DEPARTMENT OF PHYSICS

Physics Pulse

IIT (ISM) DHANBAD

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Well, electrons can attract each other!

By DARPA NARAYAN BASU (3RD SEM MSC)

On 23rd October 2024 Leon Cooper, a pioneer in superconductivity, died at the age of 94. The following writing is dedicated in the memory of Cooper.

The story of superconductivity started in 1911 at University of Leiden where H. K. Onnes observed that the resistance of mercury drops abruptly by 20 thousand times near 3.6 K. He has also shown that current flows seamlessly due to zero resistance in that temperature range. This mystery was like perpetual motion—totally startling for physicists. After that several physicists tried to unravel the mystery.

In 1933, Meissner discovered that along with zero resistance superconductor is perfectly diamagnetic; it excludes the magnetic field lines completely from it. In 1935, London brothers explained the expulsion of magnetic fields using Maxwell's equations but the mystery of zero resistance remained unsolved.

The isotope effect was discovered in 1950, which confirmed that lattice vibrations play an important role in superconductivity. Subsequent experiments revealed an energy gap, meaning electrons at the Fermi level require extra energy for transition—a surprising result. Here comes one of the heroes of our story: J. Bardeen. Around 1950, he derived an equation like that of London considering the energy gap. But the reason of the gap was still unknown.

At that time L. Cooper just completed his PhD in QFT and Bardeen thought he might be the best person to solve the mystery of the energy gap. He was indeed right!

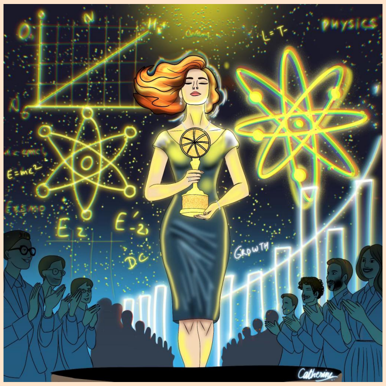
Cooper assumed a highly simplified picture that in a sea of non-interacting electrons (Fermi sea) two electrons are thrown and an attractive potential is switched on between them. But wait! How two electrons can attract each other? It turns out that at low temperature when an electron passes through lattice it leaves deformation trail affecting positive ions to come closer. Due to the increase in positive charge density another electron gets attracted. So one electron attracts another—COOPER PAIR. Assuming this Cooper successfully explained the formation of energy gap.

But generalization to many electrons was yet to be done. Here comes B. Schrieffer who was working with J. Bardeen. He guessed the solution in a correct way at absolute zero and then they were able to generalize the formulation successfully. Their theory properly explained zero resistance and their results matched with the experiments with great accuracy. In 1972, this trio was awarded Nobel prize for the groundbreaking theory in physics.

Announcement

Dr. Alexander Mook, Emmy-Noether fellow at Johannes Gutenberg University Mainz, Germany, will be visiting the Department of Physics during 20 Jan to 08 Feb 2025. He will be delivering a pedagogical lecture series on Topological Magnetism during 22 - 24 Jan 2025, at the Raman Hall. His visit is sponsored by IGSTC, DST and he will be collaborating with Prof. Ritwik Mondal at IIT (ISM) Dhanbad.

Women in Science



by Catherine

Lorentz and Lorenz: A simple misspelling will take you from Electromagnetism to Optics

By HIMANSHU (3RD SEM MSC)

A nightmare of a person like me who misspells a lot are the theories from these two distinct gentlemen. Today, let us see how these physicists from neighboring countries are related academically. Hendrik Antoon Lorentz a Dutch physicist is famous for Lorentz transformation that relates two relatively moving inertial frame. This can be simply considered as the groundwork for understanding Einstein's special theory of relativity.

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Anyone who has taken the introductory class to relativity knows that Lorentz to Einstein is what Galileo was to Newton. You must have heard his name in the class of electromagnetism as well. Lorentz force, the force that governs the motion of charged particles in electric and magnetic fields. The force behind cyclotrons and synchrotrons that allows particle accelerators to use magnetic forces to bend the paths of charged particles and do the subatomic work.

Now moving to the other guy, Ludwig Valentin Lorenz a Danish physicist is known for the Lorenz gauge which is a condition applied in electromagnetism to simplify Maxwell's equations when working with potentials. Remember those four equations (refined, actually more than four) relating electric field (E), magnetic field (B), current density (J), and charge density (ρ). It turns out that you don't have to remember those as they come out beautifully mathematically using the Lorenz gauge.

We also know him for the Lorenz-Mie theory, which is a mathematical framework used to describe the scattering of electromagnetic waves by spherical particles. It explains how light interacts with spherical particles, regardless of their size relative to the wavelength of light. After knowing all this, we realize both these physicists are standing on the shoulders of a giant, James Clerk Maxwell.

There is something else connecting them both, the Lorentz-Lorenz equation. It is a formula in optics that relates the refractive index (n) of a material to its polarizability (α) of the molecules that make up the material. Both Ludwig Lorenz and Hendrik Lorentz independently contributed to its development, which is why it's often referred to as the Lorentz-Lorenz equation. The equation sets a relation between refractive index, and polarizability.

I wonder if they had a fun discussion about getting the praise letter for work done by the other.

Since praising letter was a thing in the past and I hopefully believe it is still the case on the high table of physicists.

So next time you study any work by any one of these two gentlemen, remember there also exists another famous scientist with just an addition or subtraction of one letter in their last name.

National visits

Prof. Binata Panda visited Institute of Physics, Bhubaneswar, Odisha

Prof. Binata Panda visited Institute of Physics, Bhubaneswar, Odisha to present an invited talk in "IoP Golden Jubilee Young Women Scientists' Meet-2024" during 13-14th November 2024. The conference covered different branches of physics. The main objective of this conference was to bring together leading young women scientists across India working in these fields. Prof. Panda presented a talk on 'Gauge Covariance of Entropy Current in Higher Derivative Theories of Gravity.'

Prof. Umakanta Tripathy visited INST Mohali, Punjab to deliver an invited talk at the International Conference on Smart Materials for Sustainable Technology (SMST-2024).

Prof. Umakanta Tripathy visited IIT Bombay to deliver an invited talk at the International Conference on Optics within Life Sciences (OWLS-17).

Souradeep Bhattacharya visited Prof. A.V. Mahajan's lab at IIT Bombay for two months to perform temperature-dependent NMR measurements on some iridium-based spin-orbit coupled Mott insulators.

Subhasis Sarangi visited School of Minerals, Metallurgical and Materials Engineering, IIT Bhubaneswar to perform experiments on piezoelectric flexible films for energy harvesting applications.

Debodyuti Kar & Shinjini Pal visited Variable Energy Cyclotron Centre, Kolkata to test and characterize CLYC (Cs2LiYCl6:Ce) detector. The specialty of this detector is that it can detect neutrons and gamma rays simultaneously. The detector has been procured from Scionix, the Netherlands. It will be useful to study fission processes and most importantly for nuclear astrophysics related experiments.

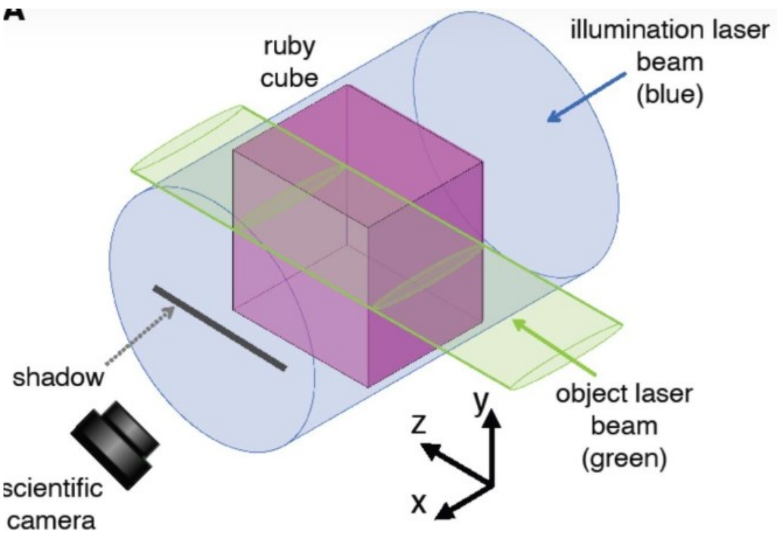
Prof. Sudipto Singha Roy visited IIT Bombay to attend a conference on "Quantum Information and Quantum Dynamics" during 28-29 October, 2024.

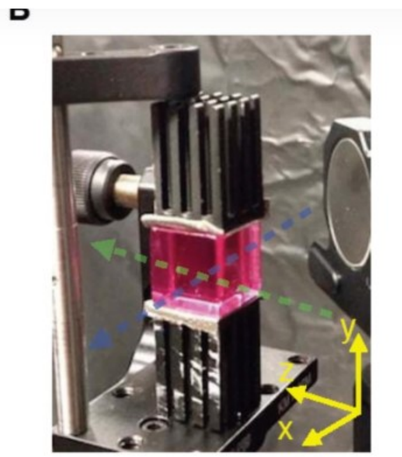
Prof. Ritwik Mondal delivered an invited talk on "Experimental realization of field-derivative torque in nonlinear magnetization dynamics" at the 'Indo-German Kick-off Workshop on Recent Progress in Topological Magnetism' organized by NISER Bhubaneswar, during 6-8 Nov 2024.

Physics News

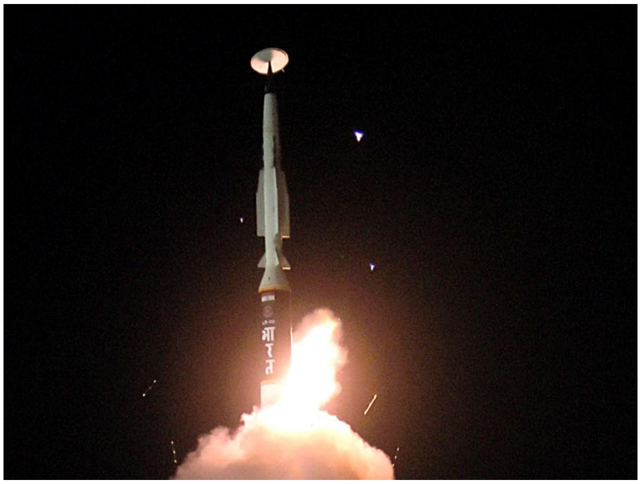
When Light Becomes Opaque

Researchers at Brookhaven National Laboratory demonstrated a surprising optical effect. Under specific conditions, a laser beam can act as if it were an opaque object, blocking light and creating a shadow! They directed a green laser through a ruby crystal and used a blue laser to illuminate the setup. The green laser altered how the ruby absorbed the blue light, reducing its ability to transmit the blue wavelength through the material. This created a dark area (a shadow) where the green laser blocked the blue light. In this way, the green laser acted like a solid object! This phenomenon occurs due to non-linear optical processes, where light interacts with a material in an intensity-dependent way, allowing one light field to influence another and create a visible shadow.





DRDO conducts historic flight trial of long-range hypersonic missile



The Defence Research and Development Organisation (DRDO) successfully conducted a flight trial of a long-range hypersonic missile on November 16, 2024. Developed indigenously by the Dr APJ Abdul Kalam Missile Complex in Hyderabad, along with various DRDO laboratories and industry partners, the missile is capable of carrying multiple payloads over a range of more than 1,500 kilometers.

The trial, attended by senior DRDO scientists and armed forces officials, marks a significant step in India's defence capabilities. Defence Minister Rajnath Singh called the achievement a "historic moment," highlighting India's growing prowess in hypersonic technology and its commitment to self-reliance in military advancements.

Interstellar: Ten Years of Inspiring Physics and Cultural Wonder

By ADITYA AKHOURI, 7 TH B.TECH. ENGG. PHYSICS

The 27th of October marks the 10th anniversary of Interstellar, and it's striking how deeply this film has etched itself into both popular culture and the world of physics. Directed by Christopher Nolan, Interstellar is more than a cinematic experience—it's a narrative that intertwines the awe-inspiring scale of the universe with the intimate struggles of humanity, all while grounded in complex scientific principles. For many, especially physics students and aspiring scientists, Interstellar is the spark that ignited a passion for discovery, leading them down paths they may never have considered. In blending science with art, the film has shown that the mysteries of the universe are not only thrilling but are within reach, accessible to anyone with curiosity and dedication.

The reason Interstellar stands out from other science-fiction films is due in large part to its collaboration with theoretical physicist Kip Thorne. Known for his groundbreaking work in gravitational physics, Thorne joined the project with a commitment to ensuring scientific accuracy, making it a rare partnership between cinema and academia. Thorne's influence is evident throughout the film, from its depiction of wormholes to its representation of time dilation, making Interstellar not just visually captivating but scientifically compelling. For physics students, Thorne's involvement meant that the universe onscreen was not a fantastical reimagining but rather a rigorous portrayal of the cosmos based on principles they could explore themselves.

One of the film's most memorable moments is its portrayal of Gargantua, a massive black hole around which much of the plot revolves. With its dazzlingly intricate depiction of gravitational lensing—light bending around the black hole due to intense gravity—Interstellar presented an image of what such a phenomenon might truly look like. This wasn't just Hollywood magic; it was a scientifically accurate visualization created by Nolan's visual effects team in consultation with Thorne. Gargantua wasn't merely a plot device; it was a revelation, illustrating how black holes, one of the universe's most mysterious objects, might appear if seen up close. For me like many physics students, Gargantua's portrayal was transformative. Concepts like black holes and time dilation, which they had only encountered in equations and diagrams, suddenly felt tangible.

I remember being 12 years old when I first watched the movie, and it is to date my all-time go-to movie for entertainment and excitement. Today, as a final year Engineering Physics B.Tech student, when I look back at my journey somewhere, I do feel the curiosity and the urge to work out solutions and possibilities were instilled into me by experiences such as Interstellar.

Its been found that the movie's influence didn't stop at theoretical understanding; it inspired countless students to reconsider their career paths. In the years since its release, Interstellar has been cited by numerous young scientists as the reason they pursued studies in gravitational waves, black holes, and astrophysics.

Some, after watching the film, began researching how gravitational waves carry information about cosmic events millions of light-years away. The realization that such phenomena were not only real but also within reach of human understanding motivated them to contribute to a field where these concepts are actively studied and explored. In addition to its scientific allure, Interstellar has also fostered a new generation of science communicators. By making complex scientific ideas accessible to a global audience, the film has shown the power of storytelling in spreading knowledge. Many students, inspired by how effectively Interstellar conveyed intricate theories, have pursued science communication alongside their studies. They hope to demystify physics for others, just as the film did for them. For one student, Interstellar served as a call to action, urging them to find ways to make difficult concepts relatable to those outside the field. Inspired by the film, they aim to make scientific knowledge as engaging and inspiring as Nolan's vision of the cosmos.

Yet, the impact of Interstellar extends beyond scientific curiosity. Its themes of exploration, resilience, and survival resonate with the broader questions facing humanity. The film contemplates humanity's place in the universe and our responsibility toward future generations, particularly in light of environmental challenges and the need for sustainable living. For some students, the film's portrayal of these existential themes has reinforced their commitment to pursuing work that might one day help humanity thrive beyond Earth. The idea that "humanity is meant to survive" in one way or another gives people purpose amidst the feeling of insignificance of the vast cosmos.

Faculty Interaction

Prof. Takahiro Maruyama, Director of the Nanomaterial Centre and Chairperson of Applied Chemistry at Meijo University, Japan, and Prof. Kaushik Ghosh from the Institute of Nano Science and Technology, Mohali, India, engaged in an interactive session with our faculty colleagues during their visit on 21 November 2024.

During this session, the possibility of a closer scientific and academic partnership between IIT (ISM) Dhanbad, Meijo University, Japan and Institute of Nano Science and Technology, Mohali was discussed.

Reflecting on a decade of Interstellar, it's clear that the film's legacy lies in more than its cinematic achievements. By blurring the line between science and art, it has introduced audiences worldwide to the thrill of astrophysics and the mysteries of the universe. For countless physics students, Interstellar is a reminder that their field is not merely a collection of theories but a gateway to understanding the unknown. It has encouraged them to embrace the endless boundaries of the universe, to push the boundaries of their knowledge, and, perhaps most importantly, to share that wonder with others.

To end, I would like to share some quotes from students of IIT (ISM) Dhanbad, other students and active physicists and researchers on their feelings about the movie:-

"Watching Interstellar felt like unlocking a door to an entirely new world. The scene where they enter the wormhole was such a powerful visual representation of what I was learning in my classes. It made me want to explore these ideas professionally, and I ended up choosing a focus in theoretical astrophysics because of that." — Jessica Liao, Astrophysics Major at MIT.

"The visual representation of the black hole in Interstellar was groundbreaking. It's not often that a movie can contribute something of scientific value, but the way they depicted Gargantua gave even physicists something to marvel at. This kind of depiction not only inspires future scientists but also gives current researchers a visual language to explain complex ideas." — Dr. Brian Cox, Physicist and Professor at the University of Manchester.

Physics Cartoon

by Tanisha

"What Interstellar did for physics communication is phenomenal. It brought ideas like relativity and black holes to the mainstream in a way that was both accurate and emotionally resonant. It inspired me to work on explaining science in simple terms and to show people that science can be both challenging and beautiful." — Emily Tran, Physics Student and Science Communicator.

"The scenes on the water planet, where an hour there equals seven years back on Earth, were just mind-blowing. It was my first encounter with the concept of time dilation in a way I could grasp visually. After that, I wanted to know everything about relativity, and I can honestly say that scene alone fuelled my passion for cosmology." — Laura Chen, Cosmology Undergrad at Stanford.

"One thing Interstellar did beautifully was to show that science and philosophy are closely intertwined. The film tackles questions that physicists think about all the time—What is time? What happens at the edge of a black hole? But it goes further to explore why we even ask these questions. It reminds us that curiosity about the cosmos is part of what makes us human." — Dr. Sean Carroll, Theoretical Physicist and Cosmologist.

"The visual representation of Gargantua was revolutionary. I remember sitting in the theater, completely captivated. At the time, I was uncertain about what area of physics I wanted to pursue, but after seeing Interstellar, I knew I wanted to study black holes. It was the kind of inspiration you don't expect from a movie, but it changed everything for me." — Dr. Ravi Singh, Postdoctoral Researcher in Gravitational Physics.

"The movie introduced fancy terms like tesseract, time dilation, and the bootstrap paradox, which sparked my interest in physics and inspired me to dive deeper into these fascinating concepts."— Neelimesh Duarah, 4th year Engineering Physics student at IIT (ISM) Dhanbad.

"The film mind-bendingly explores time dilation and the vastness of the cosmos, sparking curiosity in me. It opened my eyes to the intricate workings of the universe and inspired me to delve deeper into the realms of theoretical physics and astrophysics."—Kartik Singh, 4th year Engineering Physics student at IIT (ISM) Dhanbad.

Physics in History

- 2 December 1942, Enrico Fermi and team achieve first controlled nuclear chain reaction (Chicago Pile-1) which played a major role in the Manhattan Project, looking all around these days one may wonder if its still a controlled reaction.
- On 18 December 1926, Gilbert Lewis coined the word "Photon" in his letter to The Nature (journal). In other words, 18 Dec 1926 was the day Photon really interacted with mankind. Before that, it was hitting us as a "Light quanta" or "Energy element". Looks like Gilbert Lewis got the news of laying down the foundation stone of ISM on 9 Dec 1926 and he knew that the institute in the city of black diamond will shower photons like a diamond. That's right folks, it's the birthday month of our campus (99 and not out) looking ahead to the golden century.
- In December 1934, Soviet physicist Pavel Cherenkov discovered Cherenkov radiation. It is electromagnetic radiation emitted when a charged particle (such as an electron) passes through a dielectric medium (distilled water) at a speed greater than the phase velocity.

"Interstellar was the most perfect film I've ever seen, and one of its greatest mysteries was the fate of Earth's population. Early on, we see severe food scarcity and a reduced population, which are mysterious in both scientific and political ways. It raises many questions—what actions might governments have taken that left only a fraction of humanity surviving? What happened to everyone else as the planet deteriorated? The film hints at these things, leaving the rest to our imagination." — Gaurav Kumar, 4th year Engineering Physics student at IIT (ISM) Dhanbad. "

Physics Openings

1. **Assistant Professor Position in Quantum Information or Quantum Foundations** : The University of Calgary invites applications for a tenure-track position as Assistant Professor in the Department of Physics and Astronomy, specializing in Quantum Information or Quantum Foundations.
2. **Open Positions in 2D Materials Research – 2D-MATURE Project**: The 2D-MATURE Project is a

collaborative research network funded by the European Union's Horizon 2020 program.

Research Publications

1. Arpita Dutta, Pratyay Mukherjee, Swosti P Sarangi, Somasree Bhattacharjee, Shovon Pal, and Ritwik Mondal, Role of material-dependent properties in THz field-derivative-torque-induced nonlinear magnetization dynamics, Physical Review Materials
2. Subhadip Ghosh, Mikhail Cherkasskii, Igor Barsukov, and Ritwik Mondal, Theory of tensorial magnetic inertia in terahertz spin dynamics, Physical Review B
3. J. S. Hansdah, P. M. Sarun, and K. Asokan, Effect of carbon ion implantation on the superconducting properties of MgB_2 bulks prepared by powder-in-sealed-tube method, Cryogenics

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