AFCAT SCIENCE

MEASUREMENT AND ERRORS IN PHYSICS

(ONE LINE APPROACH)

Concept / Term	One-line Explanation	Example / Extra Info
Physical Quantity	A quantity that can be measured and expressed in units.	Length, mass, time, current
Fundamental Quantities	Quantities that are independent and cannot be derived from others.	7 SI base quantities (m, kg, s, A, K, mol, cd)
Derived Quantities	Quantities derived from fundamental quantities.	Velocity, Force, Energy, Pressure
Unit	Standard quantity used to measure a physical quantity.	Meter, kilogram, second
System of Units	Set of fundamental units used to express all quantities.	CGS, FPS, MKS, SI systems
SI System	Internationally accepted system of units (Systeme International d'Unités).	Adopted in 1960
Base Units in SI	Units of seven fundamental quantities.	m, kg, s, A, K, mol, cd
Supplementary Units	Units of plane and solid angle.	Radian (rad), Steradian (sr)
Dimensional Formula	Expression showing how a quantity depends on fundamental quantities.	$[M^1L^1T^{-2}]$ for Force
Dimensional Equation	Equation equating two sides having same dimensions.	$F = ma \rightarrow [M^1L^1T^{-2}]$
Principle of Homogeneity	Dimensions of both sides of a physical equation must be the same.	Used for equation checking
Dimensional Analysis	Method of checking correctness and deriving relations using dimensions.	Used to derive formulas
Limitations of Dimensional Analysis	Cannot give numerical constants or distinguish vector/scalar.	Fails for trigonometric formulas
Accuracy	Degree of closeness of a measured value to the true value.	High accuracy = less error
Precision	Degree of exactness or reproducibility in measurements.	Measured by least count
Least Count	Smallest value that can be measured by an instrument.	Vernier caliper = 0.01 cm
Significant Figures	Digits that convey meaningful information about precision.	Rules applied for rounding off

Error	Difference between measured value and true value.	Error = Measured – True
Types of Errors	Classified as Systematic, Random, Gross errors.	-
Systematic Error	Constant or predictable error due to instrument, method, or observer.	Zero error
Random Error	Error that occurs irregularly, unpredictable.	Fluctuations during experiment
Gross Error	Error due to carelessness or incorrect reading.	Misreading scale
Absolute Error	Difference between measured and true value (positive quantity).	$\|\Delta x\| = \|x_i - \bar{x}\|$
Mean Absolute Error	Average of absolute errors for multiple measurements.	$(\Sigma\|\Delta x\|)/n$
Relative Error	Ratio of absolute error to true value.	$\Delta x / \bar{x}$
Percentage Error	Relative error × 100.	% Error = $(\Delta x / \bar{x}) \times 100$
Propagation of Errors	Error transfer when quantities are added, multiplied, divided, etc.	Used in result calculations
Error in Sum/Subtraction	Absolute errors are added.	$\Delta Z = \Delta A + \Delta B$
Error in Multiplication/Division	Relative errors are added.	$\Delta Z/Z = \Delta A/A + \Delta B/B$
Error in Power	Relative error multiplied by power.	$\Delta Z/Z = n\,(\Delta A/A)$
Significant Figure Rules	Indicate precision in recorded data.	All non-zero digits significant
Rounding Off	Adjusting last digit based on next digit.	5 followed by 0 → round to even
Measurement	Comparison of an unknown quantity with a standard unit.	Measuring length with ruler
Order of Magnitude	Expressing quantity as nearest power of 10.	3×10^8 → order 8
Parallax Error	Error due to improper eye position while reading scale.	Avoided by keeping eye at same level
Zero Error	Error when instrument shows reading even at zero input.	Can be positive or negative
Calibration	Process of adjusting an instrument to correct readings.	Standard procedure for lab instruments
Scalar Quantity	Quantity with magnitude only.	Mass, temperature, speed

Vector Quantity	Quantity with magnitude and direction.	Force, velocity, acceleration
Dimensional Constants	Quantities having fixed dimensions.	Gravitational constant (G)
Dimensionless Quantities	Quantities without dimension.	Angle, strain, refractive index
Coherent System of Units	Derived units obtained without numerical factors.	SI system is coherent
Conversion of Units	Changing units using dimensional analysis.	m/s to km/h
Derived Unit of Force	$kg \cdot m/s^2$ in SI system.	Called Newton (N)
Derived Unit of Energy	$kg \cdot m^2/s^2$ in SI system.	Called Joule (J)
Derived Unit of Power	$kg \cdot m^2/s^3$ in SI system.	Called Watt (W)
Metrology	Science of measurement and its standards.	Maintains unit accuracy
Standard of Length	Defined in terms of wavelength of light (Kr-86).	1 meter = 1650763.73 wavelengths
Standard of Time	Defined using frequency of cesium-133 atom.	1 s = 9,192,631,770 cycles
Standard of Mass	Now based on Planck's constant.	Adopted in 2019
Planck's Constant (h)	Fundamental constant connecting energy & frequency.	$h = 6.626 \times 10^{-34}$ J·s
Avogadro Constant (N_A)	Number of particles in one mole.	6.022×10^{23} mol^{-1}

AFCAT SCIENCE – MEASUREMENT AND ERRORS

Question / Concept	One-line Answer
Can there be a physical quantity which has no units and no dimensions?	Yes, e.g., Strain
Name a scalar and a vector quantity which have same dimensions.	Speed and Velocity
Are all constants dimensionless?	No, e.g., Gravitational constant
Can a quantity have dimensions but still have no units?	No
Can a quantity have units but still be dimensionless?	Yes, e.g., Angle
Does the magnitude of a quantity depend on system of units used?	Yes, e.g., 1 N = 10^5 dyne

Does a quantity have different dimension in different system of units?	No
What are the dimensions of mass per unit length?	$M L^{-1}$
What type of quantity is Avogadro's number?	Dimensionless constant
Do all physical quantities have dimensions?	No
Name three physical quantities which have same dimensions.	Work, Energy, Torque
Name the physical quantity which is measured in the unit 'u'.	Mass
Name the physical quantity which is measured in the unit 'ly'.	Distance
What are the two complementary fundamental quantities?	Angle and Solid angle
What is the SI unit of solid angle?	Steradian (sr)
How is a light year related to metre?	1 ly = 9.46×10^{15} m
How is a parsec related to metre?	1 parsec = 3.08×10^{16} m
What is the mass of the Sun (solar mass)?	1.99×10^{30} kg
How many weeks are there in a lunar month?	4 weeks
Give the SI unit of luminous intensity and amount of substance.	Candela (cd) and Mole (mol)
State the number of significant figures in 2.64×10^4 kg.	3
State the number of significant figures in 0.0000632.	3
How would the error be affected if a researcher takes 100 observations and repeats the experiment with 500 observations?	Error reduces to $1/\sqrt{5}$ of the previous value
Which principle is used to check the accuracy of formula?	Principle of Homogeneity