PHYSICS

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1. Measurement/Unit

Derived Units and their Expression

- Frequency: Hertz (Hz) = s^{-1}.
- Power (Electric/Mechanical): Watt (W) = Joule/second (J/s) = Newton-meter/second (N·m/s).
- Pressure: Pascal (Pa) = Newton/meter² (N/m²) = kg/(m·s²). Other units include Bar, Atmosphere, and kg/cm². Note: N/m and J/m² are not units of pressure.
- Force: Newton (N) = kg·m/s². In CGS, 1 dyne = 1 g·cm/s² = 10^{-5} N.
- Spring Constant (k): Newton/meter (N/m).
- Resistivity (ρ): Ohm-meter (Ω·m). Ohm-cm (Ω·cm) is a commonly used non-SI unit. Resistivity is an intrinsic property of a material, independent of its length or cross-section.
- Energy: Joule (J) = Newton-meter (N·m) = kg·m²/s². Other units: Watt-hour (W·h). Note: kg·m/s² is a unit of force (Newton), not energy.
- Gravitational Constant (G): N·m²/kg².
- Impulse: Newton-second (N·s) = kg·m/s.
- Electric Charge: Coulomb (C) = Ampere-second (A·s).
- Electric Potential Difference (Voltage): Volt (V) = Joule/Coulomb (J/C).
- Power of a Lens: Diopter (D) = 1/meter (m^{-1}).
- Magnetic Field Strength (B): Tesla (T), Gauss (G).
- Magnetic Field Intensity (H): Ampere/meter (A/m).
- Magnetic Flux: Weber (Wb).
- Inductance: Henry (H).
- Acceleration: meter/second² (m/s² or $m \cdot s^{-2}$).
- Weight: Newton (N).
- Volume: Cubic meter (m³). 1 hectare-cm = 100 m³.
- Stress: Pascal (Pa) = N/m² (same unit as pressure).
- Thermal Conductivity: Watt per meter Kelvin (W/(m·K) or $W \cdot m^{-1} \cdot K^{-1}$).
- Linear Momentum: kg·m/s = Newton-second (N·s).
- Frequency (Sound): Hertz (Hz), s^{-1}, min^{-1}. Decibel (dB) is a unit for sound intensity level, not frequency.
- Wavelength: Angstrom (Å), where 1 Å = 10^{-10} m.
- High Speed: Mach (dimensionless quantity, defined as the ratio of an object's speed to the speed of sound).
- 1 kilowatt-hour (kWh) = 3.6×10^6 Joule (J).

Dimensional Analysis (Dimensions, Homogeneity, Applications)

- Dimensions: Powers to which fundamental units (Mass M, Length L, Time T, Electric Current A, Temperature K, etc.) are raised to represent a physical quantity.
- Principle of Homogeneity of Dimensions: An equation is dimensionally correct if the dimensions of all the terms on both sides of the equation are the same. Quantities with different dimensions cannot be added or subtracted.
- Dimensionless Quantities:
  - Are expressed as $M^0L^0T^0$.
  - Examples: Specific gravity, relative density, relative permittivity (dielectric constant), strain, angle, refractive index, Reynolds number, trigonometric ratios, Euler's number (e), other mathematical constants (π).
  - Any quantity that is a ratio of two similar physical quantities is dimensionless.
- Common Dimensional Formulas:
  - Force (Thrust): $[MLT^{-2}]$
  - Pressure (Stress, Young's Modulus): $[ML^{-1}T^{-2}]$ (Also same as Energy per unit Volume: $[ML^2T^{-2}]/[L^3] = [ML^{-1}T^{-2}]$)
  - Energy (Work, Heat, Torque): $[ML^2T^{-2}]$
    - Equivalent to Power × Time (e.g., I^2Rt, V^2t/R, VIt).
  - Linear Momentum (Impulse): $[MLT^{-1}]$ (Impulse = Force × Time)
  - Angular Momentum (Planck's Constant 'h', Angular Impulse): $[ML^2T^{-1}]$
    - Planck's constant h = Energy/Frequency.
    - Angular Impulse = Torque × Time.
  - Frequency: $[T^{-1}]$
  - Surface Tension: $[MT^{-2}]$ (Force/Length)
  - Mass Density: $[ML^{-3}]$
  - Specific Weight: $[ML^{-2}T^{-2}]$ (Force/Volume)
  - Specific Heat: $[L^2T^{-2}K^{-1}]$ (Energy/(Mass × Temperature))
  - Electric Field: $[MLT^{-3}A^{-1}]$ (Force/Charge)
  - Electric Potential (Emf, Potential Difference): $[ML^2T^{-3}A^{-1}]$ (Work/Charge)
  - Electric Dipole Moment: [LTA] (Charge × Distance)
  - Electric Flux: $[ML^3T^{-3}A^{-1}]$ (Electric Field × Area)
- Dimensional Equivalence:
  - The ratio of Inductance (L) to Resistance (R), i.e., L/R, has the dimension of Time [T] (time constant of an RL circuit).
  - Time is dimensionally equivalent to Distance/Velocity.
  - The unit of the ratio between Thrust (Force) and Impulse (Force × Time) is the same as that of Frequency ($[T^{-1}]$).
- Distinguishing Dimensions:
  - Moment of Inertia ($[ML^2]$) and Moment of a Force (Torque $[ML^2T^{-2}]$) have different dimensions.
  - Dipole moment, Electric flux, and Electric field have different dimensions.

Errors in Measurement (Types, Absolute, Relative, Percentage, Propagation)

- Error in Measurement: Difference between the true value and the measured value of a quantity.
- Types of Errors:
  - Systematic Errors: Errors that tend to be in one direction (either positive or negative). They arise due to identifiable causes and can be minimized or eliminated.
    - Instrumental Errors: Due to imperfect design or faulty calibration of the instrument (e.g., zero error, wear and tear, using a chain calibrated at one temperature in a different temperature – leads to a cumulative error).
    - Environmental Errors: Due to changes in external conditions like temperature, pressure, humidity (e.g., expansion/contraction of measuring tape with tem-

perature – causes systematic cumulative error).
    - Observational/Personal Errors: Due to individual's bias, lack of proper setting of the apparatus, or carelessness in taking observations (e.g., parallax error).
    - Errors due to Imperfection in Experimental Technique/Procedure: (e.g., heat loss in calorimetry).
    - Cumulative Error: A systematic error that adds up over successive measurements, consistently affecting the result in the same direction (e.g., a short tape will consistently overestimate length, a long chain due to high temperature will consistently under-measure length).
    - Negative Error: Occurs when the measured value is less than the true value. (e.g., using an expanded chain at higher temperature; the chain is effectively longer, so it will cover a given distance in fewer applications, leading to an underestimation of the actual length – a negative error that is cumulative).
- Random Errors: Errors that occur irregularly and are random in magnitude and direction. They arise due to unpredictable fluctuations in experimental conditions or personal judgment. They cannot be eliminated completely but can be minimized by taking multiple readings and averaging.
    - Compensating Error: Random errors often tend to cancel each other out over many observations, meaning the positive and negative errors balance out to some extent.
- Gross Errors: Errors due to carelessness of the observer, like reading an instrument incorrectly, recording observations wrongly, or using wrong values in calculations. Can be avoided by being alert and careful.

- Absolute Error (Δa): The magnitude of the difference between the true value (or mean value) and the individual measured value. Δa = |a*mean - ai*|. *Its unit is the same as the measured quantity.*
- *Mean Absolute Error (Δamean): The arithmetic mean of all absolute errors. If amean is the true value, Δamean = (Σ |Δai|) / n.*
- *Relative Error (δa): The ratio of the mean absolute error to the mean value of the quantity being measured. δa = Δamean / amean. It is a dimensionless quantity.*
- *Percentage Error (% Error): The relative error expressed as a percentage. % Error = (Δamean / amean) × 100%. It is a dimensionless quantity.*
- *Propagation of Errors: How errors combine in mathematical operations:*
    - *Error in a Sum or Difference (Z = A ± B): The maximum absolute error is the sum of the absolute errors: ΔZ = ΔA + ΔB.*
    - *Error in a Product or Quotient (Z = A × B or Z = A / B): The maximum relative error is the sum of the relative errors: ΔZ/Z = ΔA/A + ΔB/B.*
    - *Error in a Quantity Raised to a Power (Z = A^n): The maximum relative error is 'n' times the relative error of A: ΔZ/Z = n(ΔA/A).*
    - *Error in a General Combination (Z = A^p B^q / C^r): The maximum relative error is given by: ΔZ/Z = p(ΔA/A) + q(ΔB/B) + r(ΔC/C).*

Least Count of Measuring Instruments

- *Least Count (LC): Smallest measurement an instrument can make accurately.*
- *LC determines the precision of an instrument; a smaller LC means higher precision.*
- *Measurements must be reported with their last significant digit corresponding to the instrument's LC.*
- *Reporting a measurement with precision finer than the instrument's LC is incorrect (implies false precision).*

- *Example: For a meter scale with LC = 1 mm (or 0.001 m):*
  - *A reading like 25.3 cm (or 253 mm) is appropriate (precision to 1 mm).*
  - *A reading like 25.34 cm (or 253.4 mm) is over-precise (implies 0.1 mm LC).*
  - *A reading like 0.50 mm is over-precise (implies 0.01 mm LC).*
- *Precision vs. Accuracy:*
  - *Precision: Consistency/reproducibility of measurements; fineness of measurement. Directly related to LC.*
  - *Accuracy: Closeness of a measurement to the true value.*

Non-SI Units (e.g., Astronomical Unit, Light-Year, Electron-Volt)

- *Angstrom (Å): Unit of wavelength. 1 Å = 10^{-10} m. Typical atomic sizes are ~1 Å.*
- *Nanometre (nm): Unit of length. 1 nm = 10^{-9} m. Nanotechnology deals with 1-100 nm sized particles.*
- *Micron (µm): Unit of length (micrometre). 1 µm = 10^{-6} m = 10^{-4} cm.*
- *Femtometre (fm) / Fermi: Unit for nuclear sizes. 1 fm = 10^{-15} m. Smallest unit of length among common options.*
- *X-unit (XU): Unit for X-ray wavelengths. 1 XU ≈ 1.002 × 10^{-13} m.*
- *Light-year (ly): Unit of very large distance, especially astronomical distances. It is the distance light travels in vacuum in one Julian year.*
  - *Reason for use: Constant speed of light in vacuum.*
  - *1 ly ≈ 9.461 × 10^{12} km ≈ 9.461 × 10^{15} m.*
- *Astronomical Unit (AU): Unit of distance. Average distance between Earth and the Sun. 1 AU ≈ 1.496 × 10^{11} m.*
- *Parsec (pc): Unit of very large distance. 1 pc ≈ 3.26 light-years ≈ 3.086 × 10^{16} m.*
- *Furlong: Unit of distance. 1 furlong ≈ 201.168 m.*
- *Atmosphere (atm): Non-SI unit of pressure. 1 atm is the pressure exerted by a 760 mm column of mercury at 0 °C. 1 atm ≈ 1.01325 × 10^{5} Pa.*
- *Bar: Non-SI unit of pressure. 1 bar = 10^{5} Pa. 1 atm ≈ 1.01325 bar.*
- *Torr: Non-SI unit of pressure. 1 torr ≈ 133.322 Pa. (1 atm = 760 torr).*
- *Curie (Ci): Non-SI unit of radioactivity. The SI unit is Becquerel (Bq). 1 Ci = 3.7 × 10^{10} Bq.*
- *Carat: Unit of mass for gemstones (e.g., diamonds). 1 carat = 200 mg = 0.2 g.*
- *Horsepower (HP): Non-SI unit of power. 1 HP ≈ 746 W.*
- *Kilowatt-hour (kWh): Commercial unit of electrical energy. 1 kWh = 3.6 × 10^{6} J.*
- *Jiffy: Unit of time (very short interval). Not a unit of distance.*

Physical Quantities (Fundamental and Derived)

- *Physical Quantities are measurable properties of objects or systems.*
- *Fundamental Quantities (Base Quantities): Independent quantities whose units are defined independently.*
  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)*
- *Derived Quantities: Quantities obtained by mathematically combining fundamental quantities.*
  - *Volume: Unit is m^3 (e.g., Liter is a unit of volume, not fundamental).*
  - *Force: Unit is Newton (N) or kg·m/s^2.*
  - *Pressure: Unit is Pascal (Pa) or N/m^2.*
  - *Energy/Work/Heat: Unit is Joule (J) or Calorie (cal). (Joule and Calorie are units for the same physical quantity - Energy).*
  - *Power: Unit is Watt (W) or J/s.*
  - *Stress: Unit is N/m^2 (same as pressure).*

- *Scalar Quantities: Have magnitude only, no direction.*
    - *Examples: Energy, Power, Pressure, Temperature, Gravitational Potential, Mass, Length, Time, Distance, Speed.*
- *Vector Quantities: Have both magnitude and direction.*
    - *Examples: Impulse, Force, Velocity, Acceleration, Displacement, Momentum.*
- *Dimensionless (Unitless) Quantities: Quantities that are ratios of two similar physical quantities, hence having no units.*
    - *Example: Strain (change in dimension / original dimension).*
- *Amplitude of Sound Waves: Can be measured in units of:*
    - *Distance (referring to particle displacement from equilibrium).*
    - *Pressure (referring to pressure variation from equilibrium pressure, called pressure amplitude).*

Prefixes for SI Units

- *One nanometer (nm) = 10^{-9} metres (m).*
- *One nanometer (nm) = 10^{-7} cm.*
- *One metre (m) = 10^{9} nanometres (nm).*
- *The word "Nano" is derived from the Greek word "nanos," meaning "dwarf."*
- *Nanotechnology deals with particles typically of the size 10^{-9} m.*
- *One Angstrom (Å) = 10^{-10} m.*
- *The relation between Angstrom and nanometer is 1 nm = 10 Å.*
- *One-millionth part of a gram (10^{-6} g) is known as a microgram (µg).*
- *Prefix 'micro' (µ) denotes 10^{-6}.*
- *Prefix 'nano' (n) denotes 10^{-9}.*

SI Base Units and their Definitions

- *Kelvin (K): SI base unit for thermodynamic temperature. Cannot be negative; 0 K (absolute zero) is the lowest possible temperature.*
- *Candela (cd): SI base unit for luminous intensity.*
- *Ampere (A): SI base unit for electric current.*
- *Kilogram (kg): SI base unit for mass.*
- *Metre (m): SI base unit for length.*
- *Second (s): SI base unit for time.*
- *Newton (N): SI derived unit for force.*
- *Pascal (Pa): SI derived unit for pressure.*
- *Henry (H): SI derived unit for inductance.*
- *Weber (Wb): SI derived unit for magnetic flux.*
- *Coulomb (C): SI derived unit for electric charge.*
- *Kilogram-metre per second (kg·m/s): SI derived unit for momentum.*

Significant Figures

1. *Definition: Significant figures (SF) are the digits in a number that carry meaning contributing to its precision.*
2. *Rules for Determining Significant Figures:*
    - *All non-zero digits are significant. (e.g., 123.45 has 5 SF).*
    - *Zeros between two non-zero digits are significant. (e.g., 101.05 has 5 SF).*
    - *Leading zeros (zeros before the first non-zero digit) are NOT significant. They only indicate the position of the decimal point. (e.g., 0.00051 has 2 SF).*
    - *Trailing zeros (zeros at the end of a number) are significant if the number contains a decimal point. (e.g., 12.00 has 4 SF, 120. has 3 SF).*
    - *Trailing zeros are NOT significant if the number does not contain a decimal point, unless specified by scientific notation. (e.g., 1200 has 2 SF, but 1.200 x 10^3 has 4 SF).*
    - *Exact numbers (e.g., counts, defined constants like the '6' in surface area = $6s^2$) have infinite significant figures and do not limit the SF in a calculation.*
3. *Rules for Arithmetic Operations with Significant Figures:*
    - *Multiplication and Division: The result should retain the same number of significant figures as the quantity with the least number of significant figures involved in the calculation.*

- *Addition and Subtraction: The result should retain the same number of decimal places as the quantity with the least number of decimal places.*

4. *Rounding Rules:*
   - *If the digit to be dropped is less than 5, the preceding digit is left unchanged. (e.g., 7.24 rounded to 2 SF becomes 7.2).*
   - *If the digit to be dropped is greater than 5, the preceding digit is increased by one. (e.g., 7.26 rounded to 2 SF becomes 7.3).*
   - *If the digit to be dropped is exactly 5:*
     - *If the preceding digit is even, it is left unchanged. (e.g., 7.25 rounded to 2 SF becomes 7.2).*
     - *If the preceding digit is odd, it is increased by one. (e.g., 7.35 rounded to 2 SF becomes 7.4).*
5. *Application Example (Cube Calculation):*
   - *Given side (s) = 7.203 m (4 SF).*
   - *Surface Area (SA) = 6 s^2 = 6 (7.203 m)^2 = 6 51.883209 m^2 = 311.299254 m^2.*
   - *Rounding SA to 4 SF (as 7.203 has 4 SF): 311.3 m^2.*
   - *Volume (V) = s^3 = (7.203 m)^3 = 373.714754427 m^3.*
   - *Rounding V to 4 SF: 373.7 m^3.*

Systems of Units (SI, CGS, MKS)

- *Systems of Units: Standardized sets of units for fundamental quantities (length, mass, time, etc.) for scientific and technical measurements.*
- *CGS System (Centimetre-Gram-Second):*
  - *Length: Centimetre (cm)*
  - *Mass: Gram (gm)*
  - *Time: Second (s)*
  - *Derived Unit Example (Density): Density = Mass/Volume = gm/cm^3.*
- *MKS System (Metre-Kilogram-Second):*
  - *Length: Metre (m)*
  - *Mass: Kilogram (kg)*
  - *Time: Second (s)*
- *SI System (Système International d'Unités):*
  - *The modern form of the metric system, developed from the MKS system, adopted globally.*
  - *Seven Base Units:*
    1. *Length: Metre (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)*
  - *Derived Units: Units for all other physical quantities, formed by multiplying and/or dividing base units (e.g., Newton for Force, Joule for Energy).*
  - *Coherence: Derived units are formed without numerical factors (e.g., 1N = 1 kg·m/s^2).*
  - *Universality: Globally accepted for scientific, technical, and commercial applications.*

Unit Conversion Techniques

- *Length Unit Conversion:*
- *1 nanometer (nm) = 10^{-9} meter (m).*
- *To determine the number of hydrogen atoms (radius 10^{-10} m) required to form a length of one nanometre: (1 nm / 10^{-10} m) = (10^{-9} m / 10^{-10} m) = 10 atoms.*
- *Energy Unit Conversion (Electrical):*
- *1 kilowatt-hour (kWh) = 3.6 × 10^6 Joules (J).*
- *Derivation: 1 kWh = 1 kW × 1 hour = 1000 Watts × 3600 seconds = 3,600,000 Watt-seconds = 3.6 × 10^6 J.*
- *Temperature Unit Conversion (Celsius and Fahrenheit):*
- *Conversion formula from Celsius to Fahrenheit: °F = (1.8 × °C) + 32.*
- *Alternatively: °F = (⅘ × °C) + 32.*
- *Conversion formula from Fahrenheit to Celsius: °C = (°F - 32) / 1.8 or °C = ⅝ × (°F - 32).*

- *Example: 10°C converts to Fahrenheit as (1.8 × 10) + 32 = 18 + 32 = 50°F.*
- *The temperature at which Celsius and Fahrenheit scales show the same reading is -40 degrees (i.e., -40°C = -40°F).*

Units of Measurement (Definition and Characteristics)

- *Frequency: Hertz (Hz).*
- *Power of a lens: Dioptre.*
- *Standard atmospheric pressure at sea level: ~76 cm Hg, ~29.9 inches Hg, ~1013.25 millibars (mb).*
- *Distance (astronomical): Light-year.*
- *Amount of substance: Mole.*
- *Electric charge: Coulomb (C).*
- *Energy: Watt-hour (Wh).*
- *Natural units of time: Day, Lunar month, Tropical year.*
- *Non-natural/Standardized unit of time: Standard Time.*
- *Powndal: Unit of weight/force (FPS system).*
- *Radioactivity: Curie (Ci), Becquerel (Bq).*
- *Units of pressure: Pascal (Pa), Bar, Torr, Atmosphere (atm).*

2. Measuring Instruments and Scales

Barometer and Manometer for pressure measurement

1. *Barometer: Instrument used to measure atmospheric pressure.*
2. *Barometer Reading & Weather Conditions:*
    - *Sudden fall: Indicates stormy weather.*
    - *Gradual fall: Indicates rain.*
    - *Gradual rise: Indicates fine weather.*
    - *Sudden rise: Indicates cold and dry weather.*
3. *Barometer in an Elevator:*
    - *Moving upwards with increasing speed (accelerating upwards): Barometer reading increases (> normal).*
    - *Moving downwards with increasing speed (accelerating downwards): Barometer reading decreases (< normal).*
    - *At rest or constant velocity: Barometer reading remains normal.*
4. *Manometer: Instrument used to measure the pressure of gases.*
5. *U-Tube Manometer: Primarily used for measuring moderate pressures.*
6. *Bourdon Pressure Gauge: Used for measuring high pressures (e.g., 10^5 Psi).*
7. *Piezometer Tube: Measures gauge pressure (pressure relative to atmospheric pressure).*
8. *Altimeter: A type of barometer used in aircraft to measure altitude.*
9. *Fathometer: Measures the depth of the ocean.*
10. *Anemometer: Measures the velocity of wind.*
11. *Hygrometer: Measures humidity levels.*
12. *Galvanometer: Measures electric currents.*
13. *Tonometer: Measures the internal pressure of the eye.*
14. *Sphygmomanometer: Used by physicians to measure blood pressure.*
15. *Orificemeter: A device for measuring flow/discharge rate, generally considered the cheapest option.*
16. *Mc Cleod Gauge / Pirani Gauge: Used for measuring very low pressures (vacuum).*

Fundamental concepts of measurement: accuracy, precision, and errors (systematic, random, gross)

- *Cathode Ray Oscilloscope (CRO): Measures voltage, frequency, and phase of electrical signals.*
- *Doppler Effect: Principle used for precise tracking of moving objects (e.g., artificial satellites) by analyzing frequency shifts in emitted or reflected waves.*
- *Radar (Radio Detection And Ranging): Uses radio waves to detect range, altitude, direction, and speed of objects; often incorporates the Doppler principle for speed measurement.*
- *Sonar (Sound Navigation And Ranging): Uses sound waves for navigation and detection, primarily underwater.*
- *Pulsar: A highly magnetized, rotating neutron star that emits beams of electromagnetic*

radiation; not used for artificial satellite tracking from Earth.

- *Gyroscope: Measures angular velocity and detects changes in orientation; used in navigation, stabilization, and for smartphone display rotation.*
- *Accelerometer: Measures linear acceleration; detects tilt (due to gravity), free fall, shock, and vibration; used in airbag deployment and laptop hard drive protection.*
- *Odometer: Measures the total distance travelled by a vehicle.*
- *Speedometer: Measures the instantaneous speed of a vehicle.*
- *Cathetometer: Measures vertical distances or heights without contact.*
- *Lactometer: Measures the specific gravity of milk to check its purity.*
- *Dilatometer: Measures dimensional changes in materials, typically due to temperature variations (thermal expansion/contraction).*
- *Stethoscope: Used to auscultate (listen to) internal sounds of the body, such as heart and lung sounds.*
- *Sphygmomanometer: Used to measure blood pressure.*
- *Caratometer: Used to measure the purity of gold (caratage).*
- *Lux Meter: Measures illuminance (intensity of light) in lux.*

Galvanometer: principle, sensitivity, and conversion to Ammeter and Voltmeter

- *Galvanometer:*
  - *An electromechanical measuring instrument used to detect the presence and direction of small electric currents (typically microamperes to milliamperes) in a circuit.*
  - *Principle: Based on the magnetic effect of electric current. A current-carrying coil, placed in a magnetic field, experiences a torque which causes deflection proportional to the current.*
  - *Can measure current and indicate its direction.*
  - *Has a low internal resistance.*
- *Sensitivity of a Galvanometer:*
  - *Indicates the galvanometer's ability to produce a large deflection for a small current or voltage.*
  - *Quantitatively, it is related to the Torque/weight ratio of its moving system.*
  - *Current Sensitivity (I_s): Deflection produced per unit current (θ/I).*
  - *Voltage Sensitivity (V_s): Deflection produced per unit voltage (θ/V).*
- *Ammeter:*
  - *A device specifically designed to measure the magnitude of electric current in amperes.*
  - *Conversion from Galvanometer to Ammeter: A galvanometer is converted into an ammeter by connecting a very low resistance (shunt resistance, R_{sh}) in parallel with its coil.*
    - *The shunt allows most of the current to bypass the galvanometer, protecting it and extending its measurement range.*
  - *Ideal Ammeter: Has zero internal resistance.*
  - *Connection: Always connected in series with the circuit component through which current is to be measured.*
  - *Types: Moving coil ammeters typically measure DC current (average value), while moving iron ammeters measure AC or DC current (RMS value for AC).*
- *Voltmeter:*
  - *A device used to measure the potential difference (voltage) between two points in an electric circuit.*
  - *Conversion from Galvanometer to Voltmeter: A galvanometer is converted into a voltmeter by connecting a very high resistance (R_s) in series with its coil.*
    - *The high series resistance limits the current drawn from the circuit and allows the galvanometer to measure a large potential difference.*

    - *Ideal Voltmeter: Has infinite internal resistance.*
    - *Connection: Always connected in parallel across the two points where the potential difference is to be measured.*
- *Related Instruments/Concepts:*
    - *Potentiometer: Used to measure electromotive force (EMF) accurately.*
    - *Voltameter: An electrolytic cell used for chemical measurements, not for measuring voltage.*
    - *Magnetic Needle: Used to detect the presence of a magnetic field.*

Hydrometer and densitometers for liquid density measurement

- ***Hydrometer:*** *Instrument used to measure the specific gravity or relative density of liquids. Operates on Archimedes' principle of buoyancy.*
- ***Lactometer:*** *A type of hydrometer specifically designed to test the purity of milk by measuring its specific gravity.*
- ***Hygrometer:*** *Instrument used to measure the moisture content or humidity of the atmosphere/air.*
- ***Pycnometer (or Density Bottle):*** *Used for precise measurement of the density or specific gravity of liquids and sometimes powders.*
- ***Hypsometer:*** *Instrument used to measure altitude by observing the boiling point of a liquid, or to measure the boiling point itself.*
- ***Hydrophone:*** *An underwater device used to detect and record ocean sounds from all directions.*
- ***Megaphone:*** *A horn-shaped instrument used to amplify and direct a person's voice or other sounds over a distance.*
- ***Anemometer:*** *Instrument used to measure wind speed.*
- ***Tachometer:*** *Instrument used to measure the rotation speed (RPM - Revolutions Per Minute) of a shaft or disk, e.g., in engines.*

Least count and significant figures in measurements

- *Least Count (LC): Smallest value an instrument can measure.*
- *Precision: A measurement's precision is directly related to the instrument's least count; smaller LC means higher precision.*
- *LC for Vernier Caliper: Smallest main scale division / Total number of divisions on vernier scale.*
- *LC for Screw Gauge: Pitch / Total number of divisions on circular scale.*
- *Pitch of Screw Gauge: Distance moved by screw / Number of rotations.*
- *Significant Figures (SF): Digits in a measurement considered reliable and contributing to its precision.*
- *SF Rule 1 (Non-zero digits): All non-zero digits are significant (e.g., 234.5 has 4 SF).*
- *SF Rule 2 (Sandwich zeros): Zeros between non-zero digits are significant (e.g., 1005 has 4 SF).*
- *SF Rule 3 (Leading zeros): Zeros before non-zero digits (leading zeros) are NOT significant (e.g., 0.0023 has 2 SF).*
- *SF Rule 4 (Trailing zeros with decimal): Trailing zeros are significant ONLY if the number contains a decimal point (e.g., 2.00 has 3 SF; 200 has 1 SF, but 200. has 3 SF).*
- *SF Rule 5 (Exact numbers): Exact counts or defined constants have infinite significant figures.*
- *SF in Addition/Subtraction: Result is rounded to the same number of decimal places as the measurement with the fewest decimal places.*
- *SF in Multiplication/Division: Result is rounded to the same number of significant figures as the measurement with the fewest significant figures.*
- *Rounding Rule (< 5): If the digit to be dropped is less than 5, the preceding digit remains unchanged.*
- *Rounding Rule (> 5): If the digit to be dropped is greater than 5, the preceding digit is increased by 1.*
- *Rounding Rule (= 5): If the digit to be dropped is 5 (and there are no other digits after it or they are zeros), the preceding digit is increased by 1 if it's odd, and remains unchanged if it's even.*

Liquid-in-glass thermometers: types (clinical, laboratory) and their working

- *Liquid-in-glass thermometers measure temperature based on thermal expansion/contraction of a liquid (e.g., mercury, alcohol) in a sealed glass tube.*
- *Working Principle: Liquid expands when heated, rises in the capillary tube; contracts when cooled, falls in the tube. The level indicates temperature on a calibrated scale.*
- *Clinical Thermometer:*
  - *Purpose: Measures human body temperature.*
  - *Liquid: Typically Mercury (historically, now less common due to safety) or Alcohol.*
  - *Range: Narrow, usually 35°C to 42°C (94°F to 108°F).*
  - *Feature: Has a 'kink' or constriction near the bulb to prevent the mercury level from falling back immediately, allowing for reading after removal from the body.*
- *Laboratory Thermometer:*
  - *Purpose: Measures temperature in laboratory experiments.*
  - *Liquid: Mercury or Alcohol.*
  - *Range: Wider, typically -10°C to 110°C.*
  - *Feature: No kink/constriction; the liquid level falls immediately upon removal from the heat source.*
- *Temperature Scales & Conversions:*
  - *Celsius (°C), Fahrenheit (°F), Kelvin (K).*
  - *Conversion Formulas:*
    - *°F = (°C × 9/5) + 32*
    - *°C = (°F - 32) × 5/9*
    - *K = °C + 273.15 (approx. 273 for exam purposes).*
  - *Key Equivalences:*
    - *0°C = 32°F = 273.15 K (Freezing point of water).*
    - *100°C = 212°F = 373.15 K (Boiling point of water).*
    - *-40°C = -40°F (The only point where Celsius and Fahrenheit scales read the same value).*
  - *Example: 40°C = (40 × 9/5) + 32 = 72 + 32 = 104°F.*
  - *Example: 273 K ≈ 0°C = (0 × 9/5) + 32 = 32°F.*
- *Other Measuring Instruments:*
  - *Hypsometer: Measures the boiling point of liquids (and can infer altitude).*
  - *Stethoscope: Used for hearing heartbeats and other internal body sounds.*
  - *Sphygmomanometer: Used for measuring blood pressure.*
  - *Lux meter: Used for measuring the intensity of light.*

Physical balance and weighing techniques

- *A physical balance (beam balance) measures mass by comparing an unknown mass with standard masses. It works on the principle of moments and is independent of acceleration due to gravity (g). Thus, it measures the true mass of an object, irrespective of location.*
- *A spring balance measures weight (force) by the extension or compression of a spring. It operates based on Hooke's Law.*
- *Weight (W) = mass (m) × acceleration due to gravity (g).*
- *A spring balance is typically calibrated to display mass, assuming a specific standard value of 'g' at its manufacturing or calibration location.*
- *The measurement of mass taken by a spring weighing balance is correct (accurate) only at places where the acceleration due to gravity (g) is the same as the place where the spring balance was calibrated for.*
- *The reading of a spring balance will vary with changes in 'g' (e.g., different at poles vs. equator, at different altitudes, or on different celestial bodies), meaning its displayed mass reading would be incorrect if 'g' differs from the calibration 'g'.*

Potentiometer: principle, construction, and applications (e.g., measuring EMF, internal resistance)