THE QUARK

Brought to you by The Society of Physics Students

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About The Quark

The Quark is a monthly newsletter provided by the Public Relations Committee of the Society of Physics Students (SPS). Our goal is to help new students become more familiar with the Physics Department and give returning students more insight on aspects of the department they might not have been aware about.

If you have any questions about The Quark or SPS, you can email our Public Relations Officer (shanmuga.shivakumar@ttu.edu)

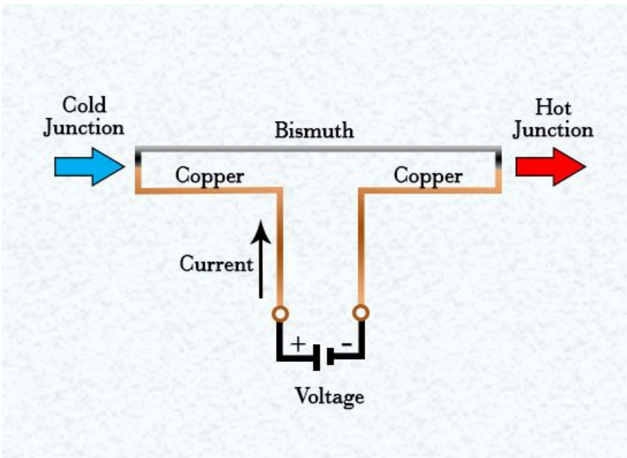
Thermo-Oscillators

By Ian Garcia

Imagine waking up to a frigid day in the middle of winter. You get up to make your morning coffee but get so sidetracked with the latest must-binge Netflix show that you forget all about your poor cup of Joe. Now, it is so cold that you're surprised you did not see Jack Frost leap in through the window and personally curse your drink. What if there was a way to keep the mug warm indefinitely, or even reverse the cooling, without increasing your energy bill? The physicists at the University of Zürich have discovered a method to continue to cool things down, or heat things up, at or above room temperature using no outside source of energy. According to the Second Law of Thermodynamics all systems must have a net increase in entropy, or in other words, heat from a hot object must disperse into the cooler objects surrounding it until all objects in a system reach the same average temperature. Fortunately, experimenters have an ace up their sleeve. To achieve the effect of continuous cooling of an object, despite it already being cold, the Peltier Effect and the Seeback Effect must be utilized.

The Peltier Effect is when you use two separate conductors in the same circuit. Due to the change in the electron's velocity as it crosses at the junctions where separate conductors meet, one junction will be cold and the other warm. The Seeback effect is when a tiny amount of voltage is generated by using two semiconductors with different temperatures.

Scientists use these effects in combination with each other in a Peltier device, which is most commonly used to cool things such as minibars in hotel rooms. They hook this up to an electric inductor which stores an electric current in the form of a magnetic field. This setup is similar to an LC circuit, where the electric charge will start off with the dissipation of the magnetic field in the inductor (L), with an electric flow to the now charging capacitor (C), and essentially bounces back and forth to create an oscillating circuit.



The Peltier Effect [6]

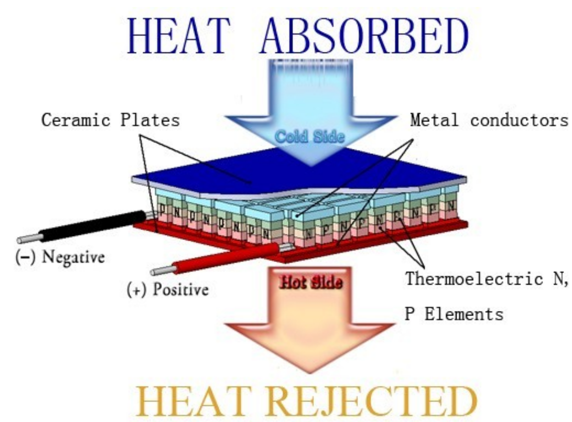


Diagram of a Peltier Device [7]

With the inductor and Peltier device connected, a "thermo-oscillator" is now formed. Heat will start in a desired object, or in the researcher's case, a cubic centimeter of copper heated to 100°C. A thermal bank at room temperature will be attached to the other end of the thermo-oscillator, which then collects heat to cool the copper block until it reaches 2°C colder than room temperature in the experiment. Although this does not seem that cold, theoretically an ideal Peltier element could reach temperatures of -47°C, which is cold enough for most commercial use. With further research and testing, a product could be created to heat and cool many things like that cup of coffee you never drank.

Professor Spotlight: Dr. Luis Grave De Peralta

By Shanmuga Shivakumar

Dr. Luis Grave De Peralta is someone who genuinely enjoys what he does. Ever since he was young, he has always been fascinated by the nature of our world, and in particular the nature of light. He always had a knack for physics and math, doing really well in those subjects while he was in school. He studied Physics at Oriente University where he received his bachelor's degree, was one of the leaders of a student organization, and trained high school students for national physics competitions. He also briefly studied at the National Academy of Science in Cuba. Due to the level of work he did in Cuba being the equivalent of a master's degree here in the US, Dr. Peralta went straight for a PhD when he was studying here at Texas Tech.

Dr. Peralta has had a very eventful life. He grew up in Cuba during the times of the Cuban Revolution and the rise of the Castro Brothers so a lot of his early experiences were heavily chained to the political climate at the time. When he was studying in the National Academy of Science, he wrote a manuscript and denounced the communist party in Cuba which got him kicked out of the Academy and sentenced to 13 years in prison. However, after 4 years, he was exiled to the US when Clinton was seeking to improve relations with Cuba. When he came to the US, Dr. Peralta washed tables in North Carolina before being invited to be a visiting professor at Texas Tech by Dr. Henryk Temkin, the Horn Professor of Electrical Engineering at the time.

After being invited to Tech, Dr. Peralta pursued a PhD in Electrical Engineering where he did material sciences research, in particular research on x-ray reflectivity, at the Nanotech Center. After getting his PhD, Dr. Peralta found a job in a start-up company that provided integrated optics circuits. He managed to get this job pretty easily because the company was owned by one of his advisors at Tech. He eventually came back to the Nanotech Center as a Postdoc and then quickly became an assistant professor in the Physics Department after about 3 years.

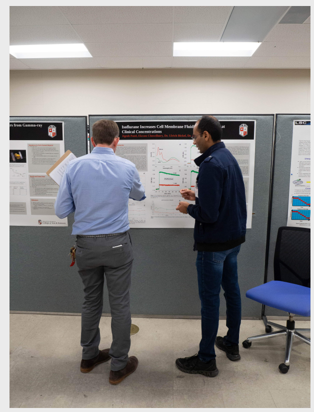
As far as research goes, Dr. Peralta has been involved with many projects, but consistently maintains interest in atomic physics and condensed matter physics. During his undergraduate years, he spent time calculating the energies of atoms and when he was in Italy for 3 months, he continued conducting research in atomic physics. Currently he is doing condensed matter research, specifically finding metals that increase the resolution of optical microscopes. While this is his official research, Dr. Peralta seeks to answer one overarching question: What is the nature of light? A lot of the research he conducts now is to help him get one step closer to this very simply put question.

Despite being a professor, Dr. Peralta actually doesn't find classes to be as helpful. He says that students "learn more

Poster Competition

Last Friday, the Physics & Astronomy Department held their 3rd annual Poster Competition where judges, comprised of several professors and other professionals in the physics field, judge research done by physics students.

A big thank you to everyone who participated in the competition and those who helped set it up!



in the lab rather than in class." This is why he enjoys letting students set up experiments on their own so that they can critically think about and understand how the experiment functions as a whole. He takes a fairly hands off approach but is always available if students have questions, which he thoroughly enjoys answering.

Dr. Peralta describes himself as a very lucky man. He worked hard to get where he is at now, but he is also very grateful for the various opportunities that allowed him the chance to do what he loves. Dr. Peralta's biggest advice to students is "Don't always trust what the professor says." He says that "using your brain" and "working hard" will be more beneficial than blindly listening to what is said during lecture.

Information: Classical or Quantum?

By: Sadman Ahmed Shanto

The twenty first century has often been hailed as the "Age of Information"; such degree is justified as computers have indeed changed the human way of life in this era. With data and information being such an integral part of our lives, it is really important that we all know what they truly mean. In this article, I aim to explain the two types of information: classical and quantum - and present a brief introduction into the field of Quantum Information and Quantum Computation. This article will be the first in a series of 4 articles for "The Quark" newsletter written with the intent of introducing Quantum Computing to undergrad physics majors in a "not so math heavy" and intuitive way.

While I believe most of our understanding of the meaning of "information" may be fairly accurate, I think it is safe to say that Rolf Landauer, German-American physicist, said it best when he said, " Information is physical". Landauer's insight into the meaning of information tells us a lot about our natural world; In three simple words, he has portrayed the universe, as we know it, as a computer, where each observable is what we call information.

Under such a premise, it is only obvious that the most common definition of information, i.e. computer memory/storage, is nothing but the physical state of some transistor. Information is indeed physical. Now, it is only natural to ask - Is information classical or can it be quantum?

The answer to this question is both. However, so far in this age of information we have mostly been dealing with information that is classical in nature. Classical information is binary- 0 or 1, true or false, yes or no - hence transistors, which can be in two distinct states, are an ideal physical realization of classical information. Using 800 of such transistors and a handful of logic gates and a current source, the first "transistorized" computer was built in January of 1952.

Learn more about the history of computers. [8]

We have made quantum leaps in terms of speed and power of computers ever since the birth of the first "transistorized" computer. However, it is to be noted that in terms of core technology not much has changed. Modern computers still run using such transistors but use more of them (billions of them in fact!), and the types of logic gates used are more or less the same. This leads one to ask, "How are the modern computers so much more powerful then?": the answer- efficiency. Computers, nowadays, are much more spatially and functionally efficient thanks to innovations in electrical engineering and material sciences, but most of the credit of such increase in power is attributed to the shrinking size and growing numbers of transistors. This phenomenon is so prominent that Gordon Moore, the co-founder of Fairchild Semiconductor, conjectured the claim that the number of transistors in a dense integrated circuit doubles about every two years. This observation about the exponential growth of computing power that Moore back in the 1970s has proved to be prophetic. Starting around 2010, however, Moore's Law began to break down and many today are asking if this "Age of Information" is coming to an end with silicon chips approaching the size of a silicon atom.

Learn more about Moore's Law. [9]

This is where the "Age of Quantum Information" will begin. Quantum computation and quantum information is the study of the information processing tasks that can be accomplished using quantum mechanical systems. So what exactly is quantum mechanics again? Quantum Mechanics is the study of the small and probabilistic building blocks of the universe. It is a mathematical framework that physicists use for the construction of physical theories to model reality. This may be very redundant for those of us who have taken one or two quantum classes, but what seems very unintuitive is how can such a physical theory be used for computation. The key insight to solving this problem comes from history. In the past, we created classical computers by thinking physically about computation and now to create quantum computers, we should think computationally about physics.

We all know 'bit' as being the fundamental concept of classical computation. The world of quantum information has been built on an analogous concept called the quantum bit (qubit). Similar to how a classical bit has a state - 0 or 1, a qubit also has a state. It in fact has two states $|0\rangle$ and $|1\rangle$ which correspond to their classical counterparts respectively, moreover, it also has a state which is a superposition of these two states.

$$|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle.$$

If you have taken a course in quantum mechanics, you can tell that this equation looks eerily similar to that of the expression of a time dependent Schrödinger equation as a linear combination of its stationary states.

$$\Psi(x,t) = \sum_{n=1}^{\infty} c_n \psi_n(x) e^{-iE_n t/\hbar}.$$

This is no coincidence, as it is such behavior of quantum systems that enable it to carry out information processing. In the equation for the qubit system, the square of the coefficient for the states represent the probability of finding the qubit in that certain state. For example, if = 0.5 and =0.75 , this would tell us that the probability of finding the qubit in state 0 would be 0.52 = 0.25 and that of state 1 will be 0.75. [Note how the normalization condition still apply]. With that being said, however, whenever we measure the state of a qubit it will only exist in a state of 0 or 1, and will continue to be in that state for consecutive repeated measurements made shortly afterwards.

This lack of this direct correspondence and inclusion of probabilities does make it difficult to intuit the behavior of quantum systems; however, there is an indirect correspondence, for qubit states can be manipulated and transformed in ways which lead to measurement outcomes which depend distinctly on the different properties of the state. The ability of a qubit to be in a superposition state runs counter to our 'common sense' understanding of the physical world around us. A classical bit is like a coin: either heads or tails up. By contrast, a qubit can exist in a continuum of states between landing on its "head" and "tail" side– until it is observed. Such phenomenon may sound strange, but in practice, qubits are very real, their existence and behavior extensively validated by experiments.

A fun problem that I would like to pose to you guys is to theorize a physical system that can be used to realize qubits. It's a problem that I think a lot about in my free time and it is also a burning research question. Do send me an email with an idea that you may have. In the next article, I will talk more about information processing a.k.a manipulating qubits using the quantum analog of logic gates very creatively called "quantum gates" and we will also discuss some applications of such information processing in the field of cryptography.

Student Spotlight: Samuel Cano

By Shanmuga Shivakumar

Samuel Cano has always been someone with diverse interests. He's always had a fascination with politics and socioeconomic issues while also being interested in math as well as its applications. As a Computer Science major and Political Science minor, Sam wants to combine his STEM knowledge with his interest in politics in order to help solve the problems we face today.

During his time at Texas Tech, Sam has been involved in a few student organizations. He was an active member in the Society of Physics Students (SPS), becoming the Webmaster in Fall 2017 and the Vice-President in Spring 2018. During his time as VP, he motivated students to apply for REU's (Research Experiences for Undergraduates), offering help to fellow students who were interested in applying and giving advice on how to apply. Currently, he works with the Student Activities Board (SAB) where he is a part of the Off-Campus Committee. He helps plan off campus events such as Altitude Park and the Corn Maize. Sam also helped form a Yang Gang here at Tech as a way to bring recognition to Andrew Yang, one of the democratic presidential nominees.

Sam has also been involved in a number of research projects with a few professors here in the physics department. He first got involved with Dr. Kunori by talking to him about high energy physics problems during his office hours. Dr. Kunori eventually asked if Sam wanted to go with him to Fermilab for an REU, which Sam happily accepted. While at Fermilab, he worked with Monte Carlo simulations to find the most optimal geometry for one of their detectors. After working in Fermilab, Sam continued his research with Dr. Kunori hear at tech, where he helped with designing a muon detector. Sam was in charge of testing the electronics of the detector as well as figuring out exactly what kind of data they were collecting and how they were going to collect it. Sam said that there was "a lot of trial and error" that went into this project. He presented this research during the 2018 Poster Competition, held annually in the Physics Department, where he received 3rd place. He also presented his research during last year's APS conference at the University of Houston where he represented our SPS chapter as well as Texas Tech. Currently, Sam is doing research under Dr. Whitbeck which is helping upgrade one of the detectors at Fermilab. He is working with machine learning algorithms by helping program a machine that assembles different parts of the detector and replaces the wafers depending on the type of data that is being collected.

Some of Sam's hobbies include playing League of Legends and practicing jiu-jitsu. Sam also enjoys getting involved in fantasy football, where he sometimes uses his knowledge of simulations to analyze the statistics of players so he can form the best team.

During the summer, Sam is going on an internship to Washington D.C. where he plans to get his foot in the door by networking with other professionals. He hopes to one day use his background in computer science and statistics to aid in solving issues that are talked about in today's political climate. Sam's biggest advice to students is to "talk to your professors outside of class." He says talking to your professors is a great way to learn more about your major and the options your major provides because it gives students a way to ask questions about topics outside of what's taught in class. It also helps with networking by building a relationship with a professional in your field.

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