at Camosun – I hadn't even taken physics in high school, I was just really interested in it. It was a lot simpler than I thought. You're not solving quantum field theory equations, you're just thinking about how things work, and everything is super interesting when you think about it.

So I cautiously went on to the next course and the next, with the assumption that eventually I was going to get exposed, like, "I'm not a physicist, these are different kinds of people, there's a different DNA for someone who could do this kind of stuff." But I was like as long as no one stops me I'm going to keep going. Then you get to the end and you're like "That was fun, better apply to grad school, I don't want a boring old job just yet."

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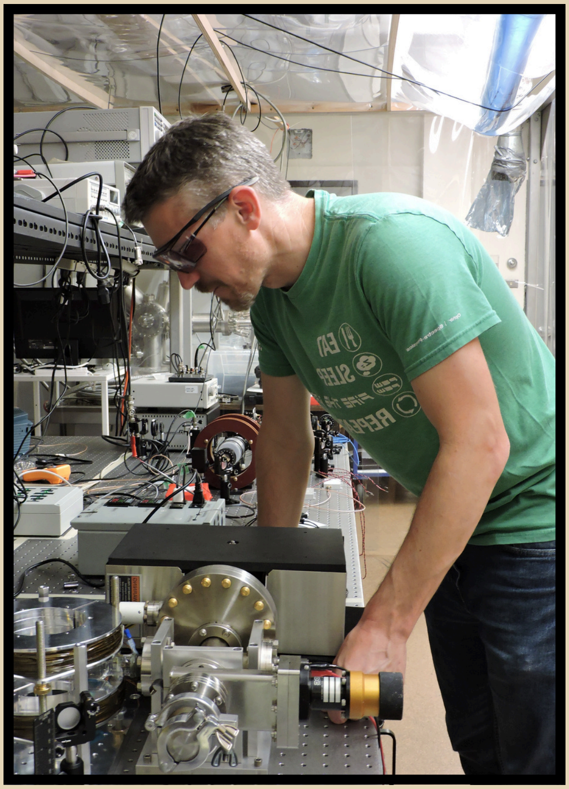
Even in grad school as a master's student I was like, “This is it, I'm not going to do any more physics than this because I'm not a physicist.” When I finished, my supervisor said, “No, you’ve really got to do a PhD.” And I was like, “I didn't plan on it, but OK.” So I did that. And then the next thing and the next thing. It was something I wound up doing out of interest and then kind of like creeping forward like, “Can I do this? Can I do this? Can I do this? Can I do this?”

Growing up is waking up to the fact that no one else knows what they're talking about, but things still get done and that means, by association, you can actually do things as well. You could do important things as well because all these other important things were done by people that also didn't know what they were talking about and kind of just stumbled on to it and figured it out.



Ash: Do you feel like you know what you're talking about now? Or do you still have moments of “What’s going on?”

Andrew: Oh, I have constant moments. It's a cliché, research is being confused, but it actually is. Sometimes I get stuck on very basic things and I get annoyed at myself, like I should know this by now. Even on the stuff I’m working on I'm still trying to figure it out. It was one of my professors here, Fred Cooperstock, said that “As an undergrad, I saw this stuff, it was very confusing to me. Now, I'm still very confused, but I'm confused at a much more sophisticated level.” And that's what it is. He’s used fancier words about it, the words have more syllables, but you're still confused.

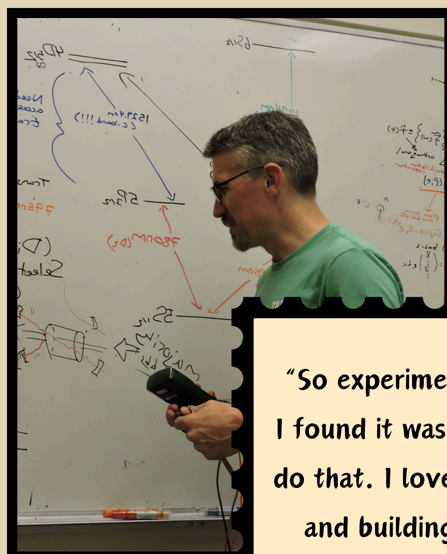
Ash: Tell us about your area of research and why you’re interested in it!

Andrew: The real answer is that whatever you end up studying, you're going to be into it when you study it enough, because the more deeply you look at something, the more interesting it is.

When I was going to grad school, I was really into programming and computer science. It was out of naivety towards my field, so I was really into computers and computing, and the idea of information. I thought quantum stuff was really cool. Then I learned about quantum computing. Quantum computing is a buzzword now, but it was not back then, like 2006 when I applied, it was new. Not too many people had heard about it, it wasn't a popular thing. So I was like, “quantum computing!” and I looked up groups that did quantum computing. There was one at a few institutions around, so I applied to those. So I went into it that way.

The stuff I’m most interested in within research is kind of the out there questions about that. For example, I’m trying to write a paper now about, when is a photon detected? That's a weird question. So a photon is one microsecond long and you can detect it with a photocurrent and that photocurrent, like the response of that detector takes nanoseconds, it's much faster than the photon. When are you actually measuring the photon? The photon is in a superposition of here, here, and here, and it's getting absorbed a various number of times. So when is the instant that photon is actually measured, or does that even make sense? It's a very silly, like 2:00 AM dorm room conversation. Like, “Yeah, man, what is a photon actually?” But that's the kind of research that I'm really actually interested in. Stuff that has probably no practical relevance. Maybe. Maybe not. Maybe it does, maybe it doesn't. But it's really interesting. We can actually ask about it and ask the question experimentally.

So experimental physics, I found it was very fun to do that. Plus I love electronics and building things, but it's specifically this field because it's very hard to see quantum mechanics unless you isolate things. If you're looking at the quantum state of an atom in this desk, it's coupled to a bunch of other atoms, and it's very noisy. You have to cool it down so the vibrations through the lattice aren’t ruining everything. It's a very complicated setup - it takes millions of dollars. A laser pointer is a little bit more simple. So you fire a laser pointer, and there’s a photon and it gives you direct access to the wave function. That was what my PhD ended up being on. It was supposed to be on improving the nonlinear coefficient of some crystal, but I kind of just like pushed and pushed and meandered towards measuring the wave function of a single photon - the temporal wave function, in time. That’s kind of the neat thing about research, by the way, you can take any direction you go. No one had cared about that question or thought about it. Maybe no one still does care about it, except for me. I care about it deeply.



“So experimental physics, I found it was very fun to do that. I love electronics and building things”

I'm just being so verbose here, I'm sorry, basically, if I could summarize it in a sentence, is that to me, it allows you to play with quantum mechanics directly, to really play with quantum mechanics with your hands.

Ash: What has been the most memorable, impactful or profound moment of your career?

Andrew: There's lots, but there's one moment I always remember. My PhD was on trying to find a new way of making photons, single photons, isolating single photons and basically long story short, we found a process that theoretically should be emitting pairs of photons, and the idea is if we drive it very weakly and we have a photodetector here that clicks when you get a photon and we're measuring the state of the electromagnetic field - there's a device called a homodyne detector that does that — and we record the data a bunch of times whenever we get a click here, we record that oscilloscope trace and just accumulate it and add it up and then you should be able to see a photon. The photon is very small. When the vacuum is there, there's a given amount of noise. When the photon is there, there should be much more noise. But shot to shot, the overall noise is just crazy all over the place.

So what I had done, you know, you have a lot of time to bang your head as a grad student. I had made a computer program that was doing a continuous averaging of the oscilloscope trace. It was triggered so whenever it got a clip from the oscilloscope it went into the hardware, took a trace and added it to the last one, did a running average of the variance of the trace.

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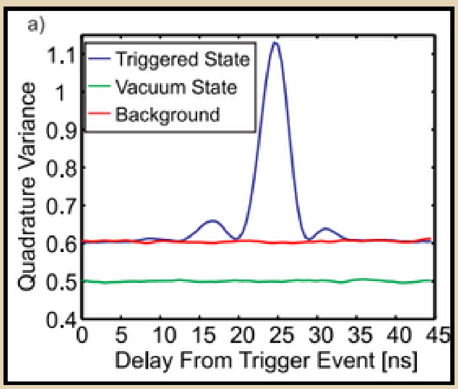
And I was looking for this photon to appear and nothing worked. And like, oh, you know, you figured out that it could never work because the photon is coming out in this directional mode.

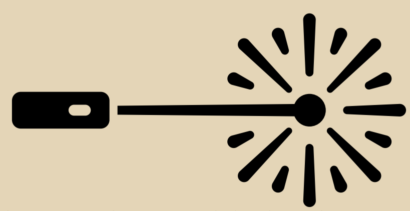
And I'm looking at the wrong place. So you fix that. Oh, that can never work because there’s so many background lights that most of these trigger events are going to be false triggers, so we'll never see that one. You get around that problem. You get around problem after problem and that's what research is. You bang your head for days like, “God it should never work because of that.” And you fix that. There's how many of those things, right? And I was working late at night in the lab. My wife and kid were visiting back home in Victoria and I was in Calgary and, you know, listening to tunes. And I was just aligning it. And I really was in the zone. And like, “I'm figuring this out, I think I understand how everything is going to go.”

> “I think this is the first time ever someone has seen a single photon produced this way”



Experimentally measured point-wise variance for the single photon experiment from Dr. MacRae's Ph.D thesis.

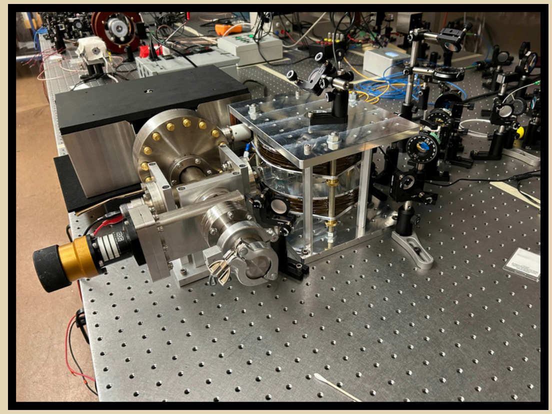
And I was looking at the screen, and it was aligning things. There's fuzz and there's fuzz. And eventually, I'm like, I think I saw something. I’m like, no, nothing. And like, I think this is it, it has to be it. And it was after it's like after a year of working on this problem, I was aligning, aligning. And I saw this little peak at the edge. And then I did it and the peak got higher and like, that's the first time. I think this is the first time ever someone has seen a single photon produced this way. And I'm actually looking at kind of the wave function of the photon. I don't think any other person has seen this. The other people in the lab had gone home and I was just working on it. Listening to this song called Lateralus by Tool. So Lateralus is very long, it’s like 11 minutes long. And that part of the song where it’s all quiet again, that’s when I saw the photon and it was awesome. And I just was like aligning it.



I'd helped out someone get into some school. When I was a PhD student. I'd helped out a student get a grade - like an undergrad, right? And his dad had, like, smuggled me a Cuban cigar. I'm not a smoker, I don’t smoke. He gave me a cigar. And over the year, a year had went by and I started calling it a “Single Photon Cigar.” I don't really like smoking, but when I get that photon, I'm gonna take a puff of that cigar. And I was aligning it, aligning and aligning it, and it was like a summer night outside. I didn't know because I was in the lab, and I finally saw the photon for the first time. So I went outside and it was like this vast starry sky, the big skies in Calgary. And I was thinking about that photon and I lit up that single photon cigar and I was like... “I don't think anybody else has seen that. Ever.”

And it was a cool feeling. And like at that point, I'm like, there's going to be some writing, some analyzing too but I didn't know like am I going to graduate? Is this project ever going to work? At that point I'm like - that's with that cigar - that I'm like, “I think I just got my PhD.” And also I don't really care that much about the PhD. I finally saw that photon. Like that was a magical moment. That was cool. That was cool.

Yeah. So I was hooked at that point if I wasn't already.



"Ultra-High vacuum system with Anti-Helmholtz coils for Magneto-Optical Trap"

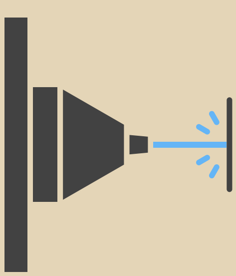
Ash: What life lessons did you learn from your undergraduate experience? What advice would you give to yourself back then and other people in that position?

Andrew: Lots of advice. One of them would be: take your time and slow down. I was taking six courses a semester at first, and I got crappier grades than I should have because I was trying to rush through everything. It's no rush. The reason is that I took a few years off and everybody else was a couple years younger than me when I started. Because I took two years off and I felt like I had to catch up. That was a mistake.

> "The biggest lesson I learned is that it's not black magic. It was figured out."

"When I'm 36, someone else is going to be 34", like that doesn't matter at all. So take your time with it. I didn't really know how to be a student, so this might not apply to most people who went right into university and were good students in high school. Don't treat the subject you understand like you're trying to come up with magical incantations. The teachers usually tell you how to study for stuff, and if you want to get your grades, you can do that. But the biggest lesson? The biggest, biggest, biggest, by far, lesson I learned is that it's not black magic. It was figured out. It was invented by people that were no smarter than you are. Really the variation between the smartest human and the average human is minuscule compared to a human and a fly, or like most other things.

The variation of intelligences between humans, to me, is probably so small so as to be irrelevant in the grand scheme of things. There are things that make it easier for some people. I struggle with this too, like what is talent. Often the stuff that true innate talent is—just take it out of intelligence and take it into sports or something like that. There's a famous case of a high jumper, he was a basketball player in high school and he said, "oh, what you do is easy. What do you high jump? 6 feet? I can do like 7." And the guy was like, "yeah, right." And he went out and he did it, he did seven. He was just naturally talented and he was naturally gifted. That's the special case where it's actually true, and it turns out he had an abnormally long, like a mutation basically, he had an abnormally long Achilles tendon and that, turns out, gave him a very springy jump. You could do that. You could actually get a surgery to get springs on that and you have the same talent as that person. Talent, natural talent is something that if it were done artificially, you would call it cheating. So there is such a thing as people who are wired such that certain things are easier to them, but it's by far not universal. They're going to be very good in a very specific way of doing it. You're going to be very good at doing it a different way. The biggest thing is it's not black magic. Anyone can figure it out. You have to come at it your way, but you can 100% figure it out. ◘



PHASTODAY:

Mission Back to the Moon

by Nathyn Sutton

Since the last crewed trip to the moon more than 50 years ago, our technology and understanding of space has increased greatly. With these advancements, NASA put forward the Artemis program in 2016 which consists of four separate missions to the moon.

The Artemis I mission, which has already concluded, was an unmanned test flight to the moon that launched at the end of 2022. The one goal of Artemis I was to make it to the moon and back safely. This was in preparation for Artemis 2 which will launch in September 2025. It used two lunar gravity assists, first to establish an elliptical orbit and then to slingshot out of it. As this mission was just in preparation for future Artemis missions, the public will never see most of the data that was acquired. There were some photos taken though, like the one below that silhouettes the moon and Earth together in the background.

Image taken during the Artemis I Mission

The plan for Artemis IV is to make the Gateway Space Station a reality, and launch no earlier than September of 2028. This will be an ongoing mission from 2028 onward. The first trip of Artemis IV will be to bring the first ESA module, as well as send two astronauts to the moon's surface to conduct research. To build the Gateway Lunar Station, four rockets will be used over a course of six years to bring the 9 different components that make up the station. Gateway will allow researchers to spend upwards of 90 days in orbit around the moon and it is expected to be in use for a minimum of 15 years, allowing for "much more information to come".

The second mission, Artemis II, will take a crew of 4 into an orbit of the moon and then return. It is expected to take 10 days from liftoff to splashdown back on Earth, and will be the first time a human has returned to the moon since Apollo 17. This mission will follow a fairly similar path to Artemis I and as such will not be touching down on the moon's surface.

On Artemis III, which has a tentative launch date of September 2026, NASA will send another 4 astronauts to the moon. This time, two crew members will conduct research on the surface for approximately a week. The other two will stay in orbit. NASA plans for touchdown to be in the Southern region of the moon due to the likelihood of frozen water and volatile elements, and of course, to research the surface to gain a deeper understanding of how the Earth may have looked in its younger days.

Artist's impression of the upcoming Gateway Lunar Station

The outcome of the Artemis program will give us a better understanding of our moon, the planet we live on, and the environment our solar system may have experienced upon its creation. Artemis IV will open up a huge array of possibilities for future research at the moon since we will be able to have an extended stay of around 90 days to conduct study. Although this program is both timely and costly, the benefits to the knowledge Artemis will bring to the scientific community outways all doubt.

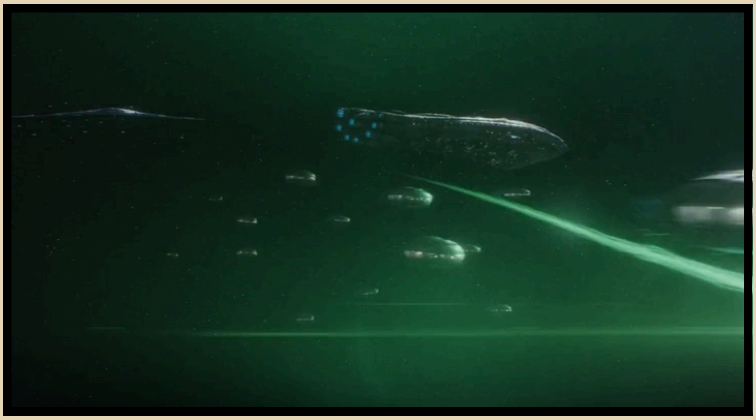
Common Sense In Science Fiction

by Rowan Dowler

A basic principle that tends to apply to most things, including physics, is following "the path of least resistance". This idea applies to humans and the development of technology by the way we tend to use the easiest solution to a problem. If not the easiest, sometimes a more complicated one that provides more convenience in the long run. For example, humans have been using ovens or equivalent technology for millennia to cook food. Even modern day ovens are not that far off from the ovens we've had for centuries. The biggest difference is that we've developed more efficient ways of generating heat by using electricity rather than fire. We also invented the microwave, which was more complicated to develop but is more convenient than an oven, while serving a slightly different purpose. However, we don't do away with old technology and methods when we invent something newer. We may have more convenience and simplicity at the same time. A good example of this is that while drills are fairly common, screwdrivers are still useful and even more common.

This kind of common sense should apply to science fiction as well.

The standard weapon often employed by soldiers in Star Wars, and many other popular science fiction stories, is some form of blaster. Every blaster type resembles some form of real-world firearms in application, having the equivalent usage to rifles, shotguns, etc. However, in many ways, modern firearms are superior to the blasters of Star Wars. Bullets arguably travel faster, and are more lethal. The only objective benefit that blasters have over conventional firearms is that soldiers don't need to carry ammunition. Blasters are powered by energy cells, which are much more efficient if you're considering mass rather than carrying bullets. This is a lot less weight that soldiers are carrying around. That is potentially a good enough reason to use blasters since very few people are fast enough to react to them anyway.



Starship chase sequence from *Star Wars: The Last Jedi*

However, any starship should be equipped with kinetic weaponry. It's much more feasible to carry a large amount of ammunition on a starship, and it offers more range. The poorly named "laser cannons" are the same technology as blasters, just with more power behind them. The energy projectiles fired are bright and hot, and therefore losing energy. At a certain point they dissipate, limiting the range of the ship's weapons. Weapons firing bullets have no such weakness, relying only on kinetic energy granting effectively infinite range while in space combat.

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If in The Last Jedi, the First Order had been using kinetic weaponry, the movie would have been much shorter. The issue this poses is that it challenges the logic of the story, making it less believable because it's utterly ridiculous to say that they haven't developed ballistic weaponry, because not only is it much simpler, but less developed groups like the Tusken Raiders are depicted to use it. There is no reason to develop and implement more advanced technology that is less effective than what you already have. No society should ever do that.

Concept art of the various armor of various factions from the 2021 film adaptation of Frank Herbert's *Dune*.

Another egregious example is not just of technology that fails to justify its own existence, but technology which is treated as if it renders less sophisticated technology redundant, when in fact it does not. In Dune, an important defense mechanism is the Holtzman Shield. The premise of this shield is that once activated, it stops all matter moving above a certain velocity from penetrating the shield.

Credit where credit is due, this technology leads to the realistic development of the partial abandonment of ranged weapons, as all projectiles are rendered useless in combat against someone with a shield. Soldiers instead use melee weapons, often just regular knives forged using very sophisticated metallurgy. In essence, they are just regular knives like we have, with an assumption to be stronger and sharper steel.

The idea of adopting this style of combat in universe is that you need precise weapons that you can move slowly enough to penetrate your opponent's shield. A knife is probably the optimal weapon for that. Unfortunately, there is a piece of technology that is exceptionally good at stopping slow moving knives from penetrating skin and it's called armor. This problem is exacerbated by the inconsistent depictions of armor in the two films. For example the Harkonnen soldiers wear full body armor which means the only effective way of defeat is by slashing at their unarmored faces and necks, while the supposedly more deadly Sardaukar, who even pose as Harkonnen, wear no form of protection at all. An even bigger issue is that Irulan wears chainmail in the film, though she doesn't fight. Her armor is most likely only ceremonial and is not intended to serve a practical purpose. In her armor though, is notable neck protection. She has substantial neck protection while all the soldiers who go into combat have none, and the vast majority of those who die are killed by having their throats slashed with a knife.

One of Princess Irulan's outfits from *Dune: Part Two* that incorporates an armor design

Suspension of disbelief is a writing convention that shouldn't typically be pushed to its absolute limit. Even in genres that Star Wars and Dune find themselves in that are inherently unrealistic like Science Fantasy or Science Fiction, the story should operate on common sense and with internal consistency. Even when dealing with concepts that are completely infeasible in real life, it is possible to have realistic ramifications on society.

An excellent example of this is the replicator from Star Trek. As unrealistic as it is as a technology, the impact it's had on the civilizations of Star Trek is very realistic. The replicator seemingly creates food and drink out of thin air. There are explanations that justify this technology to make it sound more possible, such as it not creating matter just teleporting and transmuting existing matter, but that's not relevant. What is important is how this affects the users of the technology.

A *Star Trek* replicator

Most people in Star Trek don't cook, at least on the Starfleet Ships that come equipped with replicators. This makes sense, for a lot of people, cooking is a necessity and if they could generate any dish they wanted in an instant they wouldn't bother. However, there are some who keep the art of cooking alive, because they enjoy the act of it, and because apparently there's a discernible difference in quality between handmade and replicated food. So for most people in their day to day lives, replicators remove the need to cook. But cooking is not completely absent from society because there are still reasons to do so. Another time when fresh food is prepared is throughout *Star Trek: Voyager*, where there is limited matter to fuel the replicators so the crew resorts to cooking using fresh ingredients, and retrofitting unused rooms into gardens.

A garden room from *Star Trek: Voyager*

More science fiction media should follow in Star Trek's footprints, and think carefully about how technology might come about, and how it impacts the society that invents it. ◘

Interested in learning more about the depictions of physics in science fiction media? The department of physics and astronomy offers PHYS 304: The Physics of Science Fiction, open to physics and non-physics students alike.

Welcome to the Cipher Scavenger Hunt!

by Eliza Partridge

I'll walk you through how a cipher works to help you decode the clue below. Decoding the clue will lead you to a location on campus (not in a classroom, residence building, or other private space) where you'll find a small prize – and further clues to decipher and prizes to hunt down if you wish!

The first person to solve all the clues will also win a free Phasers shirt.

Your encrypted clue is: 5CEF P8C 6OVD SSL

The above clue is an example of one-time pad (OTP) encryption. It uses a key – the "one-time pad" – consisting of a random string of characters at least as long as the message to encrypt.

Provided that the key is kept secret between sender and receiver and never reused, this encryption method is unbreakable! Common decryption techniques like letter frequency analysis don't work against this cipher.

The shift table to the right matches characters to numbers, and is used to encrypt the message. The first character in the OTP key indicates the number of positions by which the first character in the message is shifted forward. The second character in the key shifts the second in the message, and so on. If the shift would move the original character past 0, we start again from A.

Let's look at an example.

We want to encode the text "THE YEAR IS 2024".

Say our OTP key is Y P W C 2 W N J A I Q U 9 V L Z N

- T (value 20) is shifted forward by Y (value 25). 20 + 25 = 45. This is past 36, and after reaching 36 we start from 1 again. 45 – 36 = 9. The character with value 9 is I. T becomes I.
- Next, H (value 8) is shifted forward by P (value 16) to become X (value 24 = 8 + 16).
- E is shifted by W to become 2; Y is shifted by C to become 2, etc.

We end up with the cipher text "IX2 26X6 ST AQM3". Note that we didn't use the last few letters of the encryption key, since our message was shorter than the key.

To decrypt the cipher text, just shift each encoded letter back according to the OTP instead of forward. In our example, I (value 9) is shifted back by Y (value 25) to give T (9 – 5 = -16, and T (value 20) is 16 characters back from 0 (value 36)), and so on.

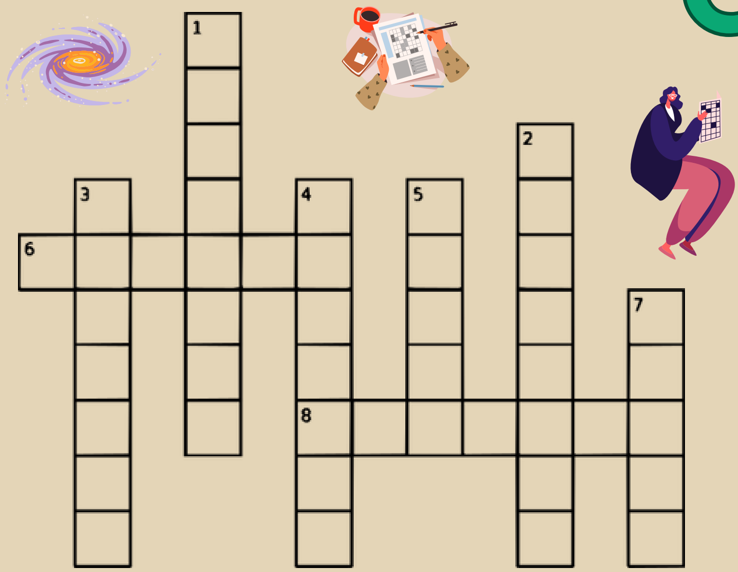
Shift Lookup Table (modified A1Z26)

Character	Shift
A	1
B	2
C	3
D	4
E	5
F	6
G	7
H	8
I	9
J	10
K	11
L	12
M	13
N	14
O	15
P	16
Q	17
R	18
S	19
T	20
U	21
V	22
W	23
X	24
Y	25
Z	26
1	27
2	28
3	29
4	30
5	31
6	32
7	33
8	34
9	35
0	36

In this case, the one-time pad uses letters from the crossword, read row by row and top to bottom. Good luck!

CROSSWORD!

by Grace Tomasi



Down:
1. A negatively charged particle in an atom
2. The product of mass and velocity
3. Common unit of force
4. Force that pulls objects towards the Earth
5. An electronic component that only allows current to flow in one direction
7. A fundamental particle that makes up protons and neutrons

Across:
6. A quantity with direction and magnitude
8. The tendency of a body to preserve its state of rest unless acted on by an external force

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