Physical World

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Science
Systematic attempt to understand natural phenomena in as much detail and depth as possible, and use the knowledge so gained to predict, modify and control phenomena

Scientific method
The scientific method involves several interconnected steps:
- Systematic observationsm
- Controlled experiments,
- Qualitative and quantitative reasoningm
- Mathematical modelling, prediction and verification or falsification of theories

Hypothesis and axioms
- A hypothesis is a supposition without assuming that it is true.
- An axiom is a self-evident truth while a model is a theory proposed to explain observed phenomena.

Physics
- Study of the basic laws of nature and manifestation in different natural phenomenon

Principal thrusts
Unification
To explain diverse physical phenomenon in terms of few concepts and laws.

Reduction
To derive the properties of a larger and a more complex problem or system into simpler constituents

Principal domains
Macroscopic domain
Phenomenon at laboratory, terrestrial and celestial scale Mainly dealt by classical physics including mechanics, electrodynamics, optics and thermodynamics

Microscopic domain
Constitution and structure of matter at the minute scales of atoms and nuclei. Mainly dealt by quantum physics

Nature of physical laws
- **Conservation of energy :** In an isolated system, total energy remains conserved.
- **Conservation of linear momentum :** In an isolated system, total linear mmomentum remains conserved.
- **Conservation of angular momentum :** In an isolated system, total mangular momentum remains conserved.
- Symmetry of nature with respect to translation in time is equivalent to the law of conservation of energy
- Symmetry of the laws of nature with respect to translation in space gives rise to conservation of linear momentum
- Isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of angular momentum

Fundamental forces in nature
Strong nuclear force
- Acts between nucleonsm
- Short range (Nuclear size $\approx 10^{-15}$ m)
- Relative strength = 1
- Mediating particles are mesons

Electromagnetic force
- Force due to virtue of charges
- Both attractive and repulsive
- Range is infinitem
- Relative strength = 10^{-2}
- Mediating particles are photonsm

Weak Nuclear Force
- Between some elementary particles particularly electron and neutrinom
- Very short range ($\approx 10^{-16}$ m)
- Relative strength = 10^{-13}
- Mediating particles are bosons

Gravitational Force
- Force of attraction by virtue of mass
- Always attractive in nature
- It is weakest fundamental force
- Range is infinite
- Relative strength = 10^{-36}
- Mediating particle are graviton

Units and Measurements

@anjit

Units

Measurement of any physical quantity involves comparison with certain basic arbitrarily chosen internationally accepted reference called units.

Classification

- **Fundamental units** – Independent of each other
- **Derived units** – Expressed as combination of fundamental units

- A complete set of these units, both the base units and derived units is known as system of units.
- Old system of units: CGS, FPS and MKS system.
- In **CGS** fundamental units are centimeter, gram and second.
- In **FPS** fundamental units are foot, pound and second.
- In **MKS** fundamental units are meter, kilogram and second.

Measurement of length

- Large distance is measured by parallax method.
- Parallax angle $= \frac{\text{Basis}}{\text{Distance}}$
- $1° = 1.745 \times 10^{-2}$ rad
- $1'' = 4.85 \times 10$ rad
- Measurement of very smallm distance like size of molecule uses, Optical microscope, Electronic microscope and Tunneling microscope
- 1 AU = 1.496×10^{11} m
- 1 ly = 9.46×10^{15} m
- 1 parsec = 3.08×10^{16} m
- Size of proton 10^{-15} m
- Radius of Earth 10^{7} m
- Distance to boundary 10^{26} m of observable universe

Measurement of mass

- SI unit is kilogram (kg)
- Unified atomic mass unit (u). It is used to measure mass of atoms and molecules
- 1 u = 1/12 × mass of one C-12 atom.
- 1 u = 1.66×10^{-27} kg
- Electron mass 10^{-30} kg
- Earth mass 10^{25} kg
- Observable universe 10^{55} kg

Measurement of tim

- Atomic standard of time: This is based on caesium clock, uncertainty gained overtime by caesium atomic clock is less than 1 part in 10^{13} (loss of 3 μs in one year)
- Time span of most unstable particle 10^{-24} s
- Travel time for light from nearest star 10^{8} s
- Age of universe 10^{17} s

Significant figures

- Reliable digits plus first uncertain digit are known as significant digit.
- A choice of change of different units does not change number of significant digits.
- All non-zero digits are significant.
- All zero between two non-zero digits are significant.
- The terminal zeros in a number without a decimal point are not significant.
- The trailing zeros in a number with decimal point are significant.

Rules of Arithmatic Operations with Significant Figuresm

- Addition/Subtraction: Final result contains as many decimal places as in number with least decimal places. e.g. 3.307 + 0.52 = 3.83
- Multiplication/Division: Result contains as many significant figures as in number with least number of significant figures. e.g. 4.11/1.2 = 3.4

Rounding off

- Preceding digit is raised by 1 if insignificant digit to be dropped is more than 5 and left unchanged of latter is less than 5.
- If insignificant digit is 5 then preceding digit is left unchanged if its even and uncreased by 1 if it is odd.

Accuracy and precision

- Every measurement by any measuring instrument contains some uncertainty called error.
- Accuracy of a measurement is a measure of how close is the measured value to true value.
- Precision tells us to what resolution the quantity is measured.
- It is not necessary that more precise value is more accurate too.

Units and Measurements

Si system of units (international system of units)

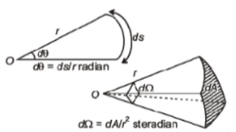
- Presently accepted internationally for measurement is SI system of units, revised in 2018. Certain rules to follow with standard symbols
- It is decimal system thus, conversion within system is easy and convenient
- It has 7 base unit and 2 supplementary units

Base Units

S.N.	Quantity	Unit	Symbol
1.	Length	meter	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Thermodynamic temperature	kelvin	K
6.	Amount of substance	mole	mol
7.	Luminous intensity	candela	cd

Supplementary Units

S.N.	Quantity	Unit	Symbol
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr



Dimensional formulae and si units of various physical quantities

Base Units

S.N.	Physical Quantity	Relation with other quantities	Dimensional Formula	SI Unit
1.	Gravitational constant 'G'	$\frac{\text{Force}\times(\text{distance})^2}{\text{Mass}\times\text{mass}}$	$\frac{[MLT^{-2}][L^2]}{M\times M} = [M^{-1}L^3T^{-2}]$	N m^2 kg^{-2}
2.	Stress	$\frac{\text{Forc}}{\text{Area}}$	$\frac{[MLT^{-2}]}{L^2} = [M^{-1}T^{-2}]$	N m^{-2}
3.	Coefficient of elasticity	$\frac{\text{Stress}}{\text{Strain}}$	$\frac{[ML^{-1}T^{-2}]}{1} = [ML^{-1}T^{-2}]$	N m^{-2}
4.	Surface tension	$\frac{\text{Force}}{\text{Length}}$	$\frac{[MLT^{-2}]}{L} = ML^{-2} = [ML^0T^{-2}]$	N m^{-1}
5.	Coefficient of viscosity	$\frac{\text{Force}\times\text{distance}}{\text{Area}\times\text{velocity}}$	$\frac{MLT^{-2}\times L}{L^2\times LT^{-1}} = [ML^{-1}T^{-1}]$	N m^{-2} or Pa s or decapoise
6.	Planck's constant 'h'	$\frac{E}{v} = \frac{\text{Energy}}{\text{Frequency}}$	$\frac{ML^2T^{-2}}{T^{-1}} = [ML^2T^{-1}]$	J s
7.	Velocity gradient	$\frac{\text{Velocity}}{\text{Distance}}$	$\frac{LT^{-1}}{L} = T^{-1} = [M^0L^0T^{-1}]$	s^{-1}
8.	Pressure gradient	$\frac{\text{Pressure}}{\text{Distance}}$	$\frac{ML^{-1}T^{-2}}{L} = [ML^{-2}T^{-2}]$	Pa m^{-1}

Errors in measurement

Errors

- **Systematic**
  - **Instrumental**
  - **Experimental**
  - **Personal**
- **Random**

- Every measurement is approximate due to errors.
- Random errors occurs irregularly.
- Least count error is smallest value that can be measured by instrument (occurs within both systematic and random errors).
- Absolute error $= \frac{\sum(|a_i - a_{mean}|)}{n}$
- Relative error $= \frac{\Delta a_{mean}}{a_{mean}}$
- Percentage error $= \frac{\Delta a_{mean}}{a_{mean}} \times 100$
- If $X = \frac{A^a B^b}{C^c}$ Then $\% \frac{\Delta x}{x} = a\left(\%\frac{\Delta A}{A}\right) + b\left(\%\frac{\Delta B}{B}\right) + c\left(\%\frac{\Delta C}{C}\right)$

Combination of errors

- **Sum and difference**: $\Delta Z = \Delta A + \Delta B$
- **Product or Quotient**: $\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$

Dimensional analysis

Dimensions

- Nature of physical quantity is determined by its dimension.
- The dimensions of physical quantity are powers to which base quantities are raised to represent it.
- The dimension of timem in speed is –1

Dimensionalequation

- The expression which shows how and which of the base quantities represent the dimension of physical quantity is called dimensional formula.
- An equation is obtainedm by equating physical quantity with its dimensional formula.
- For example $[A] = [M^0L^2T^0]$

Homogeneityprinciple

Physical quantitiesrepresented bysymbols on bothsides of amathematicalequation musthave samedimensions.

Applications

Checking dimensionalconsistency of equations

- It is based on homogeneity law. An equation is dimensionally correct if dimension of fundamental quantities of each term on left side of equation is equal to that on right hand side.

Deducing relations amongphysical quantities.

- **We should know the dependence of physical quantity on other upto three physical quantities and product type of dependence**

Limitations of DimensionalAnalysis

- Dimensional analysis is useful in deducing relations among inter dependent physical quantities but dimensional constant can not be determined.
- It can test dimensional validity but not exact relationship between physical quantities having same dimensions.
- It does not distinguish between the physical quantities having same dimensions.