FIZIKA

5th Volume

E-Magazine of the Department of Physics

Victoria Instititution (College)

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Editorial

"We especially need imagination in science. It is not all mathematics, nor all logic, but it is somewhat beauty and poetry."

---Maria Mitchell, Astronomer

From the spin of an electron to the birth of an universe, Physics utters the why behind everything. Physics is where abstract meets imagination and imagination meets logic. Isn't it wonderous? And Fizika is the place where we portray and share that wonder.

Fizika, the E-magazine of Department of Physics, Victoria Institution (College), commenced its journey from 2021. This year Fizika has touched the 5th milestone of its glorious path. We give our cordial thanks and gratitude to all the writers who have given their valuable time to cherish the magazine.

This year too we bring you insightful and enriching tales from various rooms of Physics. We present to you- The inquisitive story of spintronics, the harmonics of the great cosmos, the lore of the moon, story of astronauts, quest for extraterrestrial lives, curious cosmology, bewildering blackholes, the magnificent physics behind mobile phones and the exciting physics behind thrills.

We extend our profound gratitude to our respected Principal Madam for her kind support . We also give out our heartfelt thanks to our esteemed professors for their support and encouragement.

Lastly we extend our warm greetings to our readers for staying with us. As you take a trip through the pages, we wish you a great and enriching experience.

Bon voyage and happy reading!

Sincerely,
Shweta Mukherjee

Our Team

From left: Dhriti, Akanksha, Triparna and Ankita
6th Sem

From left: Farriyah , Shweta and Barnali
4th Sem

From left: Ariba Shamim, Zarnaz, Karina, Ariba Khanam and Talat
2nd Sem

Message from the Principal

This annual E-Magazine, FIZIKA, published by the students of the Department of Physics every year, reflects the curiosity, creativity, and dedication of our students, highlighting significant topics in physics and its allied fields. Such initiatives are crucial in fostering scientific thinking and motivating young minds toward research and innovation. I appreciate the entire team for their commitment and hard work. May "Fizika" continue to inspire, inform, and ignite the scientific spirit in our institution for many years to come. I wish the magazine every success.

Dr. Maitreyi Ray Kanjilal
Principal
Victoria Institution (College)

Message from the Department

We are delighted to express our heartiest greetings and congratulations to the students of Victoria Institution (college) for successfully bringing out the 5th volume of Annual E-Magazine "FIZIKA". This edition covers an extensive range of topics spanning from physics behind amusement rides covering Newton's laws, communication to advanced electronics, quantum physics, modern technology, astrophysics and cosmology. The variety and diverseness of the topics highlights the academic advancement of the department serving as the platform for scientific curiosity and cognitive exploration.

All the articles in the magazine reflect the critical thinking and creativity of the students showcasing their academic enthusiasm and escalating passion for scientific innovation. We sincerely appreciate the enthusiasm and efforts of the students and extend our gratitude to everyone involved with "FIZIKA" for their dedication and continuous support for its publication throughout the journey. Our belief is that this magazine will not only encourage the readers for the development of their scientific knowledge but also inspire them by fueling their passion for physics.

Ms. Swarnalekha Bandyopadhyay

Dr. Gayetri Pal

Dr. Subhendu Chandra

Dr. Shinjinee Das Gupta
HOD

Dr. Atri Sarkar

Ms. Kathakali Biswas

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Spintronics: The Bridge between Classical Electronics and Quantum Mechanics

Dhriti Nath
6th Sem

Introduction

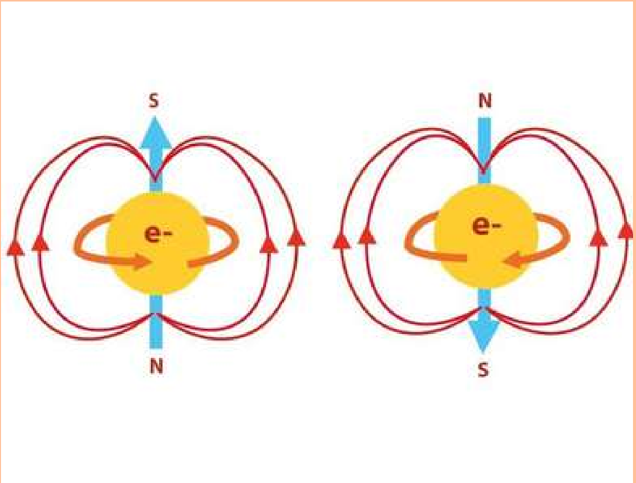
Do you remember the first computer you used or the television you watched cartoons on? It's easy to take today's technology for granted, but if you compare it to the room-sized computers of the 1960s, you'll realize how dramatically things have changed—and shrunk! As technology advances, we need to store and process ever-growing amounts of data, even as our devices become smaller. Most modern technology relies on electronics, using the charge of electrons to encode information.

A key example is computer memory, often called RAM, which temporarily stores information that the computer is actively using while it's powered on. Most memory today, like Dynamic RAM (DRAM), uses billions of tiny capacitors to store electrical charge. The computer applies a voltage to each capacitor; if it holds enough charge, it's read as a one, otherwise as a zero. Patterns of these zeros and ones represent letters, numbers, and images.

As chips become smaller, the capacitors shrink as well, making it harder to retain charge—electrons leak away, risking data loss. To prevent this, computers must frequently refresh the charge in the capacitors, a process that uses increasing power as devices miniaturize. Excitingly, new technologies such as 'spintronics' may help overcome these challenges. Instead of charge, spintronics uses the spin of electrons to encode data, offering the potential for faster, more efficient memory in the future.

Basic Concept

As the name suggests, Spintronics is essentially "spin-based electronics." In this field, both the charge and the spin of electrons are used to process and store information. This is a significant advancement over



traditional electronic systems, which only utilize the flow of electric charge to perform operations. The spin of an electron is a quantum property that can be thought of as giving the electron a tiny magnetic orientation—either "up" or "down." In spintronic devices, these spin states can be used to represent binary data (0s and 1s), similar to how traditional devices use voltage levels. In spintronics, the alignment of electron spin can be influenced through several mechanisms that enable control over magnetic and quantum states. One common method is the use of external magnetic fields, which align spins in ferromagnetic materials and are fundamental to devices like MRAM. Another powerful technique involves spin-polarized currents, where electrons injected from a ferromagnetic layer transfer angular momentum to another layer, altering its magnetization through Spin-Transfer Torque (STT). Additionally, electric fields can influence spin via Spin-Orbit Interaction (SOI), particularly in materials with strong spin-orbit coupling, enabling Spin-Orbit Torque (SOT)-based switching.

Historical Background

The electron was discovered by J. J. Thomson in 1897, with its charge precisely measured by R. Millikan. In 1922, the quantum nature of the electron's magnetic moment was demonstrated by the Stern–Gerlach experiment. The concept of electron spin was introduced by Goudsmit and Uhlenbeck in 1925 and later formalized in quantum mechanics by Wolfgang Pauli. Spin conservation in tunneling was observed in ferromagnet/insulator/superconductor junctions, opening doors to spin-based transport. The spin Hall effect, predicted in 1971 by D'yakonov and Perel', showed spin flow perpendicular to current, and was later experimentally confirmed. In 1975, Julliere discovered tunnel . magnetoresistance (TMR), where resistance varied with magnetic alignment. Spin injection into semiconductors was proposed in 1976, but only became practical in the 1980s with nanofabrication advances. The 2007 Nobel Prize in Physics honoured Grünberg and Fert for discovering giant magnetoresistance (GMR), cementing the foundation of spintronics — a field exploiting electron spin for advanced electronic applications.

Key Applications

- *Magnetoresistive Random Access Memory (MRAM)* utilizes the spin of electrons to store data in the form of magnetic states, rather than electric charge. It relies on magnetic tunnel junctions (MTJs), where two ferromagnetic layers are separated by an insulating barrier. The resistance of the junction depends on whether the magnetic orientations of the layers are parallel or antiparallel, representing binary data. The spin-dependent tunneling phenomenon—known as Tunnel Magnetoresistance (TMR)—enables MRAM to be non-volatile, meaning it retains data without power. Compared to conventional RAM, MRAM offers faster access speeds, superior endurance, and lower energy consumption, making it ideal for next-generation memory applications.

- *Spin Transfer Torque (STT)* devices are a key advancement in spintronic memory technology, particularly in STT-MRAM. These devices manipulate the magnetic orientation of a layer in an MTJ by injecting a spin-polarized current. As the current passes through a fixed magnetic layer, it becomes spin-polarized and exerts torque on the adjacent free layer, potentially switching its magnetization direction. This method avoids the need for external magnetic fields, enabling lower power operation and enhanced scalability. STT-based devices improve write efficiency and reliability, supporting high-density integration and robust non-volatile performance suitable for embedded systems and storage-class memory.

- *Spin-based transistors,* such as Spin Field-Effect Transistors (SpinFETs), utilize electron spin rather than—or in addition to —charge to control current flow. These devices typically involve injecting spin-polarized electrons from a ferromagnetic source into a semiconductor channel, where the spin state can be modulated by gate-controlled spin-orbit interaction before being detected at a ferromagnetic drain. The result is a transistor that operates with potentially lower power dissipation and higher speed than traditional CMOS transistors. Spin transistors open avenues for integrating logic and memory, enabling non-volatile computing platforms and paving the way toward post-CMOS electronics.

- **In quantum computing, spintronics plays a critical role in the realization of . spin qubits—quantum bits where information is encoded in the spin state of a single electron confined in a quantum dot or a defect in a solid-state matrix. Spin qubits offer several advantages: they have long coherence times, can be precisely manipulated using magnetic or electric fields, and are compatible with semiconductor fabrication techniques. Electron spins can also be entangled and controlled through spin-orbit coupling and exchange interactions, making them ideal for scalable quantum gate operations. Spintronic control and readout techniques are essential to developing practical quantum computing hardware based on spin systems.**

Conclusion

Spintronics stands at a unique interdisciplinary crossroad, conceptually linking the deterministic world of classical electronics with the quantum domain, where electron spin introduces new probabilistic behaviors. While most current spintronic devices operate within classical hardware frameworks, their underlying principles are deeply rooted in quantum mechanics. By harnessing the quantum property of electron spin alongside its classical charge, spintronics enables devices that are faster, more energy-efficient, and capable of storing data without power. Technologies like MRAM and spin-FETs exemplify the classical hardware enhancements possible through spin, while spin qubits in quantum dots and defects open a gateway to scalable quantum computing. This duality makes spintronics not just a technological advancement but a conceptual bridge between two foundational physics paradigms. Looking ahead, spintronics promises to drive the evolution of hybrid systems —integrating memory, logic, and quantum processing on a unified platform. As material science and nanofabrication techniques continue to evolve, the potential of spintronics in neuromorphic computing, secure communications, and fault-tolerant quantum systems will only grow. It is this convergence of classical and quantum principles that positions spintronics at the forefront of the next era in computation and information technology.

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Journal of Cosmic Harmony: Unveiling the Symphony of Spacetime

Ankita Paul
6th Sem

The direct detection of gravitational waves has ushered in a new era of astronomical observation, providing a unique window into cosmic events and fundamental physics. A review of the theoretical foundations of gravitational waves, their detection techniques, and the significance of recent observations for understanding black hole mergers, neutron star collisions, and the early universe is presented herein. The potential of future gravitational wave astronomy to further test general relativity, constrain cosmological models, and reveal previously inaccessible aspects of the cosmos is explored.

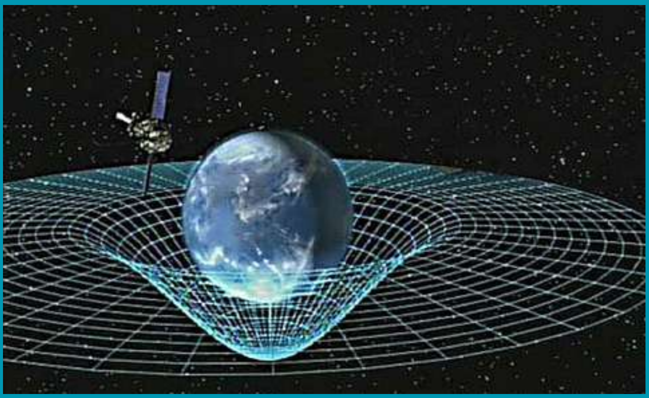
Introduction:

A century after the prediction by Albert Einstein in his theory of general relativity, gravitational waves were directly detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015 [1].

These undulations in the fabric of spacetime, generated by accelerating massive objects, convey information about their sources that is fundamentally different from that conveyed by electromagnetic radiation. Unlike electromagnetic waves, which are typically emitted by charged particles, gravitational waves are produced by the acceleration of mass itself. This key distinction allows gravitational waves to escape from regions of space where light and other electromagnetic radiation are often obscured. The detection of gravitational waves has opened a new window on the universe, permitting the observation of events such as black hole mergers [2] and neutron star collisions [3] that are imperceptible to traditional telescopes. An overview of this burgeoning field, from its theoretical foundations to the latest observational results and prospects, is provided in this article.

Theoretical Framework:

Einstein's theory of general relativity delineates gravity as a geometric property of spacetime, wherein the presence of mass and energy curves spacetime fabric, dictating the motion of objects. Within this framework, accelerating massive objects are understood to produce disturbances in spacetime that propagate as waves at the speed of light. These waves are gravitational waves.



The mathematical description of gravitational waves arises from the Einstein's field equations, which relate the curvature of spacetime to the distribution of mass and energy. Linearized solutions to these equations predict the existence of transverse waves with two polarization states, commonly denoted as "+" and "×". These polarization states describe how spacetime is distorted by the passing wave. For instance, a wave with "+" polarization will stretch space in one direction and compress it in the perpendicular direction, and vice versa, oscillating as the wave propagates. The amplitude of these waves is related to a measure of the asymmetry of the mass distribution of the source and is typically very small by the time they reach Earth, necessitating the use of extremely sensitive detectors.

By the time these waves reach Earth, their strain is exceedingly small, observed to be of the order of 10^{-21} for the merger of of two black holes. Detecting such minuscule effects requires the use of extraordinarily sensitive instruments, such as those used by the LIGO and Virgo observatories.

Detection Methodologies:

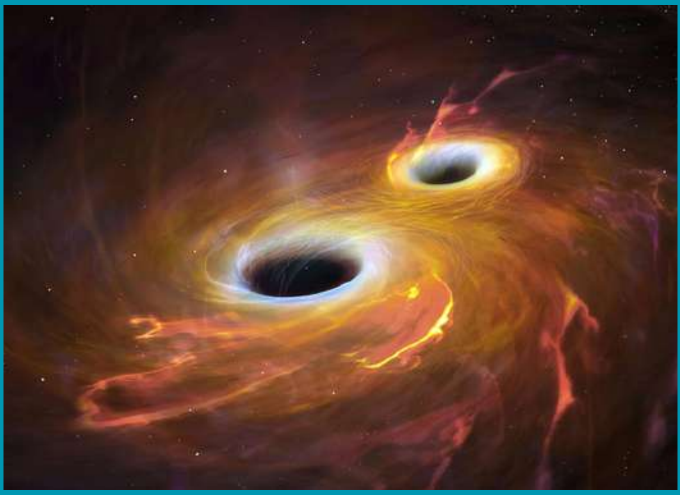
The detection of gravitational waves depends on measuring the extremely small changes in distance produced as a wave passes through. Current ground-based detectors, such as LIGO and Virgo, employ laser interferometry to achieve this. These detectors consist of two long, perpendicular arms, along which laser beams are reflected. As a gravitational wave passes by, it alternately stretches one arm while compressing the other (and vice versa), resulting in a tiny, oscillating change in the relative lengths of the arms. This change is reflected in the interference pattern of the laser beams. The fundamental principle behind laser interferometry is to precisely measure the difference in the length of the two arms. When a gravitational wave passes through the detector, it stretches one arm and shrinks the other, and then reverses this effect, causing the difference in length to oscillate. This oscillation is observed as a variation in the interference pattern of the laser beams. However, the sensitivity of these detectors is limited by various noise sources, including thermal noise (random motion of the atoms in the detector components), seismic noise (vibrations of the Earth), and quantum noise (inherent uncertainty in the measurement of light). Advanced techniques, such as vibration isolation systems to minimize the impact of ground vibrations, cryogenic cooling to reduce thermal noise, and squeezed light to mitigate quantum noise, are employed to mitigate these effects and enhance the detector's ability to detect extremely faint signals.

Future detectors, such as the planned space-based Laser Interferometer Space Antenna (LISA), will operate at lower frequencies and exhibit sensitivity to different sources, such as the inspiral of supermassive black holes. LISA will be composed of three spacecraft flying in a triangular formation, separated by millions of kilometers, with lasers exchanged between them. This space-based configuration will allow for the detection of gravitational waves in a frequency range inaccessible to ground-based detectors, opening new avenues for exploring the universe.

Observational Highlights:

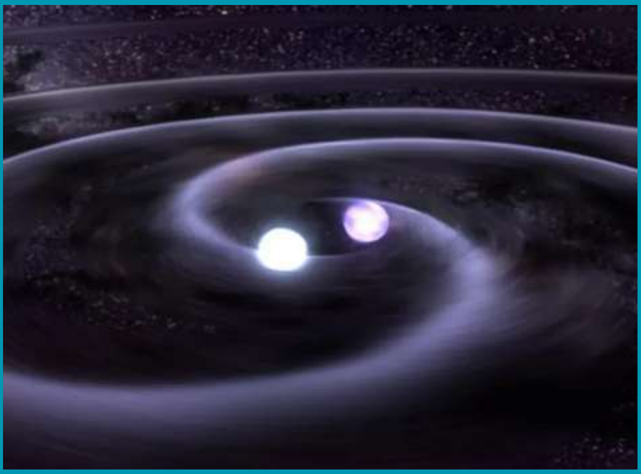
Since the initial detection in 2015, a series of groundbreaking observations have been made:

- Binary Black Hole Mergers: Most detections have originated from the mergers of binary black hole systems. These events provide important tests of general relativity in the strong-field regime and allow for precise measurements of black hole masses and spins [4, 5]. By analyzing the waveform of the gravitational waves emitted during these mergers, the masses and spins of the black holes, as well as the distance to the source, can be determined. These observations have confirmed some of the most fundamental predictions of Einstein's theory, including the existence of black holes and the nature of their interactions.



- Neutron Star Collisions: The detection of GW170817, the first binary neutron star merger, marked a milestone in multi-messenger astronomy. This event was observed in both gravitational waves and electromagnetic radiation, providing insights into the equation of state of neutron stars and the origin of heavy elements [3, 6]. Neutron stars are the densest objects in the universe, and their collisions provide a unique opportunity to study nuclear matter under extreme conditions.

The electromagnetic counterpart to GW170817, observed across the electromagnetic spectrum from radio waves to gamma rays, provided crucial information about the aftermath of the merger, including the synthesis of heavy elements like gold and platinum in the ejected material.



- Black Hole-Neutron Star Mergers: The detection of GW200105 and GW200115 confirmed the existence of black hole-neutron star systems and their mergers. These observations contribute to the understanding of the formation and evolution of compact binary systems. [7] These systems, in which a black hole and a neutron star spiral together and merge, are less common than binary black hole or binary neutron star systems, and their observation provides valuable data for understanding the dynamics of compact binary evolution and the conditions under which these systems form.

Implications and Future Directions:

The observations of gravitational waves hold significant implications for several areas of physics and astronomy:

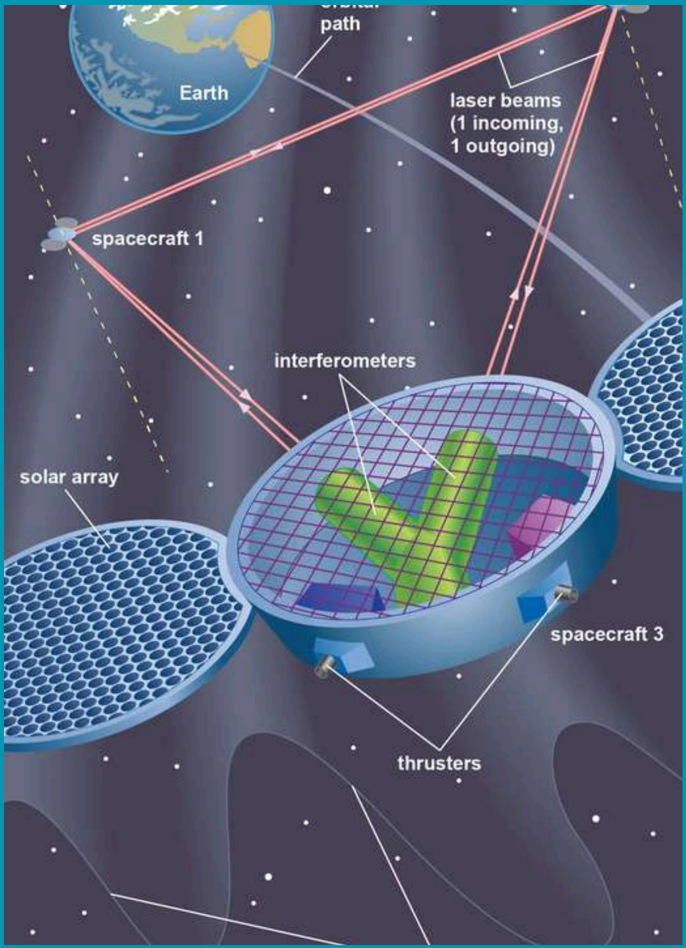
- Tests of General Relativity: Gravitational wave observations continue to furnish stringent tests of general relativity in strong gravitational fields, seeking potential deviations from the theory. To date, general relativity has withstood these tests with remarkable precision [8]. For example, the observation of black hole mergers has allowed the predictions of general relativity to be tested in the highly curved spacetime near these objects, confirming the theory's validity in extreme environments.

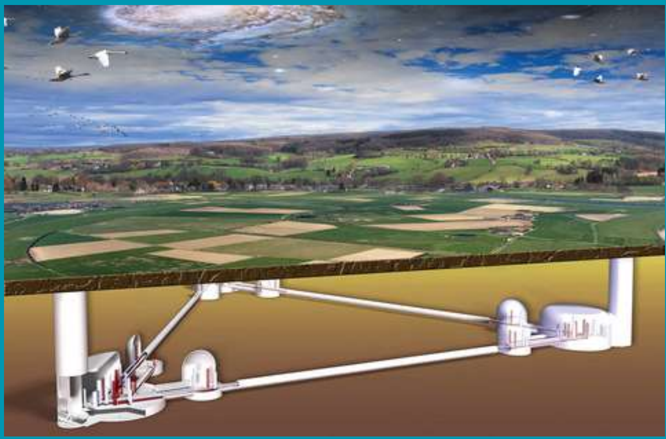
- Astrophysics of Compact Objects: Gravitational waves offer a unique way to study black holes and neutron stars, providing insights into their formation, evolution, and properties. By analyzing the gravitational waves emitted by these objects, their internal structure, masses and spins can be probed, and the processes by which they form and evolve can be studied.

- Cosmology: Gravitational waves can be utilized to probe the expansion history of the universe, measure cosmological parameters, and potentially detect primordial gravitational waves from the early universe [9]. Primordial gravitational waves, generated in the earliest moments after the Big Bang, could provide valuable information about the universe's infancy and the processes that shaped its evolution.

- Fundamental Physics: Gravitational waves may provide clues to fundamental physics, such as the nature of gravity, the existence of dark matter, and the unification of quantum mechanics and general relativity. For instance, some theories predict that gravitational waves may interact with dark matter, leaving observable signatures in the gravitational wave signal.

The future of gravitational wave astronomy holds considerable promise. Upgrades to current detectors, such as Advanced LIGO Plus and Virgo Plus, will augment their sensitivity and detection rate. New detectors, such as LISA and the Einstein Telescope, will expand the range of observable frequencies and sources. These advancements will enable a more detailed exploration of the universe and facilitate answers to some of the most fundamental questions in science. The Einstein Telescope, for example, with its underground design and advanced technology, is expected to exhibit an order of magnitude greater sensitivity than current detectors, probing deeper into the cosmos and detecting events that are currently beyond our reach.





Conclusion:

The detection of gravitational waves has inaugurated a transformative era in astronomy, providing a unique and powerful new means to probe the universe. These observations have already yielded significant discoveries, including the direct detection of black hole mergers and neutron star collisions, and have enabled unprecedented tests of general relativity in extreme conditions. The future of gravitational wave astronomy is poised to revolutionize our understanding of the cosmos, promising to unveil previously inaccessible phenomena and illuminate the fundamental laws of physics with ever-increasing clarity. As detector technology advances and new observatories become operational, we anticipate a wealth of groundbreaking discoveries that will reshape our understanding of the universe for generations to come.

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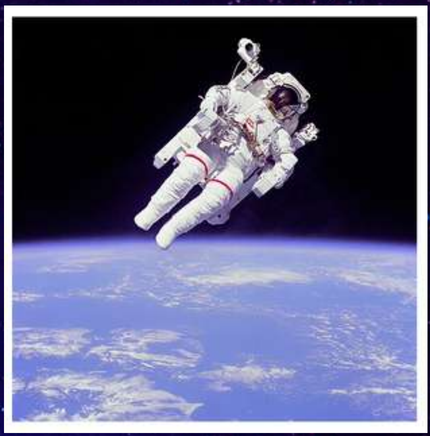
Astronauts

Farriyah Arshi
4th Sem

Journey beyond Earth: The Roles and Challenges of Astronauts

An astronaut (from the Ancient Greek (astron) , meaning 'star', and (nautes), meaning 'sailor',) is a person trained, equipped, and developed by a human spaceflight program to serve as a commander or crew member of a space craft. Although generally reserved for professional space travelers, the term is sometimes applied to anyone who travels into space, including scientists, politicians, journalists, and space tourists.



"Astronaut" is the general term for any human who travels into space, regardless of nationality. In Russia and the former Soviet Union, space travelers are known as "cosmonauts," a word derived from the Russian "kosmos," meaning "space," which itself comes from Greek. For Chinese space travelers, the term "taikonaut" (from the Mandarin "tàikōng," meaning "space") is sometimes used in international contexts, but the official term in China is "yǔhángyuán." Chinese astronauts are selected and trained by the People's Liberation Army Astronaut Corps. These different terms reflect each nation's unique spaceflight history and tradition.

Since 1961 and as of 2021, 600 astronauts have flown in space. Until 2002, astronauts were sponsored and trained exclusively by governments, either by the military or by civilian space agencies. With the suborbital flight of the privately funded SpaceShipOne in 2004, a new category of astronaut was created: the commercial astronaut.

An astronaut's profession is an extremely demanding one, that requires a certain scope of abilities and a tremendous amount of dedication and selflessness.

To begin with, one of the benefits of being an astronaut is the opportunity to explore life outside of the Earth, which essentially means explore helping further humanity's knowledge of the universe. Not only does this include working with a diverse group of people, but also creating new bonds and engaging in educational conversation about colleagues' backgrounds and cultures. Furthermore, this career path offers a chance to make a mark in history.

On the other hand, astronauts are faced with numerous difficulties throughout their journey of changing the course of humanity and space travel. However beneficial it may be, living in a space station implies leaving behind one's previous way of life and leading a somewhat solitary life without being able to turn back easily on demand. Moreover, it could be the cause of stress and anxiety. Despite the cultural enrichment one may experience difficulties, such as a health issues, including muscle weakness, impairment of blood vessels and effects of radiation exposure.

Present Astronauts in Space Missions (2025):

As of June 2025, astronauts from multiple countries are working together on the International Space Station (ISS) as part of Expedition 73. The crew includes members from NASA (USA), Roscosmos (Russia), ESA (Europe), and JAXA (Japan), who are engaged in scientific research, station maintenance, and preparing for upcoming commercial missions. In recent years, private companies such as SpaceX and Axiom Space have also sent commercial astronauts to the ISS, reflecting the growing role of private industry in space exploration.

A significant milestone for India has been achieved: Group Captain Shubhanshu Shukla became the first Indian citizen to visit the ISS, launching aboard Axiom Mission 4 on June 25, 2025. He lifted off from Kennedy Space Center's historic Launch Complex 39A aboard SpaceX's Falcon 9 as the pilot of Crew Dragon capsule "Grace". This mission marks India's return to human spaceflight for the first time in over four decades, following Rakesh Sharma's 1984 flight. The Axiom-4 mission will last around 14 days and focus on over 60 experiments, including research in microgravity, Earth observation, and growing superfood crops like moong and fenugreek in space. Although the mission has faced some delays due to technical and safety concerns, it marks a major step for India's space ambitions and paves the way for future missions like Gaganyaan.

Significance:

The ongoing collaboration between international space agencies, the rise of commercial spaceflight, and India's increasing participation reflect a new era in human space exploration. The presence of astronauts from diverse backgrounds aboard the ISS not only advances science and technology but also inspires nations and future generations to dream beyond Earth.

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Indian Astronauts


Rakesh Sharma


Kalpana Chawla


Shubhanshu Shukla


Angad Pratap


Prasanth Nair


Ajit Krishnan

The Moon : Pride of our Blue Planet

Barnali Das
4th Sem

The study of the earth-moon system provides the connecting link between purely astronomical studies of the origin of solar system and its planets, geophysical and biological studies of the evolution of the earth's geological features, atmosphere and hydrosphere and of terrestrial life.

The Formation of the Moon

About 4.5 billion years ago, during the early history of our solar system, it is widely believed that a Mars-sized asteroid, called Theia, collided with the young Earth. This giant impact scenario, supported by both simulations and lunar sample analysis, suggests that the collision ejected vast amounts of molten and vaporized debris into space. This material eventually coalesced to form the Moon. After its formation, the Moon orbited Earth at a much closer distance than it does today.

Early Consequences of a Close Moon

When the Moon first formed, it was approximately 22,530 km from Earth—about 17 times closer than its present average distance of 384,400 km. This close proximity had significant effects:

- Faster Earth Rotation: The young Earth spun much faster, resulting in much shorter days—possibly only about 5 hours long.
- Strong Tidal Effects: The gravitational pull of the nearby Moon produced much higher tides, leading to dramatic tidal forces on the early Earth.

Tidal Acceleration and the Moon's Recession

The Moon is slowly moving away from Earth due to a process called tidal acceleration. The Moon's gravity creates tides in Earth's oceans, and the friction from these tides gradually slows Earth's rotation. The energy lost by Earth is transferred to the Moon, causing it to spiral outward at a current rate of about 3.8 centimeters per year.

The Future Impact of a Receding Moon

As the Moon continues to drift away, several long-term changes are expected:

- Longer Days: The slowing of Earth's rotation will gradually lengthen the day, potentially impacting daily life by increasing the number of hours in a day.
- Weaker Tides: With the Moon farther away, tidal forces will weaken, leading to smaller ocean tides. This could disrupt coastal ecosystems, affecting species that depend on tidal environments and potentially altering ocean currents that influence global weather patterns.
- Climate and Ecosystem Effects: Weaker tides and altered ocean currents could lead to more extreme temperatures and increased climate instability. Coastal habitats could diminish, threatening marine and terrestrial species linked to these ecosystems.
- Stability of Earth's Tilt: The Moon's gravitational pull currently helps stabilize the tilt of Earth's axis, which is responsible for the regular cycle of seasons. As the Moon drifts away, Earth's axial tilt could become less stable, possibly resulting in either extreme or diminished seasonal changes, with further consequences for climate and ecosystems.

Past Moon Expeditions

The first era of Moon exploration began in the late 1950s and reached its peak during the Space Race between the United States and the Soviet Union. The Soviet Luna program achieved the first successful Moon impact (Luna 2, 1959) and the first unmanned soft landing (Luna 9, 1966). The most famous missions were NASA's Apollo program:

- Apollo 11 (1969) saw Neil Armstrong and Buzz Aldrin become the first humans to set foot on the lunar surface, famously declaring, "That's one small step for [a] man, one giant leap for mankind."
- Between 1969 and 1972, six Apollo missions (Apollo 11, 12, 14, 15, 16, and 17) successfully landed twelve astronauts on the Moon, conducting scientific experiments and collecting lunar samples.

After Apollo, lunar exploration slowed, with robotic missions from the Soviet Union and decades-long gaps in surface exploration.

Present Moon Missions

Interest in the Moon has surged in recent years, driven by new scientific, economic, and strategic goals.

- China's Chang'e program has achieved several milestones, including landing the first spacecraft on the far side of the Moon (Chang'e 4, 2019) and returning lunar samples to Earth (Chang'e 5, 2020).
- India's Chandrayaan program made significant achievements, with Chandrayaan-3 (2023) marking India as the first country to successfully land a probe near the lunar south pole.
- NASA's Artemis program aims to return humans to the Moon. Artemis I (2022) was an uncrewed test flight; Artemis II and Artemis III plan to send astronauts to orbit and land near the lunar south pole later this decade.
- Other countries and private companies (such as SpaceX and ispace) are developing their own lunar missions, including robotic landers and potential commercial infrastructure.

Prospects for Human Habitation on the Moon

With renewed exploration, the concept of establishing a human presence on the Moon is moving from science fiction toward reality.

- Near-term plans focus on building sustainable lunar bases near the south pole, where water ice has been detected in permanently shadowed craters. Water is essential not just for life support, but can be split into hydrogen and oxygen for rocket fuel.
- Technology development: Robotic construction, in-situ resource utilization (ISRU), solar energy harvesting, and closed-loop life support systems are all areas of active research for future habitats.
- International partnerships: The Artemis Accords, signed by more than two dozen nations, promote peaceful cooperation and responsible resource use on the Moon.

While many technological, economic, and ethical challenges remain, such as radiation protection, psychological health, and reliable transport—permanent lunar settlements may one day serve as research bases, mining operations, and stepping stones for deeper space exploration.

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A Cosmic Quest

Shweta Mukherjee
4th Sem

When the ancient eyes used to look up at the banner of heavens above, the joy, the wonder, the curiosity they felt is shared all these hundreds of thousands of years later, by their descendants. As we walked further down the time lane, whilst observing the enigmatic universe, we also asked an alien question, "Are we alone in here?". Let us get on a quest to try to find some answers about our potential cosmic neighbors.

तिरश्चीनो विततो रश्मिरेषामधः स्विदासीदुपरि स्विदासीत् |
रेतोधासानमहिमानमस्मिन्समुद्रे अर्णवे अभवद्या विश्वायुरुच्छ्रितः ||

"Obliquely was extended their cord; was there a below, or was there an above? Seed-bearers there were, mighty forces, potentialities. Below was the lower half, and above, the upper half. The universe emerged from this complex interaction, and from it arose the breath of life."

--- Nasadiya Sukta, Rigveda

Looking out in the Cosmic Capillaries

Life was born in Earth, amost 10 billion years after the 'Big-Bang'. On this planet alone it is estimated that there are several million to trillion species. Then what about the other planets? There are approximately 100 – 200 billion galaxies in the observable universe alone and 200 billion trillion (2×10^{23}) stars. Isn't there any form of life anywhere in this vast, ever-expanding universe? "Where is Everybody?"- This is the essence of the Fermi Paradox. Scientist Enrico Fermi asked this question on a lunch whilst discussing possibilities of alien visitations and interstellar travels. Given the sheer size of the universe and a long time available for life to evolve, it seems statistically probable that intelligent, technologically advanced civilizations should have arisen elsewhere. Despite this high probability, we have found no conclusive evidence of alien civilizations – no alien probes, no radio signals, no megastructures, and no direct visitations. This remains one of the most debated and compelling question of science. But humanity has a long history of searching for the answer to that question. From mythologies to the modern scientific rhapsodies, the search for life beyond earth continues.

Imagine that we are on a mission to find out our chatty neighbors aka active, communicative extraterrestrial civilizations that are out there in our galaxy. Our guidebook to that we'll be "The Drake Equation.". Proposed by Frank Drake in 1961, this equation shows us an idea of how probable it is to find another cosmic civilization. The brilliance of the Drake Equation lies in how it frames the profound question of whether we're alone in the universe, guiding scientific research and highlighting the vast uncertainties that still exist in our knowledge of the cosmos. But there's a catch! Given the probability, why haven't we found the spark of life somewhere out there? The "Great Filter hypothesis" offers a potential explanation to that, suggesting a highly improbable evolutionary step that either we have already passed or lies ahead, preventing widespread detectable intelligence. Our own observational limitations and biases can also play a role. Current search methods (like SETI) are restricted, and alien life or communication might be fundamentally different from what we expect, leading to ideas like the "Zoo Hypothesis". This theory suggests that there are highly intelligent life somewhere in the universe and they are observing us, our planet, without announcing their existence just like how we observe 'caged animals' in a zoo. Maybe they will contact us when the time comes. This theory was proposed by John A. Ball in 1973. There's also something called the 'Dark Forest hypothesis' which tells that ET civilizations actually try to hide their own existence because of the fear of annihilation. Despite all this the search for our celestial co-travelers remain. How do we do that, let us take a look.

Finding the Foreign Footprints

Early Greek atomists pondered infinite inhabited worlds, a concept suppressed by Aristotelian geocentric views but revived in the medieval period by thinkers like Nicholas of Cusa. The Scientific Revolution, starting with Copernicus's heliocentric model and Galileo's telescopic observations, demoted Earth's special status, making the idea of life on other planets more plausible. Enlightenment thinkers, like Kepler and Kant, further speculated on extra-terrestrial life. The 19th century saw "Mars Mania" driven by misinterpreted "canals" and early radio experimenters like Nikola Tesla even claimed possible alien signal detections.

The modern era of the search began with the 1959 paper by Cocconi and Morrison, advocating for radio searches. Frank Drake conducted the first modern SETI experiment, Project Ozma, in 1960, and later formulated the Drake Equation.

SETI, abbreviation for ‘Search for Extra Terrestrial Intelligence’ is an umbrella term for various methods to detect technological civilizations beyond earth. It is all about listening for signals from space, primarily in radio and visible light range. Researchers are on the lookout for technosignatures, which are the patterns within these signals that seem artificial, suggesting they were sent on purpose or are a byproduct of advanced technology from intelligent beings.

There are various methods to look for technosignatures, they are as follows,

- **Radio SETI:** Large radio telescopes are used to "listen" for narrow-bandwidth radio signals. These signals are distinctive because natural cosmic sources typically emit broadband noise across a wide range of frequencies. SETI experiments often focus on specific frequencies, such as the "water hole" between 1.4 and 1.7 GHz, which is considered a quiet part of the radio spectrum associated with hydrogen and hydroxyl molecules. The thought behind is that radio waves are an excellent medium for interstellar communication because they travel at the speed of light and can penetrate interstellar dust and gas relatively easily. Intelligent civilizations might use radio waves to broadcast messages, much like Earth does with its own radio and television transmissions.

Radio Telescopes

- **Optical SETI :** While radio waves are good for continuous communication, powerful, brief laser pulses could be used for signalling across vast distances. Advances in our own laser technology suggest that other civilizations might also employ this method. In this method Optical telescopes equipped with highly sensitive detectors (like photomultiplier tubes) which are used to look for flashes of light that are too bright or too brief to be natural astronomical phenomena. In 2006, Paul Horowitz and The Planetary Society constructed a 1.8-meter telescope at Harvard which began the first dedicated, all-sky optical SETI survey. The search is still in operation, completing a full survey of the sky visible from Massachusetts every 200 nights.

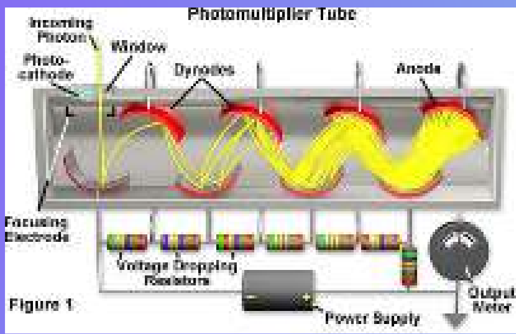
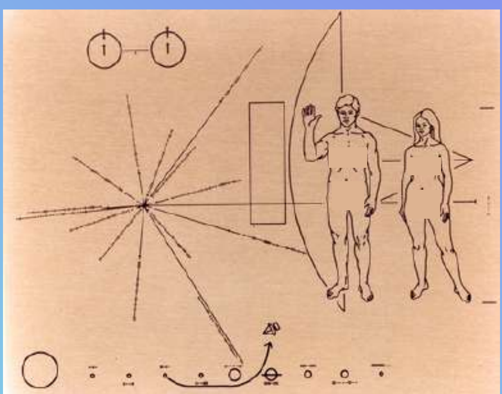


Diagram of Photomultiplier Tubes

- **Astrobiology:** There’s also a relatively newer field of study termed Astrobiology, which is a multidisciplinary field exploring the origin, evolution, distribution, and future of life across the universe. It integrates knowledge from astronomy, biology, chemistry, geology, and physics to answer fundamental questions about life beyond Earth. Key research areas include understanding life's origins on Earth, finding habitable environments in our solar system and on exoplanets, and searching for biosignatures and technosignature. Driven by advanced technology, astrobiology not only seeks extraterrestrial life but also deepens our understanding of life on Earth.

- **Other methods:** There are several other methods which involves using a variety of astronomical instruments and techniques, including spectroscopy (to analyze light for chemical signatures) and transit photometry (to detect changes in star brightness caused by orbiting objects). These methods can detect unusual chemical activity in the atmosphere of exoplanets or unusual patterns of light and heat which might be a sign of intelligent existence. The antithesis of SETI is METI which stands for Messaging Extraterrestrial Intelligence. These methodologies include sending high powered, focused transmissions designed to travel far and be detectable by advanced civilizations. Besides this, there is creation of messages using fundamental mathematics, physics, pictorial system, typically directed towards specific star systems that are considered promising candidates for hosting life, often those with known exoplanets in their habitable zones. Two of the most famous messages is Pioneer plaques & the Arecibo message.

  Pioneer Plaques (1972 & 1973): Pioneer Plaques are two identical gold plated plaques attached to the exteriors of Pioneer 10 and Pioneer 11 spacecrafts. The idea of this unique form of message is the brainchild of astronomer Dr. Carl Sagan. The plaques contain coded messages in the form of pictures Both the plaques begin with the picture of the atom of Hydrogen, an element which is found all across our universe; There are pictures of a man and a woman, position of our sun in the Milky Way galaxy and the plan of the solar system with the flight path of the Pioneer. All the sketches are mathematically and finely designed. Artist Linda Salzman Sagan and astrophysicist Dr. Frank Drake sketched the designs of the plaques.



The Pioneer Plaque

The Arecibo Message

The Arecibo Message (1974): Perhaps the most famous METI message, transmitted from the Arecibo Observatory towards the M13 globular cluster. It was a simple, binary-coded pictographic message representing numbers, atomic elements, DNA, the human form, our solar system, and the Arecibo telescope itself.

Should We Ring?

All these speculations make us wonder, if they are out there , how are they like? Well, we apparently have answer to that too. Developed by astrophysicist Nikolai Kardashev, there's a scale which measures the level of technological advancement of a civilization based on their consumption of energy. This scale is called Kardashev Scale which initially was categorized into three types.

- The first one is Type 1 civilization, which is also called the "Planetary Civilization", who can harness all the energy reaching their home planet.
- Then comes Type 2 or "Steller Civilization" who can harness the entire energy of their host star. When a Type 1 civilization learns to make a Dyson Sphere, they reach type 2. [Dyson Sphere is a megastructure which can encapsulate a star to capture its energy. This civilization has the ability to manipulate their solar system.]
- Then there's Type 3 or the "Galactic Civilization" who can harness the energy of their entire galaxy.

Whilst this was the proposition of Nikolai Kardashev, others have speculated further and subcategorized the existing categories or added new categories. After galactic, there could be Universal, Multiversal, Megaversal and Omniversal Civilization who holds the capability to manipulate every universe, multiverse and megaverse. The 'Omniversal Civilians' basically have "God-like" abilities. Karl Sagan furthered this scale and according to that humans currently stands on level 0.7276. Fascinating and scary! But the continuations of SETI experiments are debatable. Many believe in the theory of "Listen first, talk then." We don't know the potential harm (or perhaps greatness) can come if we ever manage to contact them. So it's better to know them first and then make ourselves known. Secondly, we really don't even have concrete theoretical proof that the bloom of life is somewhere there. So investing money in experiments to contact ET seems such a waste.

Gazing into the time forth

The amount of abuse we are doing on our dear planet will lead us to a great destruction. But humanity goes on and on! So there are plans of terraforming. Terraforming is the process of moderating the atmosphere, geology, geophysical structures, ecology of another planet or moon or any celestial body to make it habitable for Earthlings. Somewhere in the future perhaps this will be happening. Currently the most viable candidate for terraformation is Mars. The reason being is that it shares several Earth-like characteristics, including similar size, axial tilt for seasons, and the confirmed presence of water ice. Evidences suggest Mars once had a thicker atmosphere and liquid water, indicating it holds the necessary resources (frozen water and CO_2) to potentially restore habitable conditions. The current atmosphere of Mars is mostly CO_2, a greenhouse gas, offering a starting point for warming, and its day length is nearly identical to Earth's. However, significant challenges remain, such as Mars lost its global magnetic field, which makes atmospheric retention difficult, its low gravity posing long-term health risks, potentially insufficient volatile compounds for a dense atmosphere, and toxic perchlorates in its soil. There is also Venus, natural satellites like Titan, Europa and many more who are in potential terraforming zones.

Conclusion

The future remains unknowns. We don't know whether we'll ever receive a reply from our celestials neighbours and what consequences it shall bear. We don't know whether we'll ever be Martians. Till then and forever let us take care of Earth as we take care of our homes. Let us nurture our dear planet as we nurture our souls. Let us, the 'Humans' (an identity which we put at the back of our minds, it seems) be "Earthians" first and harmonize and let us roam in the eternal wonder of this universe and sing

"মহাবিশ্বে মহাকাশে মহাকাল-মাঝে
আমি মানব একাকী ভ্রমি বিস্ময়ে, ভ্রমি বিস্ময়ে ॥"

[Translation by Shailesh Parekh:
In this wide world, under this immense sky,
Amidst his all encompassing time,
I, a mere mortal, roam all by myself and wonder!]

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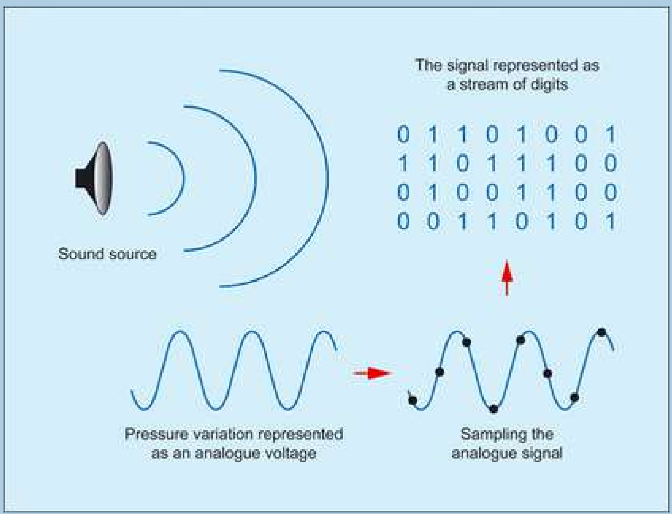
The Physics Inside Your Smartphone: A Pocket-Sized Science Lab

Ariba Khanam
2nd Sem

Smartphones are more than just communication devices, they are compact bundles of scientific wonder. In your hand lies a machine that uses principles of electromagnetism, mechanics, optics, and electronics. Every swipe, selfie, or scroll is powered by physics. Let us dive into how these principles work behind the scenes.

Signal Transmission

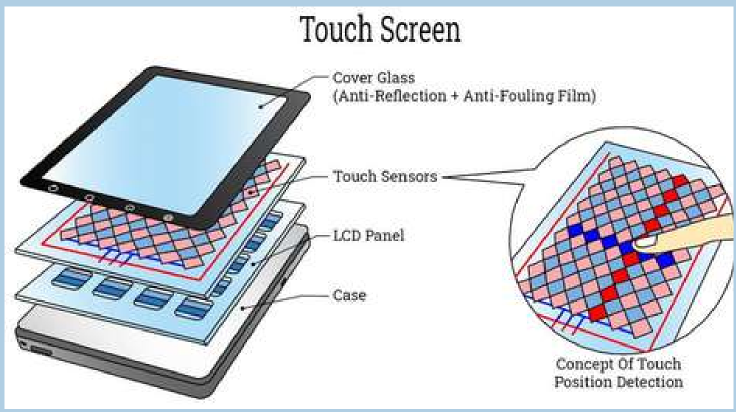
When you speak during a call, your voice is converted by the microphone into electrical signals. These signals are then digitized and transmitted as electromagnetic waves using advanced digital modulation techniques. These radio waves travel at the speed of light in vacuum ($\sim 3 \times 10^8 m/s$), governed by Maxwell's equations, and reach the nearest mobile tower.



Capacitive Touchscreen

Modern smartphones use capacitive touchscreens that rely on electrostatics. When a finger touches the screen, it alters the electrostatic field, changing the local capacitance. The phone senses this and calculates the exact location of the touch.

During transmission, signals face various physical phenomena like reflection, refraction, diffraction, and interference. These effects, explained by wave optics and electromagnetic theory. Engineers use these principles to optimize the signal quality in real-world environments.



Battery and Charging

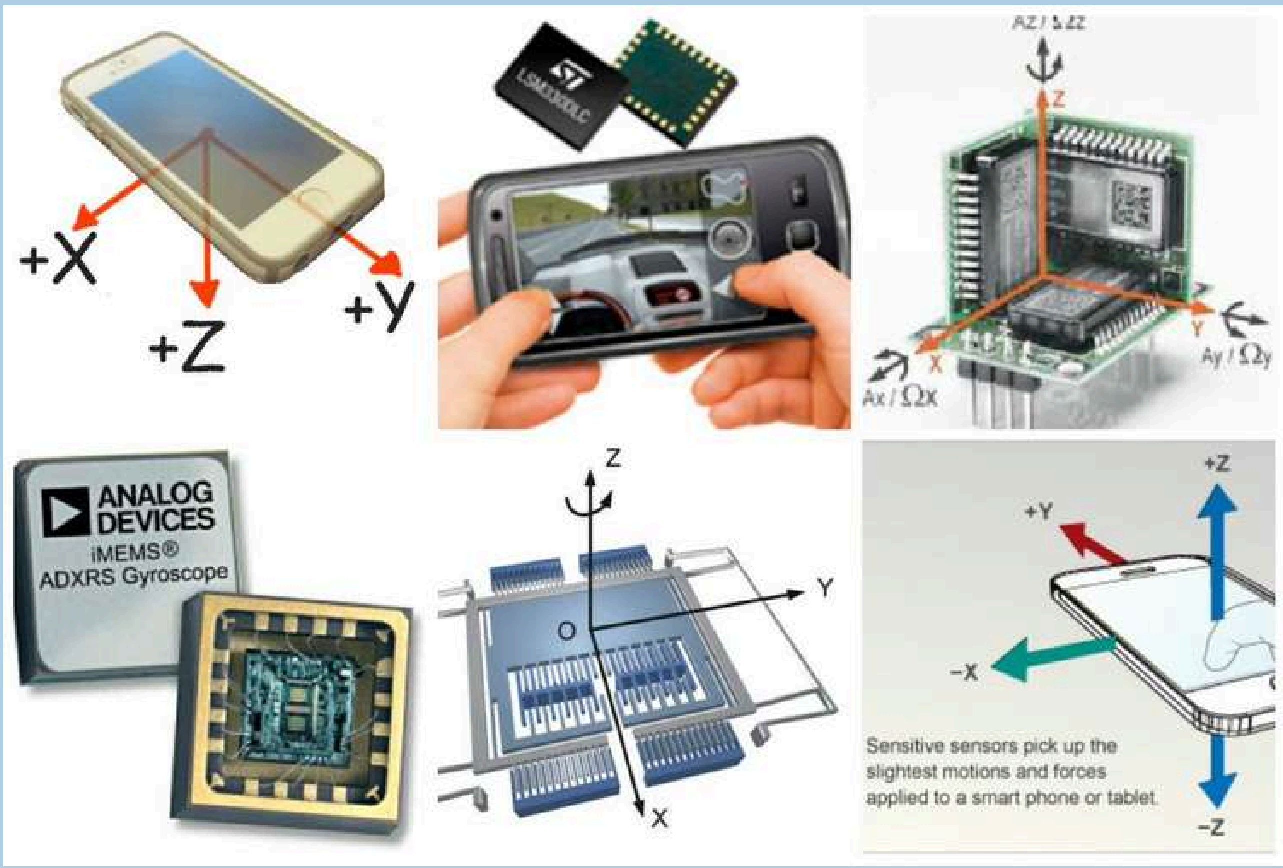
Li-ion batteries in smartphones convert chemical energy into electrical energy through electrochemical reactions. The charging process is controlled by battery management systems that regulate current and voltage, ensuring safe and efficient charging. While circuit design relies on principles like Ohm's Law and Kirchhoff's Laws. Smart circuits and controllers are responsible for preventing overcharging and protecting the battery.

Camera Technology

Smartphone cameras combine optics and semiconductor technology. Light enters through the lens, is refracted, and then strikes a CMOS sensor. The sensor uses the internal photoelectric effect to convert light into electrical signals, which are then processed by the camera's electronics to create digital images.

Built-in Sensors

Smartphones contain multiple sensors, including accelerometers, gyroscopes, magnetometers, and proximity sensors. The operation of these sensors relies on physical principles such as Newton's laws of motion, conservation of angular momentum, mechanics, electromagnetism, and infrared detection. The miniaturization and integration of these sensors are made possible by MEMS (Micro-Electro-Mechanical Systems) technology, which allows for compact and efficient sensor designs in modern devices.



Physics in Your Pocket

Apps like Phyphox transform smartphones into powerful laboratory tools. By accessing the phone's built-in sensors, users can conduct real experiments such as measuring acceleration, tracking motion, and detecting sound or light. These apps make hands-on physics experiments easily accessible and convenient.

End note

Smartphones are remarkable examples of applied physics. Whether it's making a call, taking a photo, or performing calculations, you are constantly engaging with science. Your smartphone is a true pocket-sized physics lab.

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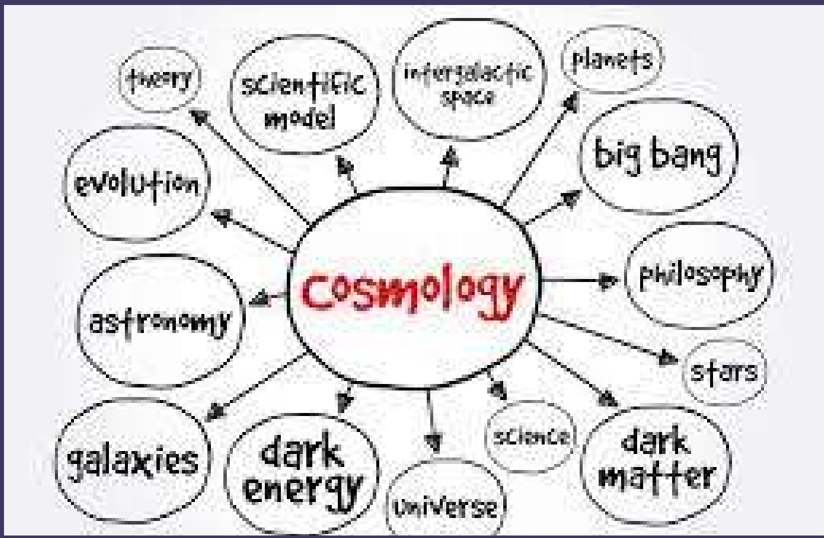
Cosmology: Unveiling the Mysteries of the Universe

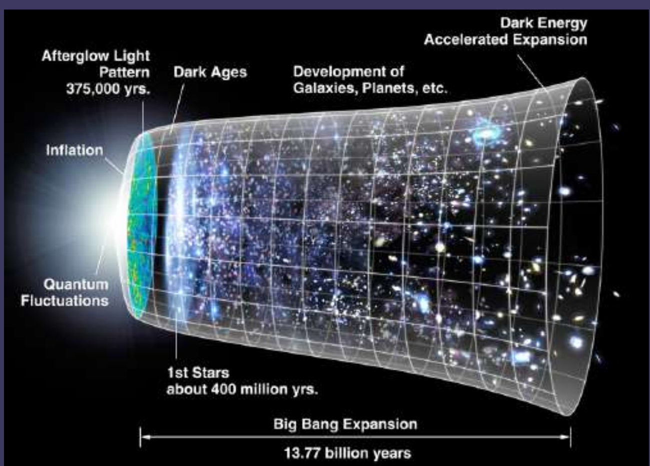
Ariba Shamim
2nd Sem



Cosmology is the study of the universe's origin, evolution, and large-scale structure. It explores fundamental questions about the cosmos, including the Big Bang, dark matter, dark energy, and the cosmic microwave background.

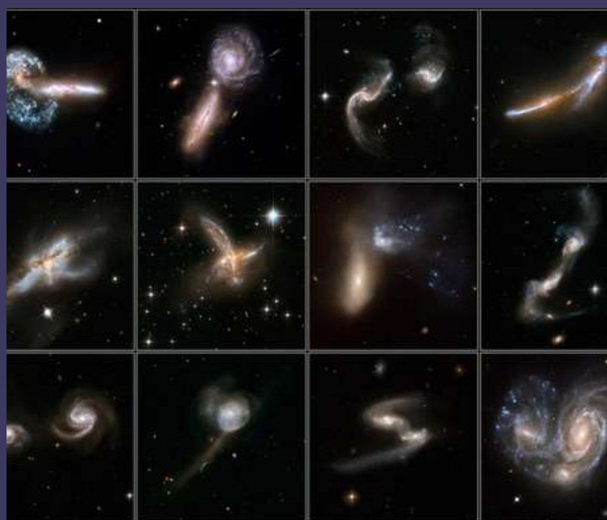
The Big Bang

The Big Bang theory is the leading cosmological model describing the origin and evolution of the universe. According to this theory, the universe began approximately 13.8 billion years ago from a singularity, a point of infinite density and temperature where space and time are undefined, and it has been expanding ever since. This rapid expansion is supported by several key observations, including the redshift of light from distant galaxies—indicating that the universe is still expanding—and the discovery of the cosmic microwave background, which is the faint afterglow of the early universe. Together, these observations provide strong evidence for the Big Bang model.



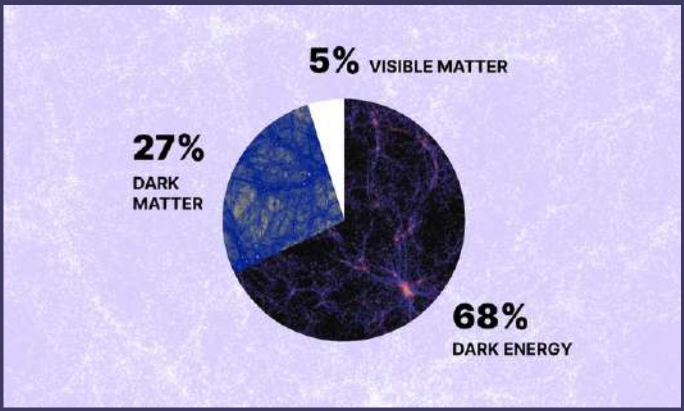
Large-Scale Structure

The universe does not have a uniform distribution of matter; instead, matter is unevenly spread out across vast regions of space. It contains vast large-scale structures, such as galaxies, galaxy clusters, and superclusters, interconnected by cosmic filaments and separated by immense voids—forming a complex "cosmic web." These structures are believed to have originated from tiny density fluctuations in the early universe. Over billions of years, gravity amplified these initial fluctuations, ultimately giving rise to the intricate and hierarchical arrangement of matter observed in the cosmos today.



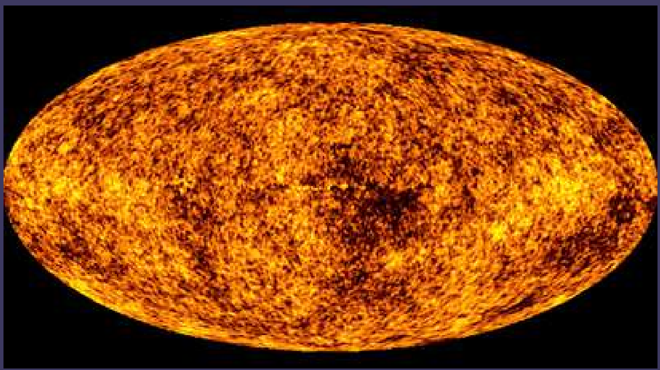
Dark Matter and Dark Energy

Dark matter and dark energy are two of the most mysterious components of the universe, together accounting for about 95% of its total mass-energy content. Dark matter, which constitutes roughly 27% of the universe, cannot be seen directly but reveals its presence through its gravitational effects on galaxies and large-scale cosmic structures. In contrast, dark energy makes up about 68% of the universe and is believed to drive the accelerating expansion observed in the cosmos. Despite their significant roles, both dark matter and dark energy remain major unsolved mysteries in modern astrophysics.



The Cosmic Microwave Background

The cosmic microwave background (CMB) is a faint, pervasive radiation that fills the entire universe, serving as a direct remnant of the Big Bang. This radiation originated roughly 380,000 years after the universe began, when temperatures dropped enough for atoms to form and light to travel freely through space. The CMB offers a detailed snapshot of the universe at that early stage, revealing tiny fluctuations in temperature that correspond to variations in the density and distribution of matter. By analyzing these patterns, scientists can better understand the universe's initial conditions, its composition, and the processes that have shaped its evolution.



Ongoing Research in Cosmology

Cosmology remains a highly dynamic and rapidly advancing field. Researchers continually seek to refine our understanding of the universe's origin, composition, and fate. Major scientific efforts are underway to address key questions about the nature of dark matter and dark energy, the formation of the first stars and galaxies, and the ultimate fate of the cosmos.

The deployment of cutting-edge telescopes, such as the James Webb Space Telescope (JWST), has dramatically expanded our ability to observe the early universe in unprecedented detail. JWST's powerful infrared instruments allow astronomers to detect light from the first galaxies and probe the atmospheres of distant exoplanets. Meanwhile, observatories like the Vera C. Rubin Observatory and the upcoming Euclid mission will offer insights into cosmic structure and the effects of dark energy on the universe's expansion.

In addition to observational advances, cosmologists are leveraging sophisticated computational tools, including large-scale simulations and artificial intelligence, to model cosmic evolution and analyze vast amounts of astronomical data. These combined efforts are pushing the boundaries of knowledge, revealing new mysteries, and reshaping our understanding of the universe on the largest scales.

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The Science of Black Holes

Karina Yadav
2nd Sem

What are Black Holes?

Black holes are regions in space where a vast amount of mass is concentrated within an incredibly small area, producing a gravitational field so strong that nothing, not even light, can escape its pull. Typically, black holes are formed when massive stars reach the end of their life cycle, run out of nuclear fuel, and collapse under their own gravity. This collapse compresses the core into an extremely dense state, giving rise to a black hole. In addition to these stellar black holes, there are supermassive black holes found at the centers of galaxies, whose formation mechanisms are still an area of active research. Some theories also propose the existence of primordial black holes, which may have formed in the early universe.

Black holes captivate both the public and the scientific community, as they represent some of the most extreme and mysterious objects in the universe. By warping space, time, and matter to their limits, black holes challenge our understanding of gravity, quantum physics, and the fundamental nature of reality itself. Their study continues to drive major advances in astrophysics and theoretical physics.

What are Black Holes made of ?

Black holes are not made of ordinary matter in the way that stars, planets, or even atoms are. Instead, a black hole is a region of spacetime where gravity has become so intense, because a large amount of mass has been squeezed into a very small area, that nothing, not even light, can escape from it.

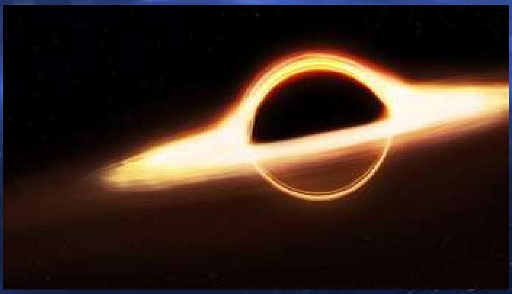
Inside a black hole, all the original matter (such as the core of a collapsing star) has been crushed down by gravity to a single point called a singularity, where density and gravity become infinite according to Einstein's theory of general relativity. However, the true nature of what exists at or inside the singularity is unknown, because our current physics (including quantum theory and relativity) cannot fully describe these extreme conditions.

Types of Black Holes?

Astronomers typically classify black holes into three main categories based on their mass: stellar-mass black holes (ranging from a few to dozens of solar masses), intermediate-mass black holes (hundreds to thousands of solar masses), and supermassive black holes (millions to billions of solar masses). The precise boundaries between these groups are still under active study and may change as new discoveries are made. Additionally, cosmologists theorize the existence of a fourth category, primordial black holes, which could have formed in the very early universe, though these remain hypothetical and have not yet been observed.

- **Stellar Black Holes:** When a star with more than about eight times the Sun's mass exhausts its nuclear fuel, its core collapses under gravity and the outer layers explode in a supernova. The remnant left behind depends on the star's original mass. Stars just above the threshold leave behind neutron stars—extremely dense, city-sized objects. More massive stars, usually with initial masses above 20–25 solar masses, can collapse directly into stellar-mass black holes. The masses of stellar black holes typically range from a few up to about 100 times the mass of the Sun, though some may be larger, especially in low-metallicity environments or after mergers. These black holes can continue to grow by accreting material from companion stars or by merging with other black holes. Most known stellar-mass black holes have been detected in binary systems, often as X-ray binaries, where the black hole draws in gas from a companion star, heating the material so it emits X-rays. While around 50 stellar-mass black holes have been confirmed in the

Milky Way through observations, astronomers estimate that there may be tens of millions to 100 million such black holes in our galaxy.



- **Intermediate-mass black holes (IMBHs):** IMBHs are thought to have masses between about one hundred and several hundred thousand times that of the Sun, bridging the gap between stellar-mass and supermassive black holes. Unlike stellar-mass black holes, which form from the collapse of massive stars, and supermassive black holes found in galaxy centers, the origin of IMBHs is not well understood. Some theories suggest they could form from repeated mergers of smaller black holes over cosmic time, or from the direct collapse of massive gas clouds in the early universe. Scientists also theorize that primordial black holes, formed within the first second after the Big Bang due to extreme density fluctuations, could, in principle, span a wide range of masses, though their existence remains unproven. This “missing link” between stellar-mass and supermassive black holes is of great interest to astronomers, but finding definitive evidence for IMBHs has proven difficult. Although several promising candidates have been identified through gravitational wave detections and unusual X-ray sources, confirming their nature remains a significant scientific challenge.

- **Supermassive Black Holes:** Nearly every large galaxy, including our Milky Way, is believed to harbor a supermassive black hole (SMBH) at its center. These enormous objects typically range from several hundred thousand to tens of billions of times the mass of the Sun. The supermassive black hole at the core of our galaxy, known as Sagittarius A* (pronounced "A-star"), has a mass of about 4 million Suns —modest compared to some SMBHs found in other galaxies. For instance, the black hole at the center of Holmberg 15A is estimated to have at least 40 billion solar masses, making it one of the largest known. Observations have revealed SMBHs in the early universe, less than a billion years after the Big Bang. While their origins remain uncertain, one possibility is that some SMBHs formed from the direct collapse of supermassive stars in the early universe, allowing them to grow rapidly.

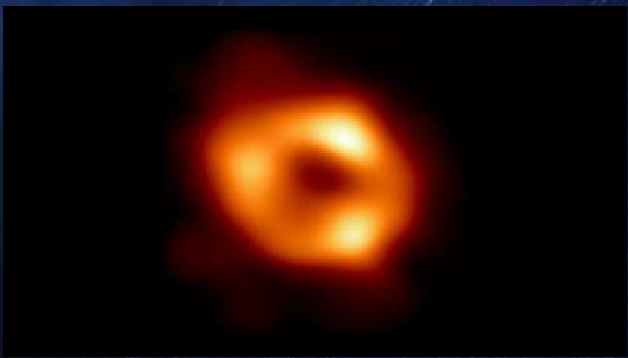
More Detailed Look at Some Key Discoveries

Recent astronomical research has revealed several remarkable insights into the nature of black holes. Scientists have identified so-called “sleeping giant” black holes, massive black holes that remain dormant for long periods, only becoming active when new matter falls into them. Observations have also captured black holes in their early stages of growth, helping us understand how these objects rapidly amass mass in the young universe. On the theoretical front, researchers are developing quantum theories of gravity to explain what happens at a black hole’s core, where the known laws of physics break down. Together, these discoveries are deepening our understanding of the universe’s most enigmatic objects.

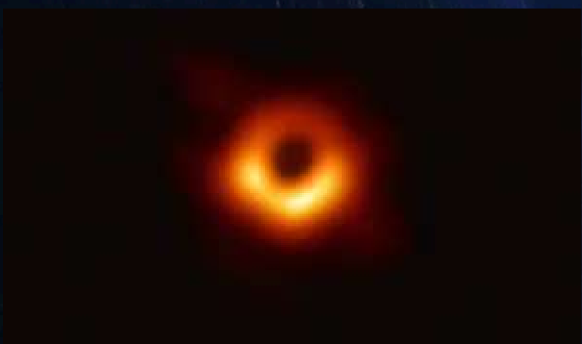
Recent Research and Discoveries

In the past few years, groundbreaking research and observations have greatly expanded our understanding of black holes, particularly some of the most notable ones in the universe.

Sagittarius A* (Sgr A*), the supermassive black hole at the center of our Milky Way galaxy, became the focus of global attention in 2022 when the Event Horizon Telescope (EHT) collaboration released the first-ever direct image of its shadow. This achievement confirmed decades of predictions about its existence and provided new insights into the behavior of matter and energy in extreme gravitational fields.



Similarly, the black hole at the center of galaxy M87 was the first to have its event horizon imaged by the EHT in 2019. This iconic image showed the dark "shadow" surrounded by a glowing ring of superheated gas, offering the strongest visual evidence yet of black holes and further testing Einstein’s theory of general relativity in the strong-field regime.



In addition, astronomers have identified TON 618 as one of the most massive known black holes in the observable universe. TON 618, a distant and extremely luminous quasar, is estimated to have a mass over 60 billion times that of the Sun. Its discovery highlights the diversity and scale of black holes that exist, even in the early universe.

These discoveries not only confirm the existence of black holes but also open new avenues for research into their origins, growth, and the fundamental physics governing them.

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Riding the Equations: The Secret Physics of Your Favorite Thrills

Zarnaz Ahmed
2nd Sem

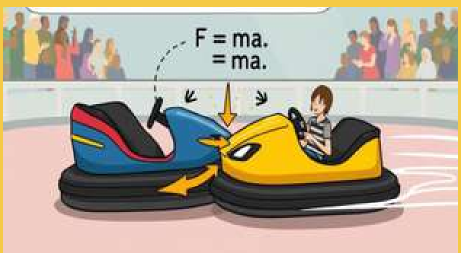
Have you ever wondered why you experience a sensation of weightlessness during a sudden fall or feel unusually heavy at the lowest point of a loop? You're not imagining things that's just physics having a party!. Whether it's the dizzying spin of a teacup ride, water ride, ferries wheel, or the relentless rush of a roller coaster, amusement parks are designed to give us an unforgettable sensory overload. But beneath the dazzling lights and the joyful cacophony, there's a silent, powerful force at play one that dictates every curve, every acceleration, and every safe stop. It's the universal language of physics, speaking to us through gravitational forces, potential energy, and kinetic energy. Prepare to see your favorite rides not just as sources of fun, but as magnificent, real-world physics experiments. Get ready to discover the science that makes your screams so satisfying!"

Bumper Cars: Newton's Three Laws of Motion

Newton's First Law: **Object in motion stay in motion,and at rest stay at rest,unless acted on by an outside force.**
A moving object will continue its motion, without decreasing speed or altering its path, until an external force is applied (like gravity, friction, or air resistance).

When you collide with another bumper car while riding in one, you experience a jolt. This occurs because your body's inertia compels it to persist in the direction it was going with the bumper car, even though the car has abruptly come to a halt.

Newton's Second Law: **The greater the mass of an object , the harder it is to change its speed. In mathematical form :** $F=ma$, **where,** F **is the applied force,** m **is the mass of the body and** a **is the acceleration.**



When riding in the bumper cars, you may have noticed that people who weigh less tend to get pushed around more than people who weigh more.The more mass (weight) an object has, the more force it takes to move it. And since all the bumper cars usually have the same top velocity, the cars carrying more mass will never travel as far as the cars carrying less mass after a collision.

Newton's Third law: **For every action, there is an equal and opposite reaction.**

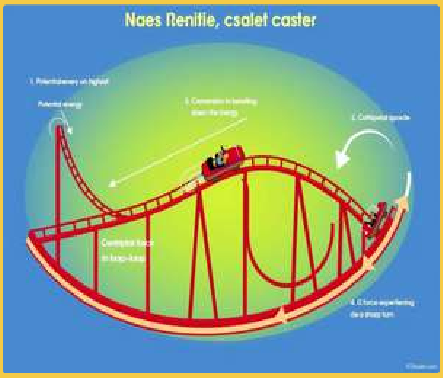
$$F_{action} = -F_{reaction}$$

When two bumper cars that are moving at the same speed and have the same weight collide, they will separate and move an equal distance apart from each other.
According to the second law, if there is a disparity in the weight being carried by the two cars, the lighter car will move farther from the impact point than the heavier car.

Roller Coaster: Putting It All Together

Roller coasters show how these laws, forces, and energies work together perfectly. Roller coasters aren't powered by motors throughout. They are pulled up first to the highest hill, gaining potential energy from their position. As they descend, potential energy (PE) converts into kinetic energy (KE). If h is the height above the ground and v velocity, then we can write,

$$PE = mgh$$
$$KE = mv^2/2$$



Moving down one hill and up the next, kinetic energy shifts back to potential energy until released again on the descent.

Thus, gravity and inertia shape your ride experience.
Loops and twists create centripetal force, keeping coaster and passengers moving in circles.

If we denote F_c as the centripetal force, m as the mass of the body, v as the velocity, and r as radius of the loop, then,

$$F_c = mv^2/r$$

Passengers' inertia resists turns, making them feel pressed into seats during loops. For every action, there's an equal reaction. Without enough force or speed, a coaster can not complete its track.

Ferris Wheel: The Gentle Giant

Ever wondered why you feel heavier at the bottom and lighter at the top of a Giant Wheel ? Its all about chaning weight as the wheel spins . Let's see the physics behind.

- **At the Bottom: your seat fights harder than gravity to push you around the curve.You feel heavier as the centripetal force and the gravitational force act in the opposite direction.**
$$F_N = mg + mv^2/r$$
- **At the Top: Gravity and the curve pull down, so your seat barely pushes up. You feel lighter (or weightless!) .**
$$F_N = mv^2/r - mg$$

As the Ferris wheel's slowdown, graceful motion showcases the effect of centripetal force . The wheel spins at near constant speed, but your direction changes constantly , this inward pulling can be explained by the centripetal force .

Water Rides: Splashdown Science

At the heart of every water ride lies the transformation of energy. The magic starts with gravitational potential energy ($PE = mgh$) as you climb to the top of a slide. This stored energy rapidly transforms into kinetic energy ($KE = mv^2/2$) as you hurtle downwards, thanks to gravity. While some energy is lost due to friction (between you and the slide, and from the water itself), engineers minimize this with smooth surfaces and flowing water. Fluid dynamics explains how the water cushions your ride, reduces drag, and even propels you on certain attractions. In essence, every splash and thrilling drop is a direct demonstration of energy conversion and the forces of fluid motion—making water rides a fantastic blend of fun and fundamental physics!

Sky Diver: Freefall and Flight

Nicco Park's "Sky Diver" simulates freefall using pure physics! As the ride lifts you 80 feet up, you gain gravitational potential energy. When released, this potential energy quickly converts into the kinetic energy and as you plummet, laws of physics actually creates the thrilling freefall sensation. Advanced braking systems then safely slow your descent, often adding exciting bounces before a final stop. It's a controlled burst of energy transformation designed for maximum exhilaration!

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