NATURE OF SCIENCE: A Debate 26

Student Learning Outcomes (SLOs)

The student will

Debates about Beauty in Physics

- [SLO: P-12-G-01] Explain, with examples, what do thinkers who hold the view that there is inherent mathematical beauty in the natural world mean by: (i) elegance of simplicity (ii) symmetry.
- [SLO: P-12-G-02] Explain, with an example, a counterargument to the claim that physical truths must be inherently mathematically elegant or display symmetry.

Debates:

- [SLO: P-12-G-03] Describe the main pros and cons in the debate about: (i) whether humans should research whether there are aliens somewhere in the universe. (ii) whether research should continue on uncovering the secrets of subatomic particles, given the advent of nuclear weapons.

Thought experiments

- [SLO: P-11-G-04] Explain how the below thought experiments helped convey important physics concepts that Would have been impractical investigate empirically: (i) Newton's cannonball

The logic of shape, quantity, and order is the subject of mathematics. The use of mathematics in everything we do. In other words, it's everywhere. In everything the mathematics can be used on a daily basis; for examples: computers, software, hardware, art, money, engineering, sports, and even ancient and modern architecture is built around it.

A fascinating subject, mathematics includes formulas, branches, equations, and mathematical reasoning. Without realizing it, math's significance in daily life can be seen in a variety of ways. In daily duties, mathematics is essential, whether it is for gaming or computation. Whether we enjoy mathematics or not, it is a necessary part of daily life. As a result, we ought to acknowledge this situation and the importance of mathematics in day-to-day living.

26.1 ELEGANCE OF MATHEMATICS

Although mathematics is an extremely elegant field, understanding its elegance requires some knowledge. The beauty of mathematics is a topic that mathematicians like discussing. The synchronizations, patterns, and assemblies of numbers and forms, the traditional principles of symmetry and balance format, make the showcase of the beauty of mathematics.

The elegance of mathematics lies in how well everything fits together, unfortunately, the great majority of people who are frightened by a fear of difficulties with numbers sometimes fail to see its beauty. This is fixed by Mathematical Elegance. The author gives an interesting and approachable picture of the mathematical world through the use of hundreds of examples.

The natural sciences, engineering, health, economics, computer science, and social sciences all depend on mathematics. The fundamentals of mathematics are unaffected by scientific experimentation, despite the fact that they are often utilized to model a phenomenon. Logical reasoning and mental consistency are encouraged by mathematics, which also offers an efficient method of developing mental discipline.

Furthermore, a comprehension of mathematics is essential for understanding the material covered in other academic courses, including natural science, social studies, music, and even the arts. For the purpose of conveying relationships of any kind quantitatively, mathematics is a highly brief language.

Through the years, poets and authors have explored, with sometimes surprising, the link between the expressive richness of natural language and the thoroughness of mathematics.

Artists have used mathematics to create bold analogies and set tight parameters within which they can express their creativity. For example; Jorge Luis Borges, who is inspired by mathematical reasons in several of his works, like the "An Aleph is a point in space that encompasses all other points, offering a unified perspective where every location on Earth can be seen simultaneously from all angles, without spatial confusion or limitation".

The Magic of Mathematics

The majority of people may associate mathematics with intricate equations, chalkboards covered with numbers, and sometimes even recollections of past tests. Mathematics is a universal language that bridges the vast scales of the universe, describing the intricate patterns of a seashell and the majestic spirals of distant galaxies with equal precision and beauty.

Mathematics is the thread that connects everything in the universe, from the fascinating patterns of the Fibonacci sequence seen in sunflowers and pinecones to the basic ideas underlying the technological advancements we use on a daily basis.

Numbers are not the only thing in mathematics. It is the fundamental component of invention as well as the language of the cosmos and the beat of nature. You are experiencing the amazing magic of mathematics every time you are surprised by the design of a building, listen to a beautiful melody, or just esteem the symmetry of a snowfall.

Mathematicians behave like Poet; who conveys a wide spectrum of human experiences and emotions with the help of flowers' delicate petals, brilliant colours, and perfumed tracks. Similarly universal equation is very much similar to flower where different parameters, numbers play role like petals, colour and even perfume to design equation, for example:

The Euler's Equation;

$$e^{i\pi} + 1 = 0$$

Euler's identity shows that geometry, calculus, and complex numbers are intimately related. Everybody knows the value of π, which represents the ratio of a circle's diameter to its circumference. Scholars have researched this universal mathematical constant for millennia. It is fundamental to geometry and can be found everywhere. Another number that is at least as significant as π is e, which is approximately 2.718281. It is used to describe how something can increase or decrease in proportion to itself, which is a fundamental idea in calculus, and it plays a special role in the definition of exponentiation. Indeed, 'e' holds the same significance in calculus as π does in geometry.

Finally, there is '*i*', the hypothetical unit. In contrast to 'e' and 'π', '*i*' is not a number. It is absent from the standard number line. It is essentially a fictitious number: Although it was long since established that negative numbers had no square roots, someone questioned whether or not this would still hold true in practice. It turns out that complex numbers—numbers with both real and imaginary components—are produced when square roots of -1 are allowed. *i*, which is the positive square root of -1, is the fundamental unit of analysis in sophisticated mathematics.

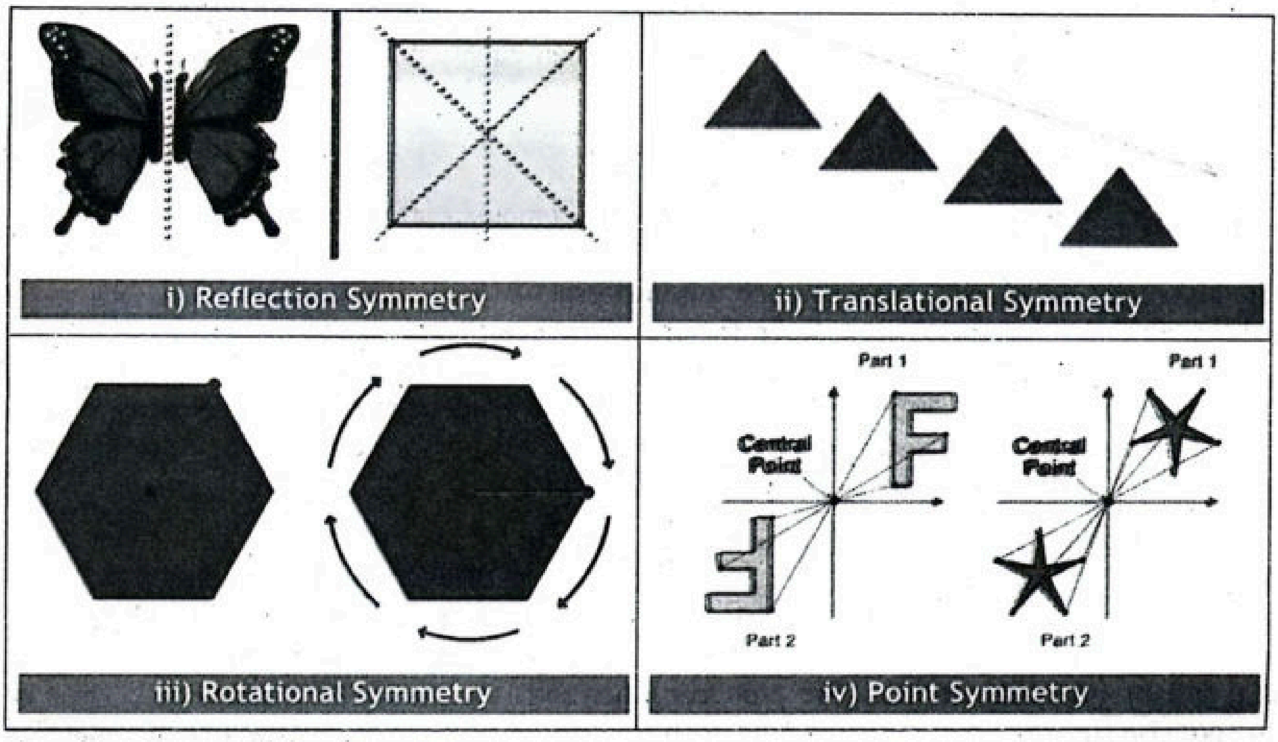
Indeed, 'e' holds the same significance in calculus as π does in geometry. π, e, *i*. the three integers that matter most in mathematics. They all appear to be quite unique, don't they? Throughout thousands of years of mathematical history, various individuals have studied them, they are all abstract, and they appear to have no clear connection to one another. They are also derived from quite distinct areas of mathematics. Complex numbers, geometry, and calculus are closely connected, as demonstrated by Euler's identity. After all, they may be explained in terms of one another, therefore they are not really distinct domains. Complex numbers can be thought of as the link between circular motion and arithmetic: The arithmetic of complex numbers provides information on angles, rotations, cycles, and periods, whereas the arithmetic of real numbers informs us about quantities.

Symmetry

In mathematics, symmetry is the balance and proportion that an object or geometric figure displays when one half reflects the other. It happens when specific points, lines, or forms perfectly match one another along a given axis. Group theory is an important area of algebra with applications in computer graphics, chemistry, and crystallography. The study of symmetry is essential to comprehend group theory.

People typically associate symmetry with reflecting a picture over a single plane to reveal the exact identical image, much like when they look in a mirror. However, that is merely one kind of symmetry. There are lots of alternative options. Rotational symmetry, for example, explains that an object's attributes remain unchanged as it is rotated around an axis, such as the Earth's orbit.

The word symmetry can be studied in the following four different phases;



i) Reflection Symmetry

ii) Translational Symmetry

iii) Rotational Symmetry

iv) Point Symmetry

Applications of Symmetry

Not only does symmetry exist in abstract mathematical ideas, but it also infuses everyday life and effects on many aspects of human existence.

Architecture: Structurally sound and aesthetically pleasing buildings are the result of architects using symmetry.

Art and Design: Artists frequently utilize symmetry in their works of art to attain harmony and balance.

Nature: The radial symmetry of starfish and the hexagonal symmetry of honeycombs are only two examples of the many examples of symmetrical wonders found in nature.

Music: Symmetry is a tool used by composers of melodies and harmonies to arouse feelings and produce enjoyable aural experiences.

The world in which we live is three-dimensional. While there are many advantages to this, according to Ivan Loseu, a mathematics associate professor at Northeastern University; it also makes for a challenging math problem. He claimed that minimizing the number of variables at play is the best route to a solution. Imagine that the Earth is rotating around the sun. Given that the motion takes place in three dimensions, the Earth's position can only be described by three variables. Given that the Earth never deviates from a specific plane, Newtonian physics allows us to further decrease the number of variables to only two. One variable is actually preferable to two, though. This is the reason why physicists track the Earth's elliptical journey using the characteristics of gravitational force.

According to Loseu,

The formula for gravity depends only on the distance between the sun and Earth. You can change the image, but the physical law doesn't change.

He said that symmetry is the single most important factor explaining why this problem can be resolved with just one variable.

According to Loseu, symmetry is any transformation that keeps your issue intact.

What Scientists say about Mathematics?

Pure mathematics is, in its way, the poetry of logical ideas.

(Albert Einstein, German theoretical physicist)

We will always have STEM with us. Some things will drop out of the public eye and go away, but there will always be science, engineering, and technology. And there will always, always be mathematics.

(Katherine Johnson, African-American mathematician)

Mathematics as an expression of the human mind reflects the active will, the contemplative reason, and the desire for aesthetic perfection. Its basic elements are logic and intuition, analysis and construction, generality and individuality.

(Richard Courant, German-American mathematician)

It is impossible to be a mathematician without being a poet in soul.

(Sofia Kovalevskaya, Russian mathematician)

Elegance of Mathematical Poetry

Pythagoras' Theorem

This equation represents the relationship between a right-angled triangle's sides, is a fundamental concept in geometry. Its simplicity and universal validity are reflected in rocket flight, building design, and a myriad of other uses.

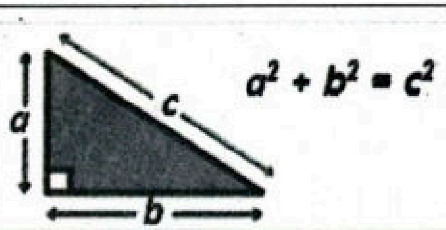


Figure 26.1: Pythagoras' Theorem.

Mass-Energy Equivalence

It is arguably the most well-known equation in physics, connecting mass (m), energy (E), and the speed of light (c). It reveals a significant truth about the inter convertibility of mass and energy with beauty and conciseness.

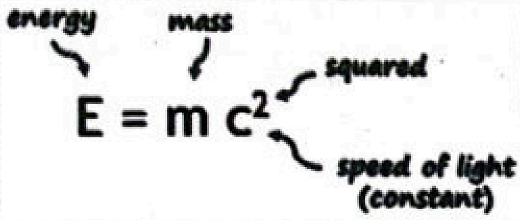


Figure 26.2: Mass-Energy Equivalence.

Planck-Einstein Relation

A fundamental formula in quantum physics, the Planck-Einstein relation (E=hv), states that a quantum of energy (E), sometimes known as a photon, is equal to the Planck constant (h) times the oscillation frequency of an atomic oscillator. Planck's equation quantized energy is employed to liberate electrons from the photovoltaic material, resulting in the creation of an electric current.

$$E = h\nu = \frac{hc}{\lambda}$$

Figure 26.3: Planck-Einstein Relation.

Euler's Identity

This equation establishes an amazingly simple relationship between five of the most important numbers in mathematics: 0, 1, π, e, and i. It unites disparate mathematical domains in harmony, bridging them like a moving poem.

$$e^{i\pi} + 1 = 0$$

Figure 26.4: Euler's Identity.

26.2 ARE ALIENS REAL?

The prospect of life beyond Earth has long fascinated human curiosity. Since man discovered that Mars and other surrounding planets were distinct from other points of light in the night sky, people have speculated about the possibility of otherworldly life. The question of whether we are alone in the universe remains unanswered even though modern technology has made it possible for us to investigate those worlds up close and even look at (and hear from) planets orbiting other stars.

A very interesting comment on existences of aliens or aloneness of Earth;

> Two possibilities exist: either we are alone in the Universe or we are not. Both are equally terrifying.
>
> (Arthur C. Clarke, science fiction author and former Planetary Society board member)

Many people have an alien belief; however, this idea is mostly based on movies and reports of UFOs (unidentified flying objects). However, science sheds light on the possibility that we are not alone in the universe and can address some of the most pressing concerns regarding the nature of life that is most likely to exist.

Where might aliens exist?

There's a chance that life from beyond the solar system exists.

The comprehensive Mars exploration program of NASA (National Aeronautics and Space Administration) and other space organizations have taught us that the red planet was once a warm, wet planet that may have supported life. Even though scientists haven't discovered any evidence of it yet, tiny life might yet be present there. Given that, several of Jupiter's and Saturn's moons have liquid water beneath their ice crusts, there is a chance that these bodies could support otherworldly life. Certain frozen worlds in the outer solar system, such as Europa on Jupiter and Enceladus on Saturn, appear to have potentially functional underground waters. And that's the only thing found in our solar system. The number of divergent settings that potentially support life is increasing as scientists discover additional exoplanets around other stars and that is the thinking domain of future research for space seeker. According to Carl Sagan (American astronomer) point of view;

There is a lot of space in the universe. If we're alone, it feels like a terrible use of space. So, NASA will continue its search.

Main pros and cons in the debate about:

"Should Humans Research the Existence of Aliens?"

Pros:

- **Expanding Human Knowledge:** Researching the existence of aliens can lead to a deeper understanding of the universe, its origins, and the possibility of life beyond Earth.
- **Potential Benefits:** Discovering alien life could lead to new technologies, resources, and insights that could benefit humanity.
- **Inspiring Future Generations:** The search for extraterrestrial life can inspire young people to pursue careers in science, technology, engineering, and mathematics (STEM).

Cons:

- **Resource Allocation:** Researching alien life requires significant funding and resources, which could be allocated to more pressing problems on Earth, such as poverty, disease, and climate change.
- **Low Probability of Success:** The likelihood of finding alien life is currently unknown, and some argue that the probability of success is too low to justify the investment.
- **Risk of Unintended Consequences:** If we were to encounter alien life, there is a risk of unintended consequences, such as contamination or conflict.

Main pros and cons in the debate about:

"Should Research Continue on Subatomic Particles?"

Pros:

- **Advancing Fundamental Knowledge:** Researching subatomic particles can lead to a deeper understanding of the fundamental laws of physics and the nature of matter.
- **Potential Applications:** Discoveries in particle physics can lead to breakthroughs in fields like medicine, energy, and materials science.

- **Inspiring Innovation:** The pursuit of knowledge in particle physics can drive innovation and lead to new technologies.

Cons:

- **Nuclear Weapons:** The discovery of subatomic particles and the development of nuclear physics led to the creation of nuclear weapons, which pose a significant threat to global security.
- **Ethical Concerns:** Some argue that continuing research in particle physics could lead to new, potentially devastating technologies.
- **Opportunity Cost:** The significant resources required for particle physics research could be allocated to other areas of science or pressing global problems.

This debate highlights the complex trade-offs and ethical considerations involved in pursuing scientific knowledge.

26.3 THOUGHT EXPERIMENT: NEWTON'S CANNONBALL

It was common knowledge that objects had a tendency to fall to the ground, but no one was sure why. Yes, the term "gravitas," which simply means "having weight" or gravity, was applied to this unexplained effect. It was Newton who explained gravity, not who discovered it. Newton provided a clear mathematical law that could be tested to explain all of these occurrences and tie them together in a straightforward manner. The apple and the Moon are both connected to the Earth by gravity. The Moon moves sideways, which accounts for their different motion and the reason it doesn't land on Earth.

There were following two curiosity points of Newton's research domain;

1. Why doesn't the Moon fall from the sky and land on Earth, given that all objects experience gravitational acceleration towards Earth?
2. Why does the Moon move in a circle instead of a straight line, if, as Galileo said, objects move with constant speed and direction until acted upon by an external force?

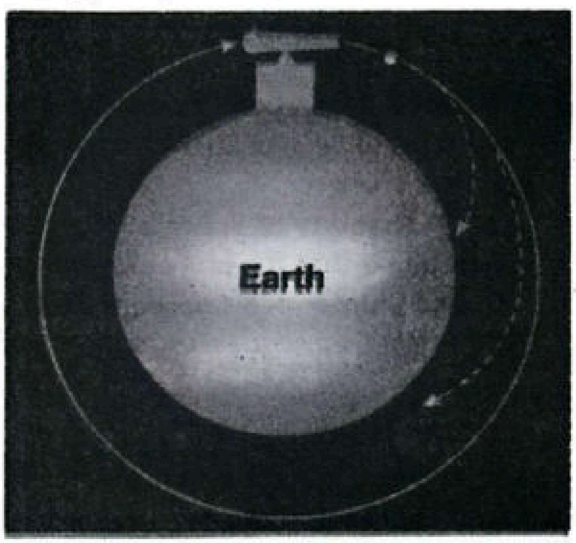


Figure 26.5: Newton's Orbital Cannon.

Newton understood; due to the combination of its orbital motion and inertia, the Moon does not fall perfectly to Earth, nor does it fly away due to the acceleration Earthward that it experiences.

Newton devised a designed experiment in which cannon was positioned on a towering mountain and shot horizontally, as shown in Fig. 26.5. He was aware that the cannonball's horizontally travel distance in a time interval (t) could be calculated by multiplying its speed (v) by the interval like; horizontal distance covered by cannon ball can be measured as;

$$X = vt$$

While the vertical distance covered by cannon can be measured as;

$$Y = \frac{1}{2}gt^2$$

Newton therefore understood that, if he selected the ideal velocity, the cannonball's trajectory would curve at precisely the same rate as the Earth's, as the Earth is spherical, and the projectile would always remain at the same height above the earth.

By doing this, he strikes a balance between the cannonball's inertia, which causes it to desire to keep going in a straight path and away from the Earth, and the acceleration brought on by the Earth's gravity, which causes the cannonball to move towards the Earth's centre. As a result, the projectile orbits the planet, never getting any closer to it yet constantly increasing in speed, though acceleration is the change in velocity i.e., the change in both the speed and direction of an object. The projectile in this instance accelerates even if its speed is constant since its direction is changing. Newton discovered that the acceleration caused by Earth's gravity (a) and the orbit's radius (r), which is measured from the orbit's centre (i.e., the Earth's centre), were connected to the cannonball's speed in the following ways:

$$\text{Centripetal acceleration} = a = v^2/r$$

Newton discovered it for a cannonball orbiting the Earth, but it holds true for any circularly moving object as well. Because of inertia, objects always prefer to move in straight lines; some sort of acceleration is required to cause them to bend into circular motion. The acceleration for Newton's cannonball came from the Earth.

Results

Newton found the following results:

1) If velocity of cannon ball is less than the orbital velocity ball will fall on the Earth.

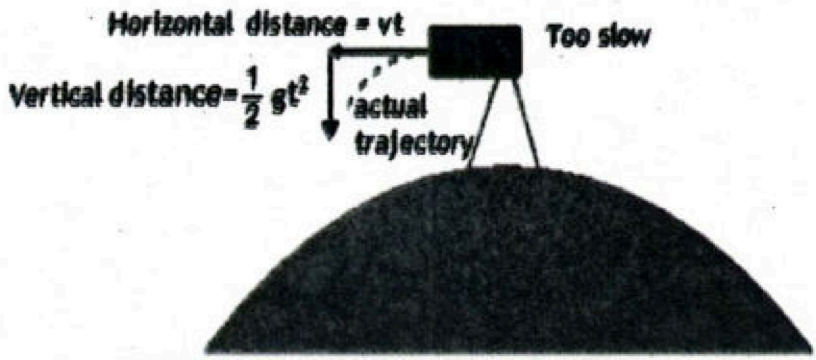


Figure 26.6: Velocity of cannon ball is less than the orbital velocity ball.

2) If velocity of cannon ball is equal to the orbital velocity ball will stay in orbit.

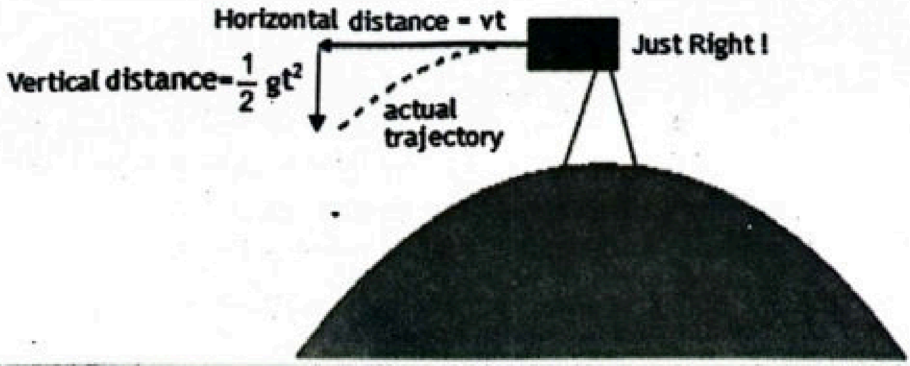


Figure 26.7: Velocity of cannon ball is equal the orbital velocity ball.

3) If velocity of cannon ball is greater than the orbital velocity ball will escape from the Earth.

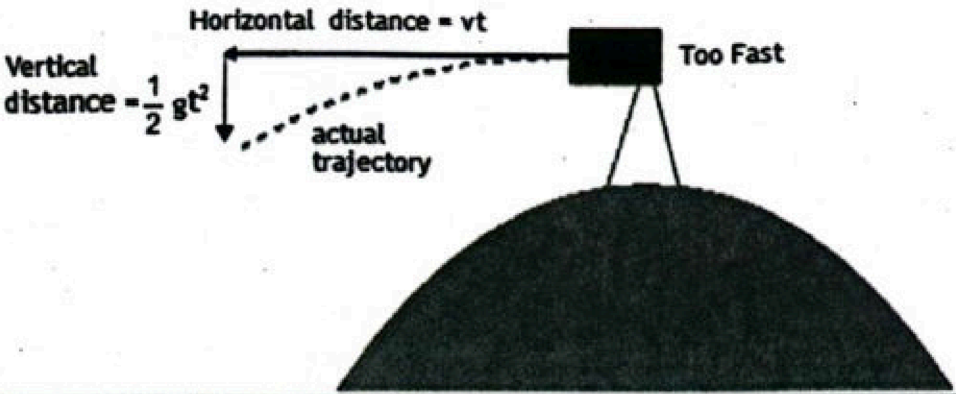


Figure 26.8: Velocity of cannon ball is greater than the orbital velocity ball.

Glossary

Absolute potential energy: The amount of work done in moving a body from Earth's surface to a point at infinite distance where the value of g is negligible.

Acoustic levitation: A method for suspending matter in air against gravity using acoustic pressure from high intensity sound waves.

Aerosol: A suspension of particles or droplets in the air and includes dust, mist, fumes or smoke.

Alpha decay: An atomic nucleus emits an alpha particle.

Amplitude: The maximum displacement of a vibrating body from mean position.

Artificial satellites: objects intentionally placed into orbit around the Earth or other celestial bodies.

Atomic mass: The number of protons and neutrons in the nucleus.

Atomic number: The number of protons in the nucleus.

Beta decay: An atomic nucleus emits a beta particle.

Big Bang theory: The whole Universe expanded outwards from this tiny point to what exists today.

Binding energy per nucleon: Total binding energy of an atom divided by the number of nucleons.

Binding energy: The minimum energy required to break an isolated nuclei into its constituent particles.

Bioelectricity: the generation or action of electric currents or voltages in biological processes.

Biosphere: Thin life supporting layer of Earth's surface. It extends from a few kilometers into the atmosphere to the deep-sea vents in the ocean.

Black body: An idealized object which is perfectly opaque and non-reflecting.

Bose-Einstein Condensation (BEC): A state of matter that forms at extremely low temperatures, such as close to absolute zero, causing particles kinetic energies to decrease significantly.

Butterfly Effect: The metaphor of a butterfly flapping its wings in one part of the world can lead to a hurricane forming in another part of world.

Capacitance: The capability of a capacitor to store charges.

Capacitor: An electric-devices used to store electric energy.

Carbon cycle: Lithosphere plays a major role in carbon cycle which is essential for regulating Earth's climate.

Cepheid variable stars: An example of standard candles.

Chaotic system: A system in which there is no equilibrium and no repeatable patterns emerge it exhibits extreme sensitivity to initial conditions.

Characteristic x-rays: X-rays produced due to transition of electrons between the shells in heavy atoms.

Choke: An inductor used in a circuit.

Climate inertia: The tendency of the Earth's climate to resist or respond slowly to changes in external factors like greenhouse gas concentrations and solar radiations.

Coherent Sources: Waves that have the same frequency and a constant phase relationship are considered coherent. This means the crests and troughs of the waves occur at the same time.

Constructive Interference: When the crests (peaks) of two or more waves overlap, they reinforce each other, producing a resultant wave with a higher intensity (brighter light, louder sound) compared to the individual waves.

Continuous x-rays: X-ray produced due to coulomb interaction of a fast-moving electron with orbital electrons or the positive nucleus.

Control Rods: Rods that are used to control the extent of reaction and do not allow the fuel to react at once.

Coriolis Force: A force resulting from the Earth's rotation.

Count Rate: The number of decays detected per unit time.

Critical Damping: When an oscillator comes to rest without any oscillation in the shortest time under damping force.

Critical Mass: The minimum mass of the material to sustain the fission chain reaction.

Critical temperature or superconducting transition temperature: The temperature below which the resistivity of substance become zero.

Critical volume: The volume occupied by the critical mass of a material.

Cryosphere: Any place on Earth where water is in its solid form.

CT scan: A medical imaging method used to get a detailed 3-D image of certain body parts.

Curie: Unit of activity.

Cycle: One complete set of positive and negative values of an alternating quantity.

Damped oscillations: Oscillations whose amplitude decreases under damping forces.

Degenerate matter: A state of matter where particles are so densely packed that quantum mechanical effects dominate over classical mechanics. This typically occurs in extremely high-pressure environments, such as the cores of massive stars like white dwarfs, neutron stars.

Destructive Interference: When the crest of one wave coincides with the trough of another wave, they cancel each other out partially or completely.

Diffraction Grating: A periodic structure with many closely spaced parallel slits or grooves.

Diffraction Pattern: The spatial distribution of intensity observed after a wave diffracts around an obstacle or through a slit. This pattern typically consists of alternating bright and dark bands due to constructive and destructive interference of the diffracted waves.

Diffraction: The bending of a wave around the edges of an obstacle or through a narrow slit.

Earth's Climate System: A complex system with five interacting components the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere.

Electron microscope: A device that is based on the wave characteristics of electron.

Electroreception: ability of some animals to detect weak naturally occurring electrostatic fields in the environment.

EMF: energy supplied by a battery per unit charge

Energy imbalance: The uneven distribution of solar energy across the Earth's surface creates an energy imbalance.

Equilibrium position: position where the spring is neither stretched nor compressed.

Exosphere: The outer most layer merging into space is the exosphere which extends from 600 km up to merging into the space.

Farad: unit of capacitance.

Filtering: In a rectifier circuit, a capacitor smooths out the pulsating direct current into a more stable, constant output.

Fission chain reaction: A fission reaction in which every time at least one released neutron goes further fission.

Fission: A process where the nucleus of an atom splits into two or more smaller nuclei, some particles like neutron and a large amount of energy.

Force constant (k): Characteristic of a spring which is defined as the ratio of the force applied to the spring to the displacement caused by the force.

Forced oscillations: oscillations under the influence any external force.

Free oscillation: Oscillates under the influence of restoring force without any external force acting on it.

Frequency: The number of vibrations or oscillations per unit time.

Fringe Spacing: The distance between two consecutive bright and dark fringes.

Full wave rectification: the complete cycle of AC signal is converted into pulsating DC.

Fusion: A process where two or more light atomic nuclei come close to each other to form a heavier nucleus by releasing a large amount of energy.

Gamma decay: When an atomic nucleus transitions from a higher energy state to a lower energy state, emitting a gamma ray in the process.

Gas centrifuge method: A method uses rapidly spinning centrifuges to separate uranium isotopes based on difference in their masses.

Gas diffusion method: A method used for enrichment of uranium in which the gas is allowed to diffuse from a porous wall.

Geostationary Satellites: satellite that remain stationary above some point on Earth.

Grating Constant (d): The distance between the centers of two adjacent slits (or grooves) in a diffraction grating.

Gravitational field strength: It is a measure of the force exerted by gravity on a unit mass at a certain point in space.

Half-life: The time it takes for half of the radioactive nuclei to decay.

Half-wave rectification: process by which one half-cycle of the AC signal is converted into DC and blocking the second-half

Heisenberg uncertainty: It is impossible to accurately define both, the position and momentum of an object simultaneously.

henry (H): unit of inductance.

Hubble's Law: The recession speed of galaxies moving away from Earth is proportional to their distance from the Earth.

Hydrosphere: All the water on the Earth whether it is in liquid water, solid ice or the gaseous water vapors form.

Hydrostatic equilibrium: The net outward pressure in the core of stars that is counterbalanced by gravity.

Impedance: combine effect of the resistance and the reactance in an AC circuit.

In phase: When the phase difference between two oscillating systems is 0° or 360°.

Interference: The interaction of two or more waves propagating through the same medium, resulting in a superposition effect that can lead to constructive or destructive interference.

Inverse piezoelectric effect: material generate stress when an electric field is applied.

Isotopes: Atoms of same element which have different mass but same atomic number.

K_α characteristic x-rays: x-ray produced due to transition from L-shell to the vacancy in the K-shell.

K_β characteristic x-rays: x-ray produced due to transition from M-shell to the vacancy in the K-shell.

K_γ characteristic x-rays: x-ray produced due to transition from N-shell to the vacancy in the K-shell.

Light Damping: The damping is said to be light when the amplitude of oscillations decreases gradually with time.

Lithosphere: The outermost solid shell of the Earth consisting of the crust and the uppermost part of the mental. It composed of various types of rocks and minerals.

Long-term Inertia: Changes in greenhouse gas concentrations like carbon dioxide take decades to centuries to fully impact the climate system.

Luminosity: Measure of the total power output of radiation emitted by a star.

Mass defect: The difference between the mass of the nucleus and sum of the masses of its constituent particles.

Medical Imaging: Range of tests used to create images of internal body parts.

Mesosphere: Above the stratosphere from 50 km to 136 km (85 miles) is the mesosphere.

Moderator: Material that slows down the neutrons in a reactor.

Monochromatic Waves: The waves having a single wavelength.

Mutual induction: Changing current in one coil induces an emf in neighboring coil.

Newton's law of universal gravitation: Every object in the universe attracts every other object with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Nuclear physics: A branch of physics that deals with the study of the atomic nucleus, its properties and interactions.

Nuclear reactor: A device used to initiate and control a nuclear fission chain reaction.

Nutrient cycles: Elements like carbon (C), nitrogen (N_2) and phosphorous (P) cycle through the biosphere impacting both living organisms and the environment.

Ocean currents: The streams of water that flow constantly on the ocean surface in definite directions.

Orbital velocity: constant tangential speed of satellite in orbit.

Oscillation or vibration: A complete round trip of an oscillating or vibrating body about the mean position.

Oscillatory or vibratory motion: A body moves to and fro about its mean position.

Out of phase: When the phase difference between two oscillating systems is 180°.

Pair annihilation: A process in which an electron-positron pair produces two photons.

Pair production: When a high energy photon interact with matter photon energy is changed into an electron-positron pair.

Parallel plate capacitor: Two identical conducting plates separated by a distance.

Pauli Exclusion Principle: Two electrons cannot occupy same quantum state.

Peak value: Maximum value of alternating quantity.

Permafrost: Permanently frozen ground found mainly in high altitude regions. It contains ice and soil that remain frozen for extended periods.

PET scanner: A powerful imaging technique that allows us for detailed observation of metabolic physiological processes within the body.

Phase difference: The fraction of a period difference between the peaks expressed in degrees.

Phase of the motion: The angle which specifies the displacement as well as the direction of a point executing SHM.

Photoelectric effect: is the process of emitting the electrons from the metal surface when the metal surface is exposed to an electromagnetic radiation of sufficiently high frequency.

Photoelectrons: The electrons which are emitted from a metal surface upon the influence of light.

Piezoelectric effect: Ability of certain materials to generate an electric charge in response to applied mechanical stress.

Potential gradient: Rate of change of potential along with displacement.

Precipitation: Any liquid or frozen water that forms the atmosphere and falls back to the Earth.

Predictability: unpredictable changes arising from dynamic interactions within the climate system rather than being directly caused by external factors.

Pressure gradient: The change in pressure measured across a given distance.

Pressure of gas: The pressure exerted by a gas molecule is a measure of the force exerted by gas molecules per unit area as they collide with the walls of their container.

Quanta: The smallest amount of energy that can be emitted or absorbed in the form of electromagnetic radiation.

r.m.s value: value of an alternating current is that steady current (d.c.) which when flowing through a resistor produce the same amount of heat as that produced by the alternating current when flowing through the same resistance for the same time.

Radiant flux intensity: Luminosity per unit area measured on the surface of the Earth.

Radioactivity: The natural process of emission of radiations from unstable nuclei.

Rectification: process of converting ac voltage into dc voltage.

Redshift: the fractional increase in wavelength (or decrease in frequency) due to the source and observer receding from each other.

Resonance: The phenomena in which the amplitude of vibration of an oscillator attains maximum value when deriving frequency equals the natural frequency of oscillator.

Root Mean Square (rms) Speed: The square root of the mean square speed of the gas molecules.

Rubens tube: A tube used for demonstrating acoustic standing waves.

Satellite: any object that orbits another object due to the force of gravity, maintaining a stable path around it.

Self-inductance: The phenomenon of changing current induces an emf in the coil itself.

Short-term inertia: The ocean and land surfaces absorb and release heat relatively slowly leading to short term inertia this is why daily temperature fluctuations occur.

Simple harmonic motion: Oscillatory motion in which acceleration of the particle is directly proportional to its displacement from the mean position and is always directed towards the mean position.

Simple pendulum: A small but heavy bob of mass m which is suspended by a light and inextensible string

Spontaneous decay: The natural process by which an unstable atomic nucleus breaks down into a more stable configuration by emitting radiation.

Standard candle: An astronomical object which has a known luminosity due to a characteristic quality possessed by that class of object.

Statistical mechanics: A branch of physics that connects the microscopic details of a system (such as motion, energy, and the interaction of individual particles) with the macroscopic observables measure (such as temperature, pressure, volume, and entropy).

Stefan-Boltzmann Law: The total energy emitted by a black body per unit area per second is proportional to the fourth power of the absolute temperature of the body.

Stopping potential or Cut off potential: In the photoelectric experiments, at certain negative voltage at which the current becomes zero.

Stratosphere: Above the troposphere from 16 kilometers to 50 kilometers (31 miles) it is called the stratosphere.

Subtropical Gyres: Large rotating currents that start near the equator are called subtropical gyres.

Super conductivity: In certain conditions, Bose-Einstein Condensation leads to super-conductivity, where electrical resistance drops to zero, allowing current to flow without resistance.

Super fluidity: A notable property of Bose-Einstein Condensation, where condensate shows zero viscosity, allowing it to flow without resistance.

Superconducting transition temperature or critical temperature: The temperature below which the resistivity of substance become zero.

Superconductors: Those substances whose resistivity become zero at very low temperatures.

Tectonic Activity: Processes like tectonics which involves the movement and interaction of lithosphere plates can have significant impact on climate over a large timescale.

Thermohaline circulation: The deep ocean currents are caused by differences in water *density*.

Thermosphere: Above the mesosphere from 136 kilometers up to about 600 kilometers (372 miles) is the thermosphere.

Threshold frequency: The threshold frequency is the lowest frequency of electromagnetic radiation that will produce a photoelectric effect in a material.

Threshold wavelength: The Threshold wavelength is the largest possible wavelength of the incident radiation which allows photoemission to take place.

Time Period: The time taken to complete one oscillation or vibration.

Troposphere: The lowest layer extending from the ground (the surface of the Earth) to about 16 kilometers (10 miles).

Type 1A supernovae: An example of standard candles.

Ultrasound: Sound waves above 20,000 Hz.

Uranium Enrichment: The process of converting non fissile material like uranium-238 into a fissile material like uranium-235.

Van Der Waals Equation: Equation that describe the behavior of real gases, but it can also be used for ideal gases as well.

Vibration or oscillation: A complete round trip of an oscillating or vibrating body about the mean position.

Vibratory or oscillatory motion: A body moves to and fro about its mean position.

Volcanic eruption: A tectonic activity that release gases and particles into the atmosphere.

Volt: unit of electric potential/e.m.f.

Voltage: The potential difference across a cell, electrical supply or electrical component.

Wave front: A surface connecting points in a wave that are in the same phase (at the same point in their cycle).

Wavelength (λ): The distance between two consecutive crests (or troughs) of a wave.

Wien's displacement law: The black body radiation curve for different temperatures peaks at a wavelength, which is inversely proportional to the temperature.

Work Function: The minimum amount of energy required to escape the electron from metal surface.

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