

FIZIKA

6th Volume

E-Magazine of the Department of Physics

Victoria Institution (College)

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Editorial

"Life is strong and fragile. It's a paradox... It's both things, like quantum physics: It's a particle and a wave at the same time." — Joan Jett

From the space cosmology to our daily life we are totally dependent on the physics and technologies. Our life is nothing without every step closure to physics everyday . Physics was never in just between mathematical equations it was always logical and "Fizika" is the proof of it.

On continuing the journey of "Fizika", the E-magazine of Department of Physics , Victoria Institution (College) from 2021 , this is the 6th volume of our glory. We give the cordial thanks and gratitude to all the writers who have given their precious time for continuing the magazine like every past 5 years.

This year we again brought some really interesting topics like :- The cosmic choreography, Orphans of the cosmos , The science of music and sound, Physics of Artificial Intelligence , The physics behind rainbows , Quark and cosmos , Physics behind GPS technology, Physics beyond equations and breaking the code of nature by holding the hands of physics.

We extend our profound gratitude to our respected Principal Mam for her generous support . We also extend our heartfelt thanks and gratitude to our esteemed professors for their support and encouragement for the continuation of "Fizika" with so much enthusiasm.

Last but not the least we extend our greetings to the reader's for staying with us . We wish you could get enriched so much knowledge with physics fun by turning the pages.

Travel across space, time, and theory. Your ticket is on these very pages."
Happy journey!!

Sincerely,
Debanjali Prasad
(2nd Sem)

Our Team



**From left: Farriyah ,
Shweta and Barnali
6th Sem**



**From left: Zarnaz, Karina, Ariba
Khanam, Ariba Shamim, and Talat
4th Sem**



**From left: Jyotishka, Maghfera and
Debanjali
2nd Sem**

Message from the Principal



Dr. Maitreyi Ray Kanjilal
Principal
Victoria Institution (College)

It gives me immense pleasure to see the 6th volume of the annual E-Magazine, brought to life by the students of our Physics Department. Over the years, this publication has come to reflect the deep curiosity, creativity, and academic dedication of our students, consistently spotlighting crucial advancements in Physics and its allied disciplines. Such student-led initiatives are vital in fostering a robust scientific temper and inspiring young minds to venture into research and modern innovation. I congratulate the entire editorial and design team for their sustained commitment and hard work. May FIZIKA continue to inspire, inform, and ignite the scientific spirit across our campus for many more editions to come. I wish this milestone volume every success.

Message from the Department

It is a matter of immense pride and pleasure to congratulate the students of the Department of Physics, Victoria Institution (College) on the successful publication of the 6th volume of the departmental e-magazine named “FIZIKA”. This dynamic edition showcases and reflects the extraordinary range of intellectual exploration, curiosity, creativity and scientific spirit of our students through a diverse collection of articles spanning the vastness of the cosmos down to the fundamental building blocks of nature.

The contributing authors have ventured across diverse fields of inquiry-delving into atmospheric geometrical optics through the physics of rainbows, acoustic principles in music and the cosmic mysteries of quarks and wandering rogue worlds. This compilation beautifully highlights the interdisciplinarity of modern physics, illustrating its vital role in engineering the future of agriculture, powering artificial intelligence and operating everyday GPS technology, demonstrating how physics connects with nature, technology and everyday life.

We highly commend our students for their rigorous analytical mindset and creative presentation of concepts beyond simple equations. The dedication of the contributors and the editorial team has successfully created a platform that elevates scientific dialogue. We trust this volume will stimulate deep curiosity, encourage independent critical thinking and inspire our readers to continuously explore the fascinating phenomena that define our universe. We wish “FIZIKA” continued success and hope it serves as a catalyst for learning, innovation and scientific exploration for years to come.



Smt. Swarnalekha
Bandyopadhyay



Dr. Gayatri Pal



Dr. Subhendu Chandra



Dr. Shinjinee Das Gupta
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Dr. Atri Sarkar



Dr. Kathakali Biswas

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The Cosmic Choreography: How Physics Awakens the Inanimate

Shweta Mukherjee

6th Sem

Look out the window at a flock of birds sweeping across the evening sky, they move and flow as if they are a single entity. Under a microscope, millions of bacteria swimming in a petri dish form massive, turbulent whirlpools that resembles turbulent fluid motion, yet every single droplet is an independent, living organism. A central, wondrous mystery at the intersection of science is how inanimate, non-living molecules can come together in specific harmony to give rise to the phenomenon of life. Traditional statistical mechanics, in equilibrium systems, constituents do not continuously consume energy to self-propel. However, a revolutionary subfield “Active Matter Physics” presents a physical bridge across this divide, studying systems where individual active agents consume internal or ambient energy to generate self-propulsion.

“न मृत्युरासीदमृतं न तर्हि न रात्र्या अह्नं आसीत्प्रकेतः ।
आनीदवातं स्वधया तदेकं तस्माद्भ्रान्यन्न पुरः किं चनासं ।”

----- Nasadiya Sukta, Rigveda

[TRANSLATION] ‘Then there was neither death nor immortality
nor was there then the torch of night and day.
The One breathed windlessly and self-sustaining.
There was that One then, and there was no other.’

The Myth of Moribund Matter

When we spread butter on toast or squeeze toothpaste onto a brush, we are handling the prime subjects of Soft Matter Physics. Traditional physics obsesses over the ultra-hard (crystals, metals) or the completely fluid (water, gases). Soft matter maps out the squishy, easily deformed middle ground—colloids, polymers, gels, and emulsions.

Left on our plate, a dollop of butter is passive. Its microscopic network of water suspended in crystalline lipid is entirely at the mercy of their environment. They only move if we push them with a knife, or if ambient temperature gives them a microscopic, random nudge (Brownian motion). The system is in quiet mechanical thermodynamic equilibrium.

But imagine if that butter suddenly started crawling across the toast on its own.

That absurd image is the boundary where soft matter becomes Active Matter. If you give every microscopic droplet its own internal engine fueled by chemical energy, the system is kicked permanently out of thermodynamic equilibrium.

This is the exact point where modern physics beautifully collides with ancient intuition. Thousands of years ago, the seers of the Rigveda wrestled with how a static, unmanifested cosmos first initiated action. They used the word Svadhā—an inherent, internal power; an impulse from within the one to breathe and expand.

The comparison is metaphorical: active matter physicists study systems that generate motion from internal energy sources, a concept that loosely echoes ancient philosophical ideas of intrinsic activity. When we look inside a biological cell, we find a mesh of protein ropes (the cytoskeleton) that is not sitting passively like a real skeleton. Instead, millions of “non-living” molecular motors (myosin) consume chemical fuel (ATP) to literally walk along these ropes, causing the cell to divide, contract, and crawl.

To a physicist, both can be modeled as active agents that convert energy into directed motion. In a metaphorical sense, this behavior echoes the ancient concept of Svadhā—an intrinsic impulse arising from within. Physically, however, their motion is driven by the conversion of chemical energy into mechanical work.

$$v_{\text{active}} = v_0 \hat{n}$$

A Question to Birth: If a collection of non-living protein molecules obeys the exact same laws of self-directed, collective motion as a swarm of living organisms, does "life" belong to biology, or is it just a unique phase of matter?

In The Beginning....

Active matter physics is a remarkably young discipline, emerged as a distinct field during the 1990s out of a daring conceptual leap. Until the mid-1990s, the coordinated swarming of living creatures was viewed strictly as a problem for behavioral biologists. The field gained major momentum in the 1990s following Vicsek's influential work, before which it was belived living organisms were too complex and "willful" to be modeled by rigid mathematical laws.

The paradigm shattered in 1995 when Hungarian physicist Tamás Vicsek published a groundbreaking computer model. He demonstrated that collective flocking did not require complex biological intelligence or a centralized leader. By treating organisms as simple, self-propelled points governed by a single rule-align your heading with the average direction of your immediate neighbors-mesmerizing, synchronized macroscopic order emerged spontaneously from chaos.

Intrigued by this simulation, theoretical physicists John Toner and Yuhai Tu took it a step further. They asked a radical question: If a glass of flowing water can be described by classical Navier-Stokes fluid equations, can a cohesive flock of birds be mathematically treated as a living, flowing fluid? Their resulting equations proved it could, laying down the first laws of "flocking hydrodynamics."

Shortly thereafter, a massive missing piece of the puzzle was solved by Indian physicist Sriram Ramaswamy and his group at the Indian Institute of Science (IISc). They realized that when micro-swimmers propel themselves through a liquid, their physical bodies generate complex stress fields in the surrounding fluid, dragging neighboring particles along with them. By defining the mathematics of these "active fluids," they showed that many biological systems can be understood using the tools of statistical physics.

What began in 1995 as a simple computer code to replicate birds has exploded into a global frontier of physics, proving that nature's complex biological ballets are entirely bound by the laws of non-equilibrium thermodynamics.

The Dynamics of Active Fluids

When active matter operates at the microscopic scale, it encounters a brutal hydrodynamic and fluid reality: the medium changes completely. Physicists quantify this environment using a dimensionless quantity called the Reynolds Number (Re), which dictates the ratio of inertial forces to viscous forces in a fluid:

$$Re = \frac{\rho v L}{\mu}$$

Where ρ is the fluid density, v is the particle velocity, L is its characteristic length scale, and μ is the fluid viscosity. For a microscopic active agent (like a cell or a micro-robot), $Re \ll 1$. At this scale, fluid viscosity dominates completely. Water ceases to feel like a liquid and feels as thick, heavy, and sticky as cold honey.

The physical consequences are radical. The moment a microscopic agent stops pumping its internal motors, it halts almost immediately after propulsion ceases, inertial forces effectively vanish.

Because there is no inertia, Edward Purcell's famous Scallop Theorem applies: a microscopic entity cannot swim by moving a paddle symmetrically back and forth. If a micro-scallop opens its shell slowly and closes it quickly, the two motions cancel each other out perfectly in a viscous fluid. It will simply slur forward a micrometer and slur backward a micrometer, ending up exactly where it started. To achieve self-propulsion, microscopic active matter must mathematically break time-reversal symmetry.

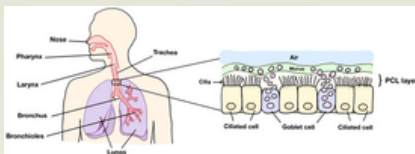
The Swarming Cosmos

How does nature actually manifest these equations? Active matter manifests across vastly different scales, coordinating millions of individual micro-engines into macro-scale harmony.

Ciliary Locomotion:

Every single second, active matter is keeping us alive. Our respiratory tract is lined with millions of cilia-tiny, microscopic hair-like structures. To clear mucus and dust out of our lungs, they must move fluid at a low Reynolds number. To bypass the Scallop Theorem, cilia break time-reversal symmetry by performing an asymmetrical beating cycle. They push hard in a rigid, sweeping "effective stroke" to move the mucus, then curl up tightly into a flexible, low-drag "recovery stroke" to snake back close to the cell surface.

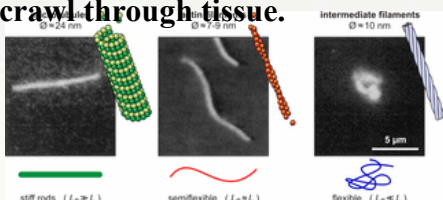
There is no central nervous system instructing these millions of hairs when to bend. The mesmerizing, synchronized wave (called a metachronal wave) can arise through hydrodynamic and mechanical coupling. When one cilium moves, it drags the sticky, honey-like fluid around it, which mechanically pulls and forces its immediate neighbor to follow a fraction of a second later.



ciliary locomotion

Intracellular Cytoskeletons (The Architecture of Your Cells):

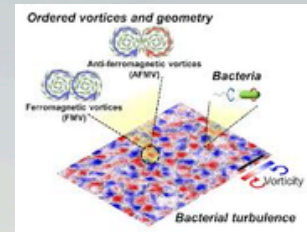
Inside our cells, the cytoskeleton is not a dead, rigid frame. It is a dense, active network of protein filaments (actin) and millions of molecular motors (myosin). These motors consume ATP fuel to literally walk along the filaments. When millions of these non-living protein motors pull simultaneously, they generate collective stress waves that allow the cell to divide, heal wounds, or crawl through tissue.



cytoskeleton

Bacterial Turbulence (The Swirling Micro-Vortices):

If we place millions of swimming bacteria (like E. coli) into a stagnant droplet of water, they do not swim randomly. Once the density passes a critical threshold, they spontaneously organize into massive, turbulent whirlpools. This "bacterial turbulence" looks exactly like a boiling, chaotic fluid, except the kinetic energy is coming entirely from the individual flagella corkscrewing through the water.



bacterial turbulence

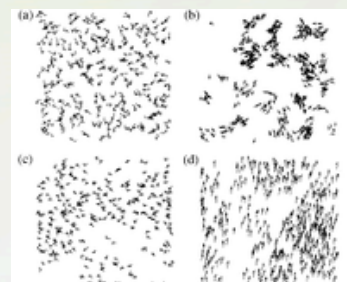
Macroscopic Phenomena: Flocking and MIPS

This coordination scales all the way up to macroscopic systems, revealing two distinct, profound behaviors:

Collective Flocking (The Vicsek Model): For swarms of starlings (murmurations) or schools of fish, Tamás Vicsek demonstrated in 1995 that global coordination requires only a simple mathematical rule: at every time step, each agent samples its immediate neighbors, averages their direction, aligns its own path with theirs, and adds a tiny bit of random noise (η):

$$\theta_i(t+1) = \langle \theta_j(t) \rangle_{j \in R} + \eta_i(t)$$

If the noise is low, a phase transition occurs and they spontaneously march together as a single unit.



viscek model



flock of starlings

Motility-Induced Phase Separation (MIPS):

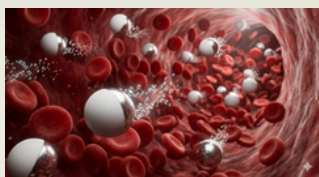
Conversely, even when active particles don't try to align, their self-propulsion creates a striking structural shift. When these particles crash head-

on, their internal engines keep pushing them forward, trapping them against each other like a highway traffic jam. More particles pile up from behind faster than they can turn around. This causes the material to spontaneously "freeze" into a dense, solid-like clump surrounded by a dilute gas phase—emerging out of purely repulsive, non-sticky parts.

Following to The Future

We are no longer just observing active matter; physicists and engineers are increasingly using principles from non-equilibrium physics and active-matter theory to design new materials, microscopic machines, and collective robotic systems.

Janus Micromotors for Targeted Drug Delivery: Scientists are manufacturing synthetic "Janus particles"—microscopic spheres coated on only one half with a catalyst like platinum. When dropped into a biocompatible chemical fuel, the asymmetric reaction on one side propels the sphere forward. These artificial micro-swimmers are being investigated as potential targeted drug-delivery systems.



janus particles

Autonomous Smart Textures (Ciliary Carpets): By printing micro-arrays of artificial, magnetically or chemically driven cilia, engineers are creating smart surfaces. These "ciliary carpets" can manipulate fluid flows and transport delicate micro-cargo across silicon chips without a single mechanical gear, conveyor belt, or external pump.

Swarm Robotics: Instead of controlling thousands of micro-drones or autonomous marine robots with a vulnerable, centralized supercomputer, engineers are programming them with basic Vicsek alignment rules. These robotic swarms can

collectively navigate disaster zones, map out oil spills, or self-assemble into bridges and structures using purely local, agent-to-agent communication.

Self-Healing Dynamic Materials: Scientists are developing active polymer networks in which energy-consuming components help repair damage and restore material integrity. These systems could lead to future self-healing materials.

Conclusion: The Universe Awakes

Active matter physics fundamentally shifts our perspective of the cosmos. It reveals that the astonishing collective behaviors we find so mesmerizing in living nature, and the routine mechanical marvels keeping us alive every second, are not mystical biological anomalies. Instead, they are the mathematically predictable, emergent consequences of a universe driven out of equilibrium.

By looking closely at the squishy, self-propelled systems around us, we find a brilliant modern validation of ancient thought. Nature is not merely a collection of passive particles responding to external forces. Given a microscopic engine and a steady supply of fuel, matter can exhibit surprisingly life-like collective behaviors. Ultimately, active matter provides a powerful framework for understanding many collective behaviors observed in living systems of non-equilibrium thermodynamics, offering a profound mathematical framework revealing how the laws of physics quite literally awaken the inanimate.

We are not detached observers looking at a cold, mechanical, dead universe. We are an integral part of an active, waking cosmos that initiates its own rhythm, breathes by its own internal impulse, and dances in exquisite, self-organizing harmony. From the inanimate molecule to the beating heart, the universe seems to echo the ancient idea of Svadhā through its capacity for self-organization--and it is the beautiful mission of physics is to decode its song.

আকাশ-ভরা সূর্য-তারা, বিশ্ব-ভরা প্রাণ,
তাহারি মাঝখানে আমি পেয়েছি মোর স্থান,
বিস্ময়ে তাই জাগে, জাগে আমার গান..."

"The sky is full of the sun and stars, the universe is full of life,
In the midst of this, I have found my place,
And so, in sheer wonder, my song awakens..."

References

- https://sanskritdocuments.org/doc_veda/naasadiiya.html
- <https://doi.org/10.1103/PhysRevLett.75.1226>
- Google Books / Oxford Academic portal.
- "Aakash bhora surjo tara" by Rabindranath Tagore
- https://www.researchgate.net/figure/Bacterial-turbulence-and-ordered-interacting-vortices-Bacterial-turbulence-consists-of_fig1_360532794
- <https://home.uni-leipzig.de/pwm/web/?page=cytoskeleton§ion=introduction>
- https://www.researchgate.net/figure/arious-patterns-of-collective-motion-produced-by-the-classic-Vicsek-model-of-collective_fig1_328334070
- <https://www.mdpi.com/2227-7390/13/11/1703>
- <https://en.wikipedia.org/wiki/Kinesin>

Orphans Of The Cosmos : The Invisible Worlds Wandering The Dark

Barnali Das

6th Sem

Beneath the familiar tapestry of the night sky lies a haunting cosmic reality: trillions of homeless, dark worlds drifting entirely alone through the interstellar void. Orphans of the Cosmos explores the spectacular physics behind rogue planets, from their violent evictions into an endless winter to the hidden, subsurface oceans where alien life might thrive in absolute darkness.

The Myth Of The Night Sky

When we look up at night, we see points of light. We have been taught since childhood that every planet in the universe orbits one of those warm stars, just like Earth orbits the Sun.

But observational astronomy has recently revealed a hauntingly beautiful secret. The empty, pitch-black space between those stars isn't actually empty. It may contain billions or even trillions of rogue planets drifting through interstellar space. Astronomers call them rogue planets, but they are essentially the ghosts of our galaxy.

How A Planet Gets Evicted

How does a world lose its home? It boils down to a violent game of cosmic billiards.

- **The Setup:** Billions of years ago, a young planet is forming peacefully within the swirling disk of its mother star.
- **The Bully:** Nearby, a massive gas giant like our Jupiter is also growing. Because gravitational pull intensifies with both mass and proximity, the giant planet exerts a crushing orbital dominance.
- **The Slingshot:** One common mechanism involves gravitational interactions with giant planets that can eject smaller worlds from their parent systems like a stone from a slingshot.
- **The Exile:** With a silent, terrifying acceleration, the smaller world crosses the system's outer threshold and plummets into interstellar space. The umbilical cord to its sun is cut forever.



The Eviction Scene (generated using AI)

The Ultimate Endless Winter

What happens to a world with no sun? On a cosmic timescale, its fate is sealed almost immediately. Deprived of stellar warmth, surface temperatures may fall to around -200°C or lower on many rogue planets. For many rocky rogue planets, much of the atmosphere may eventually freeze onto the surface, blanketing the planet in an unyielding armor of exotic frost.

On these worlds, time itself loses meaning. There are no mornings, no sunsets, no seasonal shifts, and no years. It is a state of perpetual, silent night.

The Secret Underground Oceans

It is easy to assume that a frozen, sunless planet must be completely dead. But the laws of physics offer a spectacular plot twist.

Even though the surface is locked in a permanent deep freeze, the planet's core remains packed with radioactive elements left over from its birth. As these elements naturally decay over eons, they generate immense geothermal heat from the inside out. In some cases, radioactive heating may sustain subsurface liquid oceans beneath thick ice layers trapped kilometers beneath a frozen crust.

Deep on this pitch-black ocean floor, hydrothermal vents spew superheated, mineral-rich water into the cold abyss. Primitive alien ecosystems could thrive around these vents, harnessing chemical energy instead of sunlight to survive. These creatures would live, evolve, and die completely unaware that stars or galaxies even exist. To them, the universe is just a warm, dark sea bounded by a ceiling of ice.

How The Physicists Find The Invisible

If these planets are dark and emit no light of their own, how do scientists know they are actually there? They rely on a cosmic phenomenon called Gravitational Microlensing, which hinges on a fundamental rule of Einstein's universe: mass warps spacetime, and warped spacetime bends light.

Imagine a incredibly distant background star shining steadily. If an isolated rogue planet drifts directly between Earth and that star, the planet's gravitational field acts like a giant magnifying glass. As it passes through the line of sight, the planet's gravity bends and intensifies the background star's light, causing the star to brighten for hours, days, or sometimes weeks before smoothly fading back to its normal state.

By precisely measuring the duration and intensity of this symmetric spike in brightness, astronomers can estimate the mass of the unseen object. It is a profound realization: we discover these invisible ghosts not by looking at them, but by watching how they warp the light of the stars behind them.



Rogue
Planet In
Artist's
Imagination



Gravitational Micro-lensing

Conclusion

Using this light-bending technique, astronomers have come to a remarkable realization: rogue planets may be as numerous as, or even more numerous than, the stars in our galaxy. While their true numbers remain uncertain, these dark wanderers could constitute a vast hidden population of worlds.

These cosmic outcasts are not rare anomalies; they may represent a significant and previously overlooked population of worlds. They stand as a profound reminder of the sheer resilience of cosmic matter. They prove that a world doesn't need the cozy warmth of a solar system to keep its heart beating. Sometimes, the most fascinating things in the universe are the ones navigating the deep dark, entirely on their own.

References

- PICTURE COURTESY : INTERNET
- <https://medium.com/>
- https://en.wikipedia.org/wiki/Main_Page
- https://en.wikipedia.org/wiki/Rogue_planet
- <https://www.britannica.com/science/rogue-planet>
- <https://science.nasa.gov/universe/exoplanets/free-floating-planets-may-be-more-common-than-stars/>

The Physics of Music and Sound

Karina Yadav

2nd Sem

Music is often celebrated as the universal language of human emotion, yet beneath its profound beauty lies a physical foundation governed by the laws of acoustics and wave mechanics. When a performer interacts with an instrument, they manipulate local sound pressure and command exact mathematical relationships to create the art we hear.

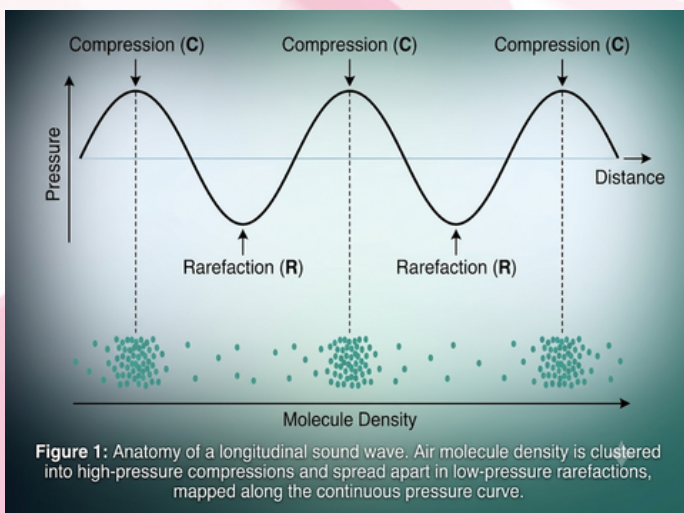
The Architecture of Sound: Anatomy of a Wave

Sound is a mechanical, longitudinal wave that propagates through a compressible medium—most commonly, air. Unlike transverse waves, where particles oscillate perpendicular to the direction of wave travel, sound waves move via a sequence of periodic compressions and rarefactions.

- **Compressions:** High-pressure zones created when a vibrating surface pushes adjacent air molecules closer together.
- **Rarefactions:** Localized low-pressure zones left behind as the vibrating surface rebounds.

These pressure disturbances propagate outward at the speed of sound, which in ambient air at 20°C is approximately $v=343$ m/s. The physical properties of these waves directly dictate our perception of pitch (frequency f), loudness (amplitude), and physical spacing (wavelength λ) through the fundamental wave equation:

$$v = f\lambda$$



Standing Waves and the Physics of Strings

When a string fixed at both ends is plucked, bowed, or struck, waves travel down its length and reflect off the boundaries. The opposing waves interfere with one another, creating a stable pattern known as a standing wave.

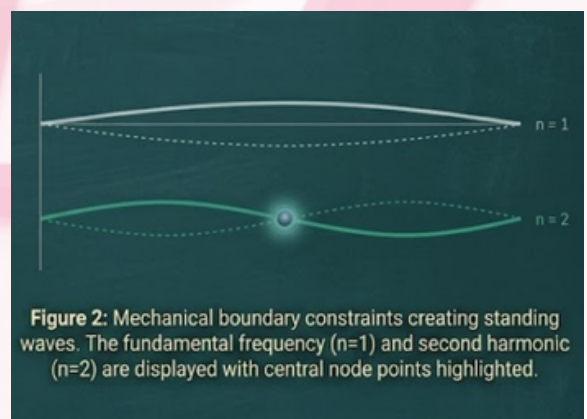
The boundaries cannot move and are called nodes, while the regions of maximum displacement are called antinodes.

The simplest pattern is the fundamental frequency (or first harmonic), where the length of the string (L) is exactly equal to half a wavelength ($L = \frac{\lambda}{2}$), meaning the fundamental wavelength is:

$$\lambda = 2L$$

By adjusting the tension (T) or linear mass density (μ), musicians alter the wave velocity (v) according to the string velocity formula, which directly changes the fundamental pitch:

$$v = \sqrt{\frac{T}{\mu}}$$

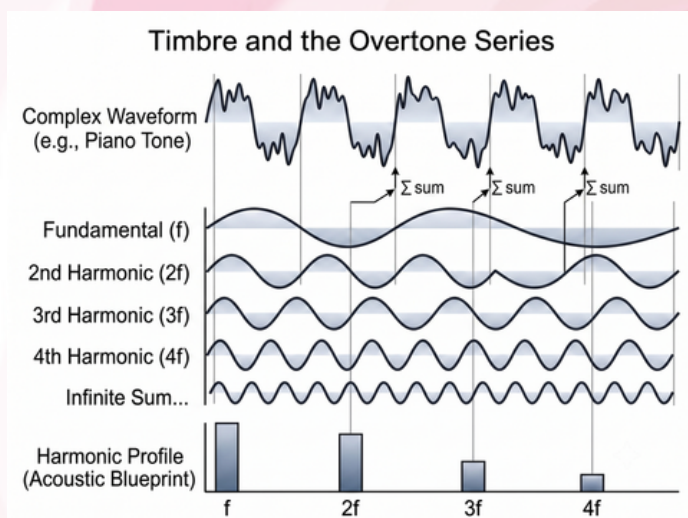


Timbre and the Overtone Series

Why do a piano and a clarinet sound entirely different even when playing the exact same note at the identical volume? The answer lies in timbre (tone quality), which is governed by the overtone series.

Instruments rarely produce a pure, isolated sine wave. Instead, they vibrate at their fundamental frequency (f) and multiple integer multiples simultaneously, such as $2f, 3f, 4f$, and so on. These higher frequencies are collectively referred to as harmonics (or overtones when counting above the fundamental).

Through Fourier Analysis, any complex, periodic musical waveform can be broken down into a sum of simple sine waves, each with its own discrete frequency and amplitude. The distinct acoustic profile of an instrument arises primarily from its unique pattern of harmonic amplitudes and resonances



The Mathematics of Harmony

Intervals that sound clean and pleasing (consonant) are constructed of notes whose fundamental frequencies form simple, whole-number ratios.

- **The Octave (2:1 Ratio):** If middle C sits at 261.6 Hz, the C an octave above is exactly 523.2 Hz. Because of this perfect integer alignment, their overtones align closely and produce consonance.
- **The Perfect Fifth (3:2 Ratio):** Aligns the third harmonic of the lower note with the second harmonic of the higher note, creating a deeply stable acoustic blend.

Conversely, when two frequencies are incredibly close but not perfectly aligned (such as 440 Hz and 442 Hz), their waves phase in and out of step. This produces an alternating cycle of constructive and destructive interference, a pulsing volume well known as beating.

The beat frequency (f_b) is mathematically defined by the absolute difference between the two interacting waves:

$$f_b = |f_1 - f_2|$$

References

Wikipedia

Benade, A. H. (1990). *Fundamentals of Musical Acoustics*. Courier Corporation.

Rossing, T. D., Moore, R. F., & Wheeler, P. A. (2002). *The Science of Sound* (3rd ed.). Addison-Wesley.

Hall, D. E. (2002). *Musical Acoustics* (3rd ed.). Brooks/Cole.

Rossing, T. D. (Ed.). (2010). *The Science of String Instruments*. Springer Science & Business Media.

Fourier, J. (1822). *Théorie Analytique de la Chaleur* [The Analytical Theory of Heat]. Firmin Didot. (Historical reference establishing the mathematical groundwork for Fourier Analysis).

Campbell, M., & Greated, C. (1994). *The Musician's Guide to Acoustics*. Oxford University Press.

Physics of Artificial Intelligence: How Science Powers Smart Machines

Ariba Khanam

4th Sem

Introduction

Artificial Intelligence (AI) is one of the most exciting technologies of the 21st century. Today, AI is used in smartphones, social media, online shopping, self-driving cars, medical diagnosis, and even space exploration. It allows machines to perform tasks that usually require human intelligence, such as learning, decision-making, problem-solving, and recognizing patterns.

Many people think that AI is only related to computer science, but physics also plays an important role in the development of intelligent machines. From the tiny electronic components inside computers to advanced research in quantum computing, physics provides the foundation that makes AI possible. Understanding the connection between physics and AI helps us appreciate how science powers the smart technologies we use every day.

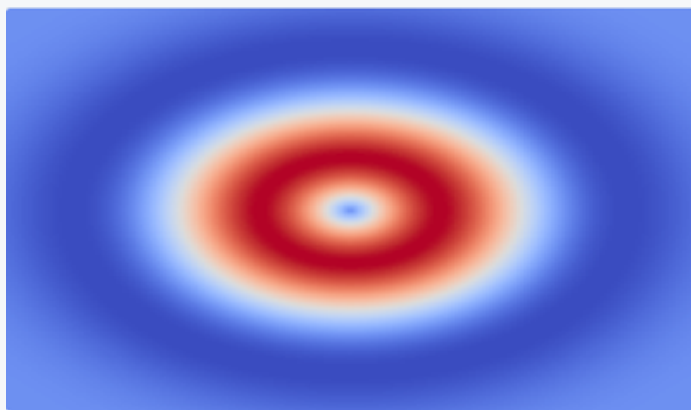


Fig 1: Mathematical mapping of electron density and quantum wave states inside semiconductor crystal grids, the fundamental physics discovery enabling modern silicon microchips.

AI in Physics Research

The relationship between physics and AI is not one-sided. While physics helps create AI, AI is also helping physicists make new discoveries.

Scientists use AI to analyze large amounts of experimental data that would take humans years to study. In particle physics, AI helps researchers identify important patterns from high-energy particle collisions. In astronomy, AI is used to detect planets, study distant galaxies, and analyze images from powerful telescopes.

- **Cosmological node clusters:** Neural networks are heavily used in modern astrophysics to map the cosmic web (the large-scale structure of the universe made up of filaments and nodes where galaxy clusters form).
- **Deep sky observations:** AI algorithms process immense, multi-band image data from wide-field surveys (like the Rubin Observatory or the Euclid space mission) to detect faint, distant celestial bodies that are otherwise difficult for humans to catalog manually.

AI in Space Exploration

Space missions generate enormous volumes of information, and AI helps scientists manage and analyze this data with high efficiency. These intelligent systems are deployed across satellites, robotic spacecraft, and planetary rovers.

AI algorithms can autonomously identify interesting geological features on distant planets, assist in real-time navigation, and make critical operational decisions when communication with Earth experiences significant time delays. As space exploration advances, AI is expected to play an even greater role in upcoming, long-duration missions to the Moon, Mars, and beyond.

AI is currently being used to explore Mars,

- **Self-Driving Navigation:** Because real-time control from Earth is impossible due to significant communication delays, rovers use AI-driven computer vision to automatically detect terrain hazards and chart safe driving paths.

- **Autonomous Scientific Targeting:** Using smart systems like AEGIS, rovers can independently identify high-value geological features, aim lasers, and analyze rock compositions without needing immediate human commands.
- **Intelligent Space Landing:** During the critical descent to the Martian surface, AI systems quickly capture images of the approaching ground, compare them to existing satellite maps, and dynamically steer the craft away from dangerous boulder fields and cliffs.
- **Data Prioritization:** Mars missions generate massive volumes of information; AI algorithms process this data on-site to prioritize and compress the most critical scientific discoveries for transmission back to Earth over limited deep-space bandwidth.

The Physical Foundation of AI

Every AI system runs on electronic devices such as computers, smartphones, and servers. These devices are built using semiconductors, primarily silicon. The behavioral properties of semiconductors are explained by the principles of modern physics, particularly quantum mechanics and solid-state physics.

Billions of microscopic transistors are packed tightly inside modern computer chips. These transistors act as electronic switches that work in unison to process and route digital information. Without the monumental breakthroughs in physics that led to the invention of transistors and integrated circuits, modern artificial intelligence simply could not exist.

Energy and Computing Power

AI systems require extraordinary amounts of computing power. Training advanced AI models involves processing massive datasets and performing trillions, or even quadrillions, of mathematical calculations every single second. This computational intensity demands vast amounts of electrical energy and highly optimized hardware.

Sustainability Challenge: Data centers supporting global AI applications consume immense electrical energy. Physicists and engineers continuously collaborate to optimize the thermodynamic efficiency of these facilities.

Physics plays an indispensable role in helping engineers design faster, more energy-efficient processors. Core principles of electricity, thermodynamics, and heat transfer are critical because microchips inevitably generate substantial waste heat while processing data. Advanced, well-engineered cooling systems are mandatory to prevent hardware overheating and to guarantee stable, continuous performance.

Quantum Computing and AI

One of the most exciting frontiers connecting physics and AI is quantum computing. Unlike traditional computers that process information using classical bits, quantum computers leverage quantum bits, or qubits. These qubits operate based on the fundamental principles of quantum mechanics, such as superposition and entanglement.

Although quantum computing is still an emerging technology, scientists anticipate that it will eventually solve complex computational problems significantly faster than today's most powerful supercomputers. Quantum computing may eventually accelerate certain AI and optimization tasks, though practical applications remain an active area of research, enabling faster neural network training, superior optimization algorithms, and vastly superior problem-solving capabilities.

AI in Everyday Life

Today, AI is already an integral part of our daily lives. Virtual assistants, recommendation systems, facial recognition software, language translation tools, and navigation apps all rely on AI. Behind these software technologies are the physical devices, electronic circuits, sensors, and communication networks that operate strictly according to the fundamental laws of physics.

Conclusion

Artificial Intelligence is transforming the modern world, but its ongoing success depends heavily on the principles of physics. From semiconductors and computer chips to thermodynamic energy architectures and quantum computing, physics provides the physical foundation upon which intelligent machines are built.

This powerful partnership between physics and artificial intelligence perfectly demonstrates how seemingly separate scientific disciplines intersect to drive breakthrough innovation. As technology continues to advance, the connection between physics and AI will grow even stronger, fundamentally shaping the future of global science, industry, and everyday life.

References

Wikipedia

<https://www.geeksforgeeks.org/artificial-intelligence/computational-power-to-train-ai/>

<https://engineadvocacyfoundation.medium.com/ai-essentials-what-is-compute-and-how-is-it-measured-36951f78485a>

<https://ourworldindata.org/grapher/artificial-intelligence-training-computation>

<https://www.satnow.com/community/what-is-the-role-of-ai-in-space-exploration-and-satellite-operations>

The Physics Behind Rainbows: An Analysis of Atmospheric Geometrical Optics

Talat Anjum

4th Sem

The creation of a rainbow is one of nature's most spectacular optical illusions. A rainbow is not a physical object located in a specific place in the sky; rather, it is a localized pattern of light dependent entirely on three elements: a light source (the Sun), suspended water droplets (rain or mist), and the position of the observer's eyes. To understand how a rainbow forms, we must analyze the three-step journey a single ray of white sunlight takes as it interacts with a spherical raindrop: refraction, internal reflection, and dispersion.

The Path of Light Inside a Droplet

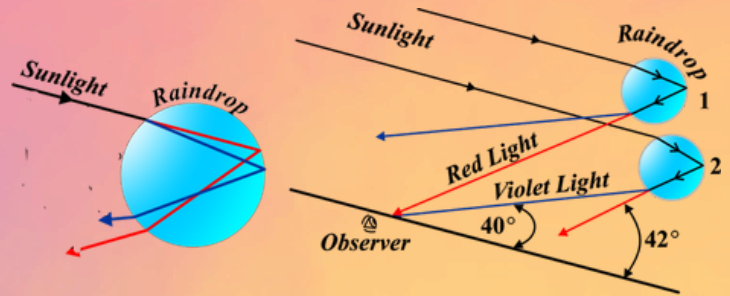
Step I: Refraction (The Entry Bend) White sunlight travels through the air in a straight line. However, when it encounters a raindrop, it transitions from a medium with a lower refractive index (air) into one with a higher refractive index (water). According to Snell's Law, this change in refractive index causes the light wave to slow down and alter its trajectory. This intentional bending of light is called refraction.

Step II: Internal Reflection (The Bounce) Once the light has traveled through the interior of the water droplet, it strikes the back inner wall of the droplet. Instead of passing completely through into the air behind the rain, a substantial portion of the light bounces off this boundary. The curved back wall of the droplet essentially acts like a tiny, concave mirror, reflecting the light forward and downward, back toward the front of the drop.

Step III: Dispersion (The Split) As the reflected light exits the lower front half of the droplet, it moves from water back into the air. This causes it to bend a second time. Crucially, white sunlight is made up of a spectrum of colors, each possessing a different wavelength. Because of a phenomenon called dispersion, different wavelengths experience different refractive indices:

- Violet and Blue light have shorter wavelengths, causing them to slow down more and bend at a sharper, steeper angle.
- Red light experiences a lower refractive index and therefore bends less.

Consequently, the single beam of white sunlight exits the raindrop spread into its constituent colors.



The Golden Angles and Spatial Geometry

Even though every single droplet splits white light into a full spectrum, your eye only sees one specific color from one specific droplet at any given time. This restriction is governed entirely by the fixed exit angles required by geometrical optics.

Color Band	Wavelength Property	Exit Angle (Relative to Sunline)	Relative Position in Arc
Red	Longer (~700nm)	42°	Outermost Band
Yellow / Green	Medium (~550nm)	41°	Middle Bands
Violet	Shorter (~400nm)	40°	Innermost Band

Because these viewing angles are mathematically locked, a specific spatial alignment is necessary: the Sun must be behind the observer and the rain or mist must be situated in front of you.

When observing the sky, droplets situated at a higher altitude direct the 42° red light rays perfectly into your pupil, while their shorter violet rays pass over your head. Conversely, droplets situated lower down direct the 40° violet rays directly into your eye, while their red components strike the ground below your vision line. This explains the immutable sequence of colors from red on the top edge down to violet on the bottom edge.

Why is it an Arc?

The curved bow shape stems from three-dimensional geometry. Your eye acts as the point vertex of a giant geometric cone, with the sun-line serving as its center axis. Any raindrop capable of reflecting color bands into your pupil must sit along the perfectly circular periphery of that cone. The horizon usually cuts off the lower portion of this pattern, restricting our view to a semi-circular arc. At high flight altitudes, passengers can occasionally look down and observe full-circle rainbows.

Secondary Rainbows and Alexander's Dark Band

During high-intensity storms, a fainter secondary rainbow can sometimes be seen hovering outside the primary arc. This phenomenon occurs when sunlight enters the lower hemisphere of a raindrop, prompting two internal reflections instead of one before exiting.

This secondary reflection yields two highly notable physical consequences:

- **Color Inversion:** The second internal bounce crosses the light rays over again within the droplet, completely reversing the spectrum. In a secondary rainbow, red occupies the innermost edge and violet is displayed on the outermost edge.
- **Alexander's Dark Band:** The sky sitting directly between the primary and secondary rainbows appears distinctly darker than the surrounding atmosphere. This optical gap occurs because the laws of angular deviation mathematically forbid single-reflection drops from focusing scattered light above 42° and double-reflection drops from focusing light below 50° , leaving an unlit zone between them

Summary

A rainbow is not a localized object, but a dynamic, position-dependent configuration. Every observer sees an entirely personal rainbow composed of different light rays from completely separate sets of raindrops.

References

Wikipedia

https://unifyphysics.com/dispersion-of-light-through-a-prism/#google_vignette

Nussenzweig, H. M. (1977). The Theory of the Rainbow. *Scientific American*, 236(4), 116–127. <https://doi.org/10.1038/scientificamerican0477-116>

Jackson, J. D. (1999). From Alexander of Aphrodisias to Young and Airy. *Physics Reports*, 320(1), 27–36. [https://doi.org/10.1016/s0370-1573\(99\)00088-5](https://doi.org/10.1016/s0370-1573(99)00088-5)

CERN's March 2026 Breakthrough: The Doubly Charmed Baryon Ξ^{+cc}

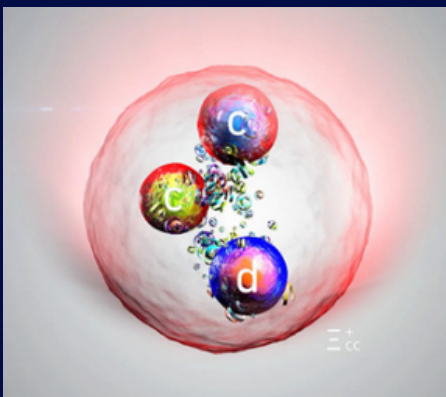
Ariba Shamim

4th Sem

In March 2026, the LHCb collaboration at CERN announced a groundbreaking discovery that has profoundly shifted our understanding of quantum chromodynamics (QCD). Analyzing high-luminosity proton-proton collision data gathered during the ongoing Run 3 of the Large Hadron Collider, physicists isolated a newly observed member of the doubly charmed baryon family.

Introduction

The new particle acts as a massive cousin to the conventional proton. While a standard proton is composed of two light up quarks and one light down quark (uud), this newly observed baryon replaces the up quarks entirely with two massive charm quarks, yielding a valence configuration of ccd .

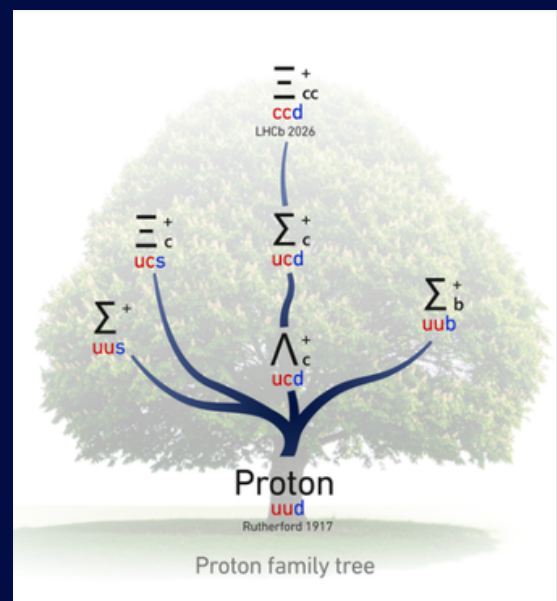


Because charm quarks carry immensely more mass than light quarks, this new particle is approximately four times heavier than a standard proton, concentrating a massive energy profile into an incredibly tight subatomic volume.

The discovery provides an ideal cosmic laboratory for testing the strong nuclear force, governed by QCD. In a traditional proton, the three light quarks dance in an incredibly complex, relativistic cloud where the energy of virtual gluons dominates the mass of the particle.

However, in a doubly charmed baryon, the two heavy charm quarks behave like a massive heavy-element core, with the single light down quark orbiting around them. This configuration allows theoreticians to simplify their math, treating the

system analogous in some respects to a hydrogen-like system bound by the strong force rather than electromagnetism.



The Doubly Charmed Ξ^{+cc} Baryon: A Subatomic Heavyweight

To appreciate the unique nature of this exotic particle, it helps to contrast its internal structure with the everyday matter that builds our world. Ordinary matter relies on standard protons and neutrons. A normal proton is composed of three lightweight building blocks: two up quarks and one down quark (uud).

The doubly charmed Ξ^{+cc} baryon radically disrupts this blueprint:

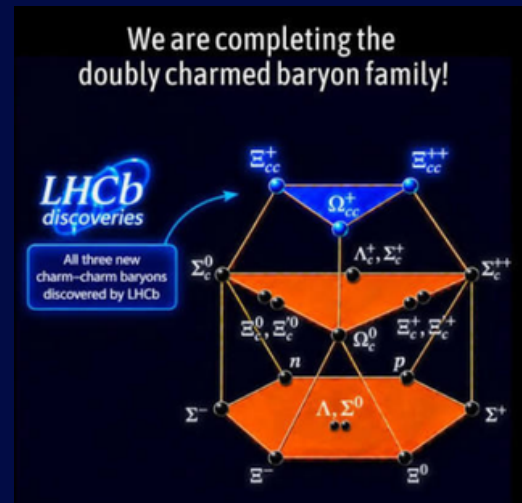
- **The Quark Blueprint:** It swaps out the two light up quarks for two heavy charm quarks, while retaining a single light down quark (ccd).
- **The Massive Payload:** Because charm quarks are fundamentally far more massive, this particle is approximately four times heavier than a standard proton.

- Its mass is comparable to that of a helium nucleus despite being a single baryon.

This discovery serves as the first monumental victory for the upgraded LHCb detector, which recently underwent a massive hardware overhaul during the Large Hadron Collider's scheduled Long Shutdown.

Hunting for a doubly charmed baryon is notoriously difficult due to its incredibly brief lifespan. The particle decays via the weak nuclear force in a fraction of a picosecond (a trillionth of a second), traveling less than a single millimeter before exploding into a cascade of lighter particles. Capturing this fleeting event required two brand-new technical upgrades:

- **The Overhauled Vertex Locator (VELO):** This cutting-edge pixel tracking detector is positioned just millimeters away from the primary proton-proton collision zone. VELO allows the system to trace the trajectories of debris back to their exact origin with microscopic accuracy.
- **A Purely Software-Based Trigger System:** Older iterations of the detector relied on rigid hardware filters to discard uninteresting collisions. The upgraded system streams and processes over 30 million collisions per second purely via software algorithms, allowing real-time filters to identify and isolate rare, multi-stage decay paths instantly.



References:

Official CERN March Announcement (Heavy Proton-like Particle): <https://home.cern/lhcb-collaboration-discovers-new-proton-particle/>

Official CERN June Announcement (Final Family Member): <https://home.cern/lhcb-discovers-the-final-missing-member-of-a-doubly-charmed-particle-family/>

LHCb Experiment Outreach Documentation:
<https://lhcb-outreach.web.cern.ch/2026/06/03/observation-of-the-doubly-charmed-baryon-%CF%89cc>

Invisible Forces Around Us: The Physics Shaping Everyday Life

Zarnaz Ahmed

4th Sem

Introduction to the Unseen Forces Around Us

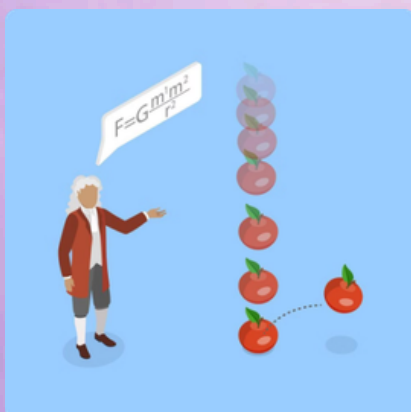
Have you ever wondered what keeps your feet firmly on the ground, allows an airplane to fly, or makes your mobile phone connect to the internet? The answer lies in invisible forces. Some are fundamental forces of nature, while others emerge from interactions between matter and fluids. Although we cannot see these forces with our eyes, we experience their effects every moment of our lives.

From the instant we wake up until we go to sleep, invisible forces are constantly at work. They help us walk, communicate, travel, and even protect our planet. These unseen forces are the silent architects of nature, keeping the universe in balance and making life on Earth possible.

Let's explore some of the most important invisible forces we experience everyday.

Gravity - The Force That Keeps Us Grounded

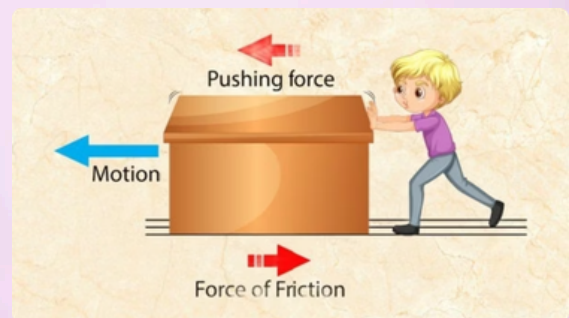
Gravity is the invisible force that attracts all objects with mass towards one another. It keeps us firmly on Earth, causes rain to fall, and holds the Moon in orbit around our planet while keeping the planets revolving around the Sun. Without gravity, life on Earth would not exist as we know it.



Fun Fact: Astronauts appear to "float" in space not because there is no gravity, but because they are continuously falling around Earth while orbiting it!

Friction The Force That Gives Us Grip

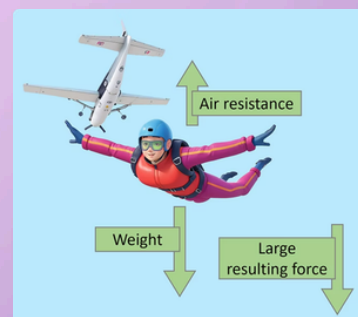
Friction is the force that acts whenever two surfaces touch. It helps us walk, write, hold objects, and stop vehicles safely. Although friction can cause wear and tear, it is essential for almost every activity we perform.



Fun Fact: A banana peel becomes slippery because it releases a gel-like substance that greatly reduces friction between your shoe and the floor!

Air Resistance The Force We Can't See

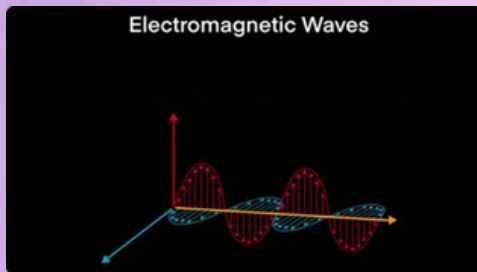
Air resistance is the force that opposes the motion of objects moving through air. It slows down falling objects and helps parachutes work. While airplanes and birds must overcome air resistance to move forward, they rely on a different invisible force called lift to fly. Engineers design vehicles to reduce air resistance to improve speed and fuel efficiency.



Fun Fact: A skydiver can reach speeds of around 190 km/h before air resistance balances gravity, creating a constant speed called terminal velocity.

Electromagnetic Force: The Power Behind Modern Life

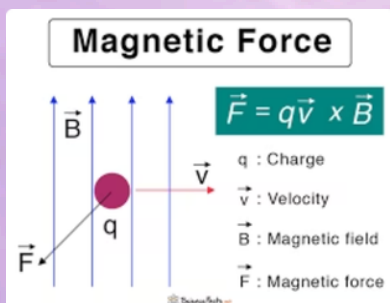
The Electromagnetic Force is one of the fundamental forces of nature, responsible for electricity, magnetism, and light. It is the invisible backbone of our modern world, allowing mobile phones, computers, Wi-Fi, televisions, and countless electronic devices to function. Even the visible light that helps us see is just a tiny sliver of the vast electromagnetic spectrum.



Fun Fact: The light leaving the Sun travels at nearly 300,000 km per second, taking only about 8 minutes and 20 seconds to reach Earth!

Magnetic Force: Nature's Invisible Compass

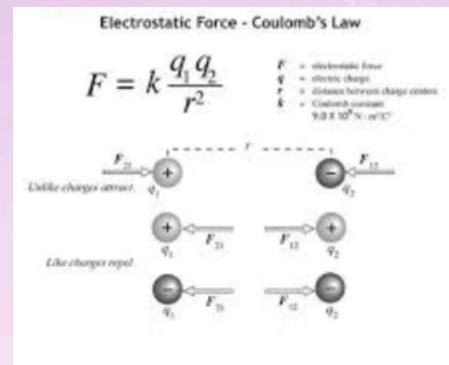
Magnetic force attracts or repels certain materials and is used in many everyday devices, including speakers, electric motors, and compasses. Earth's magnetic field and atmosphere work together to shield life from much of the harmful radiation and charged particles arriving from space and helps many animals navigate during migration



Fun Fact: Some birds, sea turtles, and even certain bacteria can naturally sense Earth's magnetic field to find their way over thousands of kilometres !

Electrostatic Force -Tiny Charges,Big Effects

Electrostatic Force acts between electrically charged objects. It is responsible for static electricity, such as a balloon sticking to a wall or the tiny shock you sometimes feel after touching a metal object.



Fun Fact: A single lightning bolt is a giant electrostatic discharge and can heat the surrounding air to about 30,000°C, around five times hotter than the surface of the Sun

Buoyant Force - The Secret Behind Floating

Buoyant force is the upward force exerted by a liquid or gas on an object. It allows ships to float, helps us swim, and enables submarines and hot-air balloons to operate



Fun Fact: The largest cruise ships weigh over 200,000 tonnes, yet they float because they displace enough water to create a buoyant force equal to their weight

References:

www.google.com
www.collinsdictionary.com
<https://www.sciencenews.org/blog/scicurious/banana-peel-slipperiness-wins-ignobel-prize-physics>

Physics behind GPS Technology

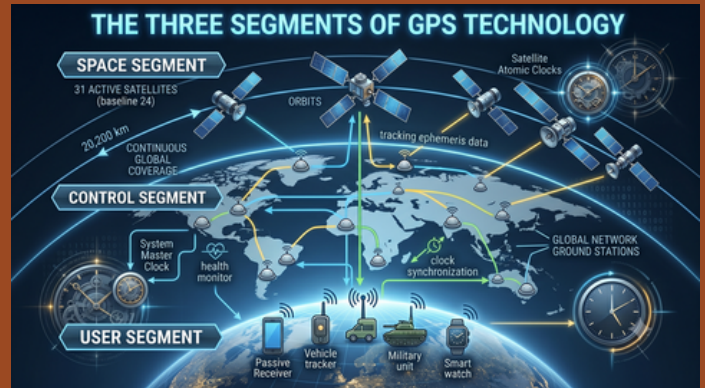
Maghfera Sabnam

2th Sem

What is GPS?

Owned by the U.S. government and operated by the U.S. Space Force, the Global Positioning System (GPS) is a satellite-based navigation network.

It delivers precise location and time data to receivers worldwide, provided they have a clear line of sight to at least four satellites.



System Infrastructure

The Three Segments of GPS Technology

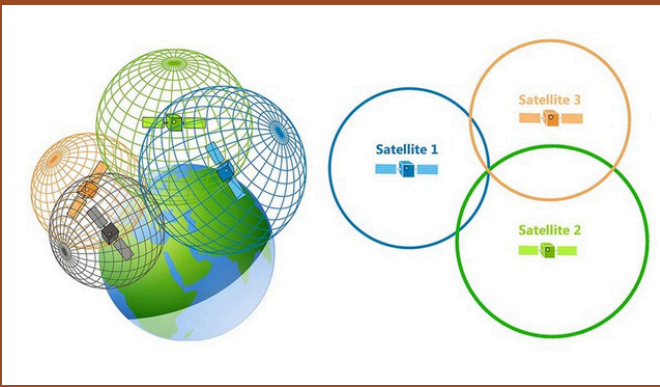
To understand how GPS functions, the system can be divided into three distinct segments working in harmony: the Space, Control, and User segments.

- **Space Segment:** A constellation of more than 30 active satellites (with a baseline requirement of 24 satellites) orbiting the Earth at approximately 20,200 km. This specific orbital configuration ensures continuous, global coverage of any point on Earth.
- **Control Segment:** A global network of ground stations responsible for monitoring satellite health, tracking precise orbital paths (ephemeris data), and keeping the satellites' ultra-precise atomic clocks highly synchronized.
- **User Segment:** Billions of passive receivers integrated into smartphones, vehicles, and military hardware. These devices decode the incoming radio signals from multiple satellites to calculate precise three-dimensional positions and exact global time.

Positioning Logic

GPS receivers are completely passive; they do not transmit any signals. Instead, they calculate their estimated location by measuring how long it takes for a radio signal to travel from multiple known points in space (satellites) to the receiver.

- **1 Satellite:** Places you anywhere on the surface of a 3D sphere centered around that satellite.
- **2 Satellites:** The intersection of two spheres narrows your location down to a 2D circle.
- **3 Satellites:** The intersection of three spheres narrows your location down to just two precise points in space. Because one point is typically discarded as an impossible location (such as deep space), three satellites are geometrically enough to determine your three-dimensional position (Latitude, Longitude, and Altitude) provided that the receiver clock is already highly synchronized.
- **4 Satellites:** The crucial fourth satellite is required to solve for Time. Because user receivers use cheap quartz clocks rather than expensive atomic clocks, a fourth satellite is mathematically necessary to correct the receiver's clock error, perfectly aligning it with GPS time to lock in your exact coordinates.



The Distance Equation: Time of Flight

To determine its distance from a satellite, a receiver calculates the "Time of Flight", the tiny delay between when a radio signal is broadcast and when it arrives. Because the receiver and the satellite generate the exact same digital code at the exact same time, the receiver can shift its own code until it perfectly matches the incoming satellite signal. This shift reveals the travel time (Δt).

Using the constant speed of light, the fundamental physics equation is straightforward:

$$\text{Distance} = c \times \Delta t$$

- **Speed of Light (c):** 299,792,458 m/s (approximately 3×10^8 m/s).
- **The Margin of Error:** Because light travels so fast, precision is everything. A timing error of just 1 nanosecond (1 ns) translates to a 30 cm (approx. 1 foot) distance error on the ground. This extreme sensitivity is exactly why the system demands relativistic corrections and atomic clocks.

The Atomic Heartbeat

To maintain the extreme timing precision required for navigation, each GPS satellite carries multiple ultra-precise atomic clocks (utilizing Cesium or Rubidium vapor). These clocks are marvels of engineering, stable to within one second every few million years.

- **Why Such Precision is Required:** Because radio signals travel at the speed of light, timing errors propagate instantly into massive distance errors. A discrepancy of just one microsecond (1 μ s) in a clock translates immediately to an instantaneous 300-meter (nearly 1,000 feet) location error on the ground.

- **The Continuous Reset:** Even with atomic stability, the clocks still drift by a few nanoseconds over time. To prevent these tiny drifts from accumulating and compromising accuracy, the Control Segment regularly monitors clock drift and uploads updated clock-correction parameters to the satellites.

Special Relativity: Time Dilation by Velocity

GPS satellites travel at a tremendous speed of approximately 14,000 km/h (3.87 km/s) relative to the Earth's surface. According to Einstein's Theory of Special Relativity, a clock in motion ticks slower relative to a stationary observer on the ground.

- **The Velocity Effect:** Because of this high orbital velocity, time for the satellite clocks stretches. If left uncorrected, this speed causes the onboard atomic clocks to tick slower, falling behind Earth-based clocks by approximately 7 microseconds (μ s) per day.

General Relativity: Gravitational Time Dilation

In addition to their speed, GPS satellites operate roughly 20,200 km above the Earth's surface, where the gravitational field is significantly weaker than it is at ground level. According to Einstein's Theory of General Relativity, gravity warps the fabric of spacetime, causing clocks in a weaker gravitational field to tick faster than those deeper inside a gravity well.

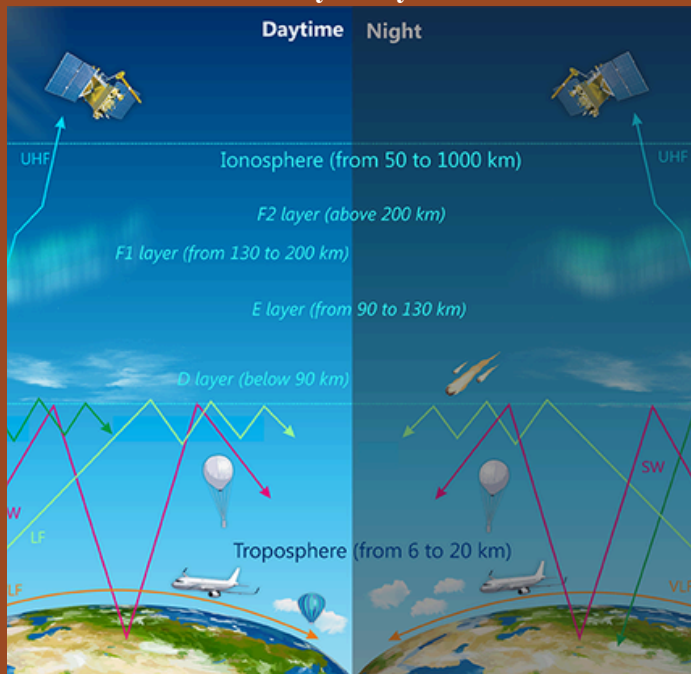
- **The Gravitational Effect:** Because they are positioned high up in Earth's gravitational well, the weaker gravity causes the satellite clocks to run faster than clocks on the ground. This gravitational blueshift adds a gain of approximately 45 microseconds (μ s) per day.

The Atmospheric Problem

Although radio waves travel at the vacuum speed of light (c) through empty space, they experience

propagation delays and small refraction effects as they pass through the atmosphere when they enter Earth's atmosphere. Because the atmosphere is not a uniform vacuum, index of refraction variations cause signal propagation delays that can distort distance calculations.

- **The Ionosphere:** This upper layer (ranging from roughly 50 km to 1,000 km above Earth) is filled with gases ionized by solar radiation. This plasma medium introduces a frequency-dependent dispersive delay. Modern dual-frequency GPS receivers exploit this physics property—comparing two different frequencies (L1 and L2) allows them to calculate and cancel out the bulk of the ionospheric error.
- **The Troposphere:** This lowest layer of the atmosphere contains weather, dry air, and highly variable water vapor. Unlike the ionosphere, the troposphere is non-dispersive (it delays all radio frequencies equally), making its localized, turbulent effects harder to predict. Engineers use empirical atmospheric models to estimate and correct for this wet and dry delay.



Global Navigation Satellite Systems (GNSS) currently operating worldwide

System	Region	Satellites	Status
GPS	Global	31	Fully Operational
GLONASS	Global (Russia)	24	Operational
Galileo	Global (EU)	30	Operational
NavIC (IRNSS)	Regional (India)	7	Operational

References

Wikipedia

Global Positioning System Standard Positioning Service (SPS) Performance Standard, Department of Defense, United States of America, 5th Edition.

Parkinson, B. W., & Parkinson, B. (1997). "The Origins of GPS: An Engineering Memoir". GPS World, 8(5), 44-54. [3] Pogge, R. W. (2017).

"Real-World Relativity: The GPS Navigation System". The Ohio State University, Department of Astronomy Course Series. [4] Ashby, N. (2003).

"Relativity in the Global Positioning System". Living Reviews in Relativity, 6(1), 1. (Provides the rigorous mathematical physics behind the atomic clock frequency offset built into the hardware before launch).

Misra, P., & Enge, P. (2011). "Global Positioning System: Signals, Measurements, and Performance". Ganga-Jamuna Press. (Core text backing up the Ionosphere L1/L2 dual-frequency cancellation physics and code phase time delays).

Physics Beyond Equations

Debanjali Prasad

2th Sem

Introduction

Richard Feynman once said, *“Nobody ever figures out what life is all about, and it doesn't matter. Explore the world. Nearly everything is really interesting if you go into it deeply enough.”* Today, almost every one of us relies on technology to build a better future. Yet, for many, the mere word “physics” conjures up dread of a notoriously difficult subject. While it certainly can be challenging, if we approach physics with curiosity and connect it to our daily lives, that perspective changes completely.

Let's look at physics from a different angle. We constantly harness it to serve our own needs, but what if we look at it through the lens of nature's benefits? Let's introduce you to some facets of physics that are right in front of our eyes, phenomena we see every day but rarely stop to truly consider. What if we explore some of these fascinating sides of the universe?

Sustainable Cooling Through Evaporative Physics

Consider a structure made of hollow, earthenware clay pots stacked together. When utilized in windy areas or paired with simple fans, this setup transforms hot air into a refreshing, cool breeze. By keeping the clay pots wet, the hot air loses its heat to the evaporating water as it passes through the tubes. It sounds simple, but that is the beauty of physics, specifically, the principle of evaporative cooling.

This method offers an incredible, eco-friendly alternative to modern air conditioning. While conventional AC units are constantly evolving,



some refrigerants can contribute to climate change if released into the atmosphere, and air conditioners consume significant electrical energy. Why not shift our focus toward sustainable engineering? Embracing a little innovation can be life-changing for both us and Mother Earth. This transition cannot be achieved by a single person overnight; it requires a collective commitment to protecting our planet. What begins as a creative concept can become a powerful reality the moment we choose to build it.

Saving Natural Resources

Let's shift our focus to how physics can help conserve our most vital resource: water. We know that heat causes water to evaporate, but we can alter this process with a simple setup. Imagine two tanks: Tank A contains open, stagnant water, where evaporation happens rapidly due to direct exposure to the sun and wind. Tank B, however, is filled with porous clay bricks. Here, one might observe that the water evaporates much slower (provided that, the bricks, shade the water, reduce airflow, trap humid air), conserving more water than Tank A.

This phenomenon is influenced by the porous structure of the clay bricks and the way they interact with water and air. The microscopic pores within the clay draw water into the material through capillary action, distributing moisture throughout the brick network. At the same time, the stacked bricks partially shield the water from direct sunlight and reduce the movement of air across the exposed surface.

These effects create a more humid microenvironment around the water and reduce the rate at which water vapor is carried away by the surrounding air. Since evaporation occurs most rapidly when warm, dry air continuously flows over an exposed water surface, limiting

airflow and trapping moisture can significantly slow water loss.

As a result, porous clay structures can help conserve water while relying solely on simple physical principles, making them an effective and sustainable solution in hot environments.

Earth and clay are truly hidden gems of sustainable engineering when we apply a little bit of physics to them. As **Albert Einstein** beautifully put it:

"Look deep into nature, and then you will understand everything better."



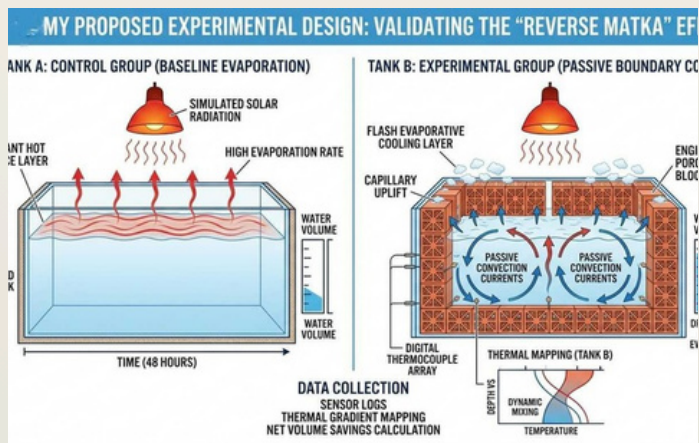
‘As Sir J.C. Bose demonstrated through his pioneering work, the value of a scientific instrument lies not in its financial cost, but in the ingenuity and resourcefulness of its design.’

References

<https://share.google/LioYmfKbsMSgHVMRE>
Source:- www.youtube.com

<https://share.google/7tiwvdTM9kIvCPRNl>
Source:- www.facebook.com

<https://share.google/hWwak4TAOGy0NJi5U>
Source:- mudkart.com



Fun with Physics

Let's look at a fun, hands-on project that puts these principles to work. By using a large earthen pot (matka), a DC motor, an exhaust fan, wires, water, and some sunboard for framing, you can build your own clay-pot air cooler. When you fill the pot with water and switch on the fan, it draws air across the chilled, evaporating surface of the clay, creating a remarkably refreshing breeze.

This DIY device is incredibly eco-friendly and budget-friendly, consuming only a tiny fraction of the electricity required by a standard air conditioner. For larger spaces, scaling up the project by placing large, fan-assisted clay pots in the corners of a room can provide noticeable cooling in hot, dry environments. While it won't replace the deep freezing power of a mechanical AC, it offers an incredibly smart, low-cost, and sustainable way to keep our living spaces comfortable.

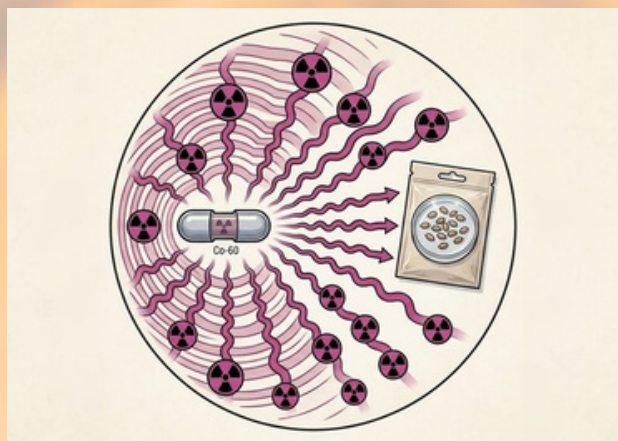
Breaking the Code of Nature: How Radio-physics is Engineering the Future of Food

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2th Sem

Introduction

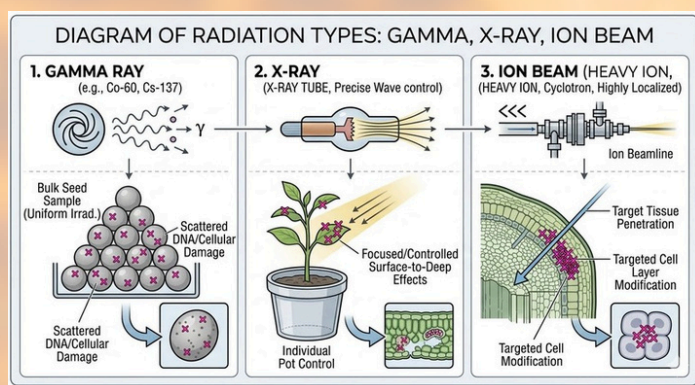
Imagine a technology that helps crops adapt to the challenges posed by climate change, reduces our reliance on chemical pesticides, and boosts crop yields. It achieves all of this without introducing foreign genes into the plant's DNA. This is *mutagenesis*, a powerful field of agricultural science getting a cutting-edge upgrade through modern radio-physics.



Gamma-Induced Mutagenesis

As global temperatures rise and unpredictable weather patterns threaten farmlands, traditional farming methods are struggling to keep pace. To safeguard our food supply, university labs and nuclear research facilities are stepping in, using precision radiation to give our crops a vital evolutionary upgrade.

Unleashing Controlled Radiation



The journey of a new crop variety starts in a specialized laboratory. Scientists gather thousands of seeds, pollen grains, or plant tissues and expose them to carefully calibrated doses of radiation. To achieve this, physicists rely primarily on three tools:

- **Gamma Rays:** Emitted from isotopes like Cobalt-60, these rays penetrate deeply and uniformly through tissue.
- **X-Rays:** These high-energy electromagnetic waves offer precise control over exposure levels.
- **Ion Beams:** Streams of accelerated, charged particles that deliver dense energy to cause targeted genetic changes.

The goal is not to create artificial transgenic plants. Instead, the radiation acts as a powerful mutagen, creating random genetic changes throughout the genome. As the waves or particles pass through a seed, they interact with water molecules inside the cells. This process creates free radicals that can damage DNA and introduce mutations. When the cell's natural mechanisms heal these breaks, it occasionally makes minor replication errors. Radiation accelerates the generation of mutations that would otherwise accumulate gradually through natural processes. With radio-physics, they happen in seconds.

Breeding the Survivors

Scientists harvest the seeds from these radiation survivors and grow them over multiple generations to ensure the new traits are stable. To test their resilience, breeders expose the plants to harsh environmental stressors, such as severe drought, pest infestations, or poor soil conditions.

Throughout this process, researchers evaluate the plants using field testing and, increasingly, genomic tools to verify that the beneficial mutations are locked in without causing adverse side effects. Any plants that show signs of weakness or poor health are immediately culled from the program. The top-

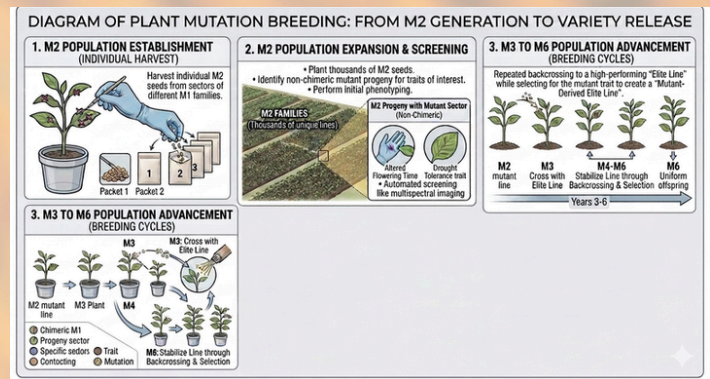
performing survivors are then moved out of the greenhouses and into open-air field trials to face real-world elements like unpredictable wind and rain. Only the absolute strongest, highest-yielding varieties are selected to produce the seeds for the next generation of climate-resilient agriculture.

A Safe Non-GMO Revolution

This powerful partnership between radio-physics and agriculture has already contributed over 3,400 officially registered crop varieties that help feed millions worldwide. These include drought-resistant rice in Asia and disease-resistant bananas in Africa.

The ultimate advantage of this technique is its safety and regulatory simplicity. In many countries, mutation-bred crops are regulated differently from transgenic GMOs because no foreign DNA is introduced. Mutation-bred crops have been cultivated and consumed for decades and are generally considered as safe as conventionally bred crop varieties.

By using radio-physics to safely accelerate evolution, scientists are giving humanity a vital tool to secure the future of the global food supply.



References

<https://nucleus.iaea.org>

<https://www.iaea.org>

<https://www.sciencefocus.com>

<https://www.Wikipedia.com>