



India has a rich history of traditional and regional measurement systems

India officially adopted the **International System of Units (SI)**, the modern metric system, in **1956** and fully implemented it by **1962**. This means that for all official, scientific, industrial, and commercial purposes today, India uses meters, kilograms, seconds, liters, etc., just like most of the world.

I. Traditional Indian Units of Length

These were often based on human body parts or natural phenomena, leading to variations.

• Smallest Units (often conceptual/microscopic):

- **Parmanu:** (literally "atom") - A very tiny, conceptual unit.
- **Rajahkan:** (dust particle from a chariot wheel)
- **Liksha:** (egg of a louse)
- **Yookamadhya**
- **Yavamadhya**

• Body-based Units:

- **Angul (Angula):** Approximately the width of a finger (around 1.7 to 2.0 cm, historically around 0.66 to 0.78 inch). This was a fundamental unit.
- **Dhanurmushti:** 8 Anguls (approx. 16 cm)
- **Vitasti (or Bilisht/Balisht):** A span, from the tip of the thumb to the tip of the little finger when stretched (12 Anguls, approx. 22-24 cm or 9 inches).
- **Hast (or Haath):** A cubit, from the elbow to the tip of the middle finger (2 Vitasti

or 24 Anguls, approx. 45-48 cm or 18 inches).

- **Dand (or Dhanush):** A rod or a bow length (4 Aratni/Hast, approx. 1.8-1.9 meters or 6 feet).

• Larger Units (for distance):

- **Rajju:** 10 Dand (approx. 19.2 meters)
- **Krosh (or Kos/Goruta):** A measure of distance, often equivalent to about 3.2-3.8 km (approx. 2 miles).
- **Yojana:** A larger measure of distance, historically ranging from about 8 km to 15 km (approx. 5 to 9 miles). Its value varied significantly.

• Mughal/Pre-Metric Era Land & Length Units:

- **Girah:** Width of 3 fingers (used during Mughal period, particularly with Gaz).
- **Gaz (or Guz):** A yard-like unit, widely used across India, though its exact length varied by region and ruler (e.g., Akbar's Ilahi Gaz was about 33-34 inches or approx. 84-86 cm).
- **Bigha:** A unit of land area, its size varies vastly by region (e.g., in some parts of North India, 1 Bigha is about 2500 m² or 0.62 acre, but it can be very different elsewhere).
- **Biswa:** A subdivision of Bigha (e.g., 1 Bigha = 20 Biswa in some areas).
- **Kanal:** Primarily used in Northern India (Punjab, Haryana, HP, J&K) for land area, often 8 Kanal = 1 Ghumaon.
- **Marla:** A subdivision of Kanal.
- **Kaththa (or Kattha):** Another regional unit for land area, prevalent in Eastern India, with varying sizes.





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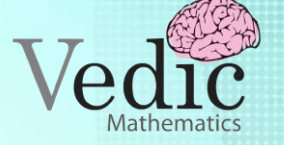
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- **Decimal:** Often used in land records, with 1 acre = 100 decimals.

II. Traditional Indian Units of Mass (Weight)

These units were often based on the weight of seeds, especially for precious metals.

• Smallest Units (for precious metals/medicines):

- **Chawal:** (grain of rice)
- **Dhan:** (weight of one wheat berry)
- **Ratti:** A small red seed (*Abrus precatorius*), widely used by goldsmiths. Its weight is approximately 120 mg to 125 mg.
- **Masha:** 8 Ratti (approx. 0.9 to 1 gram).
- **Tola:** A fundamental unit for weighing gold and silver, standardized by the British to 180 grains, which is **11.6638 grams**. (Still informally used for jewelry).

• Larger Units (for commodities):

- **Chattanka:** 4 or 5 Tola (approx. 58 grams).
- **Pav:** $\frac{1}{4}$ Seer (approx. 233 grams).
- **Seer (or Ser):** A common unit for commodities, typically around **933 grams** (close to 1 kg), though its value varied.
- **Paseri:** 5 Seer (approx. 4.6 kg).
- **Maund (or Man):** 40 Seer (approx. **37.32 kg**). This was a large unit for bulk goods.

III. Traditional Indian Units of Volume (Capacity)

Used for grains, liquids, etc.

• Smallest Units:

- **Bindu:** (a drop)

- **Shanam:** (approx. 3.55 ml, like a teaspoon)

- **Kuppi:** (approx. 700 ml)

• Intermediate Units:

- **Aazhaakku:** (approx. 168 ml)
- **Uzhakku:** (approx. 336 ml)
- **Padi:** A measure of dry volume, often for grains (value varied, but around 1 to 1.5 liters in some regions).
- **Naazhi (or Nazhi):** Often equivalent to Padi.
- **Marakkal:** A larger measure for grains (around 12-13 liters).

• Larger Units:

- **Kuruni:** (a multiple of Naazhi/Padi)
- **Pathakku:** (a multiple of Kuruni)
- **Thooni:** (approx. 21.5 liters)
- **Kalam:** A very large unit, especially for rice, could be around 64.5 liters or even more.
- **Pothi (or Modai):** A large sack measurement, often 96 Padi.

IV. Traditional Indian Units of Time

Ancient Indian astronomy and religious texts had very detailed and intricate systems for measuring time, from infinitesimally small to vast cosmic cycles.

• Micro Units:

- **Parmanu:** Smallest indivisible unit of time (conceptual, often linked to movement of an atom).





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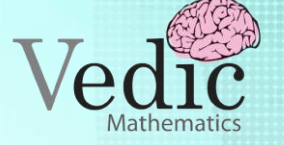
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- **Truti:** The time it takes for a needle to pierce a lotus leaf (very small, approx. microseconds).

- **Nimesha:** The blink of an eye.

- **Lava**

- **Intermediate Units:**

- **Kashtha**

- **Kala**

- **Ghati (or Naazhigai in Tamil):** Approx. 24 minutes.

- **Muhurtham:** Approx. 48 minutes (2 Ghati).

- **Prahara (or Pehar):** A watch of the day/night, approx. 3 hours. (Day and night were each divided into 4 praharas).

- **Larger Units:**

- **Dina (Day):** 60 Ghati.

- **Paksha:** 15 days (a fortnight).

- **Masa:** Month (2 Paksha).

- **Ritu:** Season (2 Masa).

- **Ayana:** Half-year (3 Ritu).

- **Varsha (Aandu):** Year (2 Ayana).

- **Yuga (Mahayuga, Kalpa):** Cosmic time cycles, extending to millions and billions of human years.

What are Units?

A **unit** is a standard quantity used to express a physical quantity. It provides a common reference point for describing how much of something there is. Without units, numbers representing physical quantities would be meaningless. For example, if you say "The length is 5," it's unclear if you mean 5

meters, 5 feet, or 5 inches. Saying "The length is 5 meters" makes it precise.

What are Measurements?

Measurement is the process of comparing an unknown physical quantity with a known standard quantity (the unit). It involves using instruments to determine the value of a physical quantity. Every measurement has two parts: a **numerical value** and a **unit**.

1. **A numerical value:** This tells you "how much."
2. **A unit:** This tells you "What kind" of quantity is being measured.

For example, if you say "5 kilograms," 5 is the numerical value, and kilograms is the unit, specifying that you are measuring mass.

The International System of Units (SI Units)

To ensure consistency and ease of communication in science and engineering worldwide, the **International System of Units (SI)** is universally adopted. It's a coherent system built upon seven fundamental (base) units, from which all other units (derived units) can be formed.

SI Base Units:

These are the seven independent physical quantities that form the foundation of the SI system:

1. Length: meter (m)

- Definition (simplified): The distance light travels in a vacuum in $1/299,792,458$ of a second.
- Common instruments: Ruler, measuring tape, caliper, micrometer.

2. Mass: kilogram (kg)

- Definition (simplified): Defined by the Planck constant (h).





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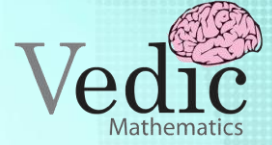
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- Common instruments: Weighing scale, balance.

3. Time: second (s)

- Definition (simplified): The duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
- Common instruments: Stopwatch, clock.

4. Electric Current: ampere (A)

- Definition (simplified): The constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.
- Common instruments: Ammeter.

5. Thermodynamic Temperature: kelvin (K)

- Definition (simplified): Defined by the Boltzmann constant (k_B). 0 K is absolute zero.
- Common instruments: Thermometer. (Celsius and Fahrenheit are common derived units for temperature).

6. Amount of Substance: mole (mol)

- Definition (simplified): Contains exactly $6.02214076 \times 10^{23}$ elementary entities (Avogadro's number). Used for counting atoms, molecules, ions, etc.

- No direct instrument; determined by mass and molar mass.

7. Luminous Intensity: candela (cd)

- Definition (simplified): The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of $1/683$ watt per steradian.
- Common instruments: Photometer.

SI Derived Units:

These units are formed by combining the base units through multiplication or division. Examples include:

- Area:** square meter (m^2)
- Volume:** cubic meter (m^3)
- Speed/Velocity:** meter per second (m/s)
- Acceleration:** meter per second squared (m/s^2)
- Force:** newton (N) = $kg \cdot m/s^2$
- Pressure:** pascal (Pa) = N/m^2
- Energy/Work:** joule (J) = $N \cdot m$
- Power:** watt (W) = J/s
- Frequency:** hertz (Hz) = s^{-1}
- Charge:** coulomb (C) = $A \cdot s$
- Voltage/Electric Potential Difference:** volt (V) = J/C
- Resistance:** ohm (Ω) = V/A



Importance of Units and Measurements:

1. **Clarity and Precision:** Ensures that scientific and engineering data are clear, unambiguous, and precise.
2. **Reproducibility:** Allows experiments and observations to be reproduced and verified by others.
3. **Global Communication:** Facilitates international collaboration and understanding among scientists and engineers.
4. **Technological Development:** Essential for design, manufacturing, and quality control in all technological fields.
5. **Safety:** Crucial in fields like medicine, construction, and aviation where errors in measurement can have catastrophic consequences.

Accuracy and Precision in Measurements:

- **Accuracy:** How close a measurement is to the true or accepted value.
- **Precision:** How close multiple measurements are to each other (reproducibility).

A good measurement is both accurate and precise.

Errors in Measurement:

No measurement is perfectly accurate. Errors can arise from:

- **Systematic Errors:** Consistent errors due to faulty equipment, incorrect calibration, or flaws in the experimental design. These affect accuracy.
- **Random Errors:** Unpredictable errors that vary from one measurement to the next due to unpredictable fluctuations. These affect precision.

- **Personal Errors:** Errors due to the observer's limitations or biases.

Systems of Units

Historically, many different systems of units existed. However, for scientific and global commerce, the need for standardization led to the development of internationally accepted systems.

1. **The International System of Units (SI Units) - The Modern Metric System:** This is the most widely used and accepted system globally. It's a coherent system based on seven fundamental (base) units from which all other units (derived units) are formed.

SI Base Units:

- **Length: meter (m)** - Defines distance.
- **Mass: kilogram (kg)** - Defines the amount of matter in an object.
- **Time: second (s)** - Defines duration.
- **Electric Current: ampere (A)** - Defines the flow of electric charge.
- **Thermodynamic Temperature: kelvin (K)** - Defines heat intensity. (Celsius is a common derived unit, where $0^{\circ}\text{C} = 273.15\text{K}$)
- **Amount of Substance: mole (mol)** - Defines a specific number of particles (Avogadro's number).
- **Luminous Intensity: candela (cd)** - Defines the power emitted by a light source in a particular direction.

SI Derived Units (Examples): These units are formed by mathematically combining base units.

- **Area:** square meter (m^2)
- **Volume:** cubic meter (m^3)
- **Speed/Velocity:** meter per second (m/s)

- **Force:** newton (N) = $\text{kg}\cdot\text{m}/\text{s}^2$
- **Energy/Work:** joule (J) = $\text{N}\cdot\text{m}$
- **Power:** watt (W) = J/s
- **Pressure:** pascal (Pa) = N/m^2
- **Frequency:** hertz (Hz) = s^{-1}
- **Voltage:** volt (V)
- **Resistance:** ohm (Ω)

2. **Imperial/US Customary System:** This system is still primarily used in the United States and, to a lesser extent, in the United Kingdom for some applications. It includes units like:

- **Length:** inch, foot, yard, mile
- **Mass/Weight:** ounce, pound, stone (UK), ton
- **Volume (Liquid):** fluid ounce, pint, quart, gallon
- **Temperature:** Fahrenheit ($^{\circ}\text{F}$)

General Units and measurement list

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

B. Common SI Derived Units (with Special Names)

These units are formed by combining base units and have been given specific names for convenience:

Quantity	Unit	Symbol	Definition in Base Units
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$\text{kg}\cdot\text{m}\cdot\text{s}^{-2}$
Pressure	pascal	Pa	$\text{N}\cdot\text{m}^{-2}$
Energy, Work, Heat	joule	J	$\text{N}\cdot\text{m}$
Power	watt	W	$\text{J}\cdot\text{s}^{-1}$
Electric Charge	coulomb	C	$\text{A}\cdot\text{s}$
Electric Potential (Voltage)	volt	V	$\text{J}\cdot\text{C}^{-1}$
Electric Resistance	ohm	Ω	$\text{V}\cdot\text{A}^{-1}$
Electric Conductance	siemens	S	$\text{A}\cdot\text{V}^{-1}$
Electric Capacitance	farad	F	$\text{C}\cdot\text{V}^{-1}$
Magnetic Flux	weber	Wb	$\text{V}\cdot\text{s}$
Magnetic Flux Density	tesla	T	$\text{Wb}\cdot\text{m}^{-2}$
Inductance	henry	H	$\text{Wb}\cdot\text{A}^{-1}$
Luminous Flux	lumen	lm	$\text{cd}\cdot\text{sr}$
Illuminance	lux	lx	$\text{lm}\cdot\text{m}^{-2}$

Quantity	Unit	Symbol	Definition in Base Units
Activity (radioactive)	becquerel	Bq	s^{-1}
Absorbed Dose (radiation)	gray	Gy	$J \cdot kg^{-1}$
Dose Equivalent (radiation)	sievert	Sv	$J \cdot kg^{-1}$
Catalytic Activity	katal	kat	$mol \cdot s^{-1}$

C. Other Common SI Derived Units (without Special Names)

These are formed directly from base units:

- **Area:** square meter (m^2)
- **Volume:** cubic meter (m^3)
- **Speed/Velocity:** meter per second (m/s)
- **Acceleration:** meter per second squared (m/s^2)
- **Density:** kilogram per cubic meter (kg/m^3)
- **Momentum:** kilogram meter per second ($kg \cdot m/s$)
- **Angular Velocity:** radian per second (rad/s)
- **Dynamic Viscosity:** pascal-second ($Pa \cdot s$)

Temperature Scales (Units of Temperature)

These are the systems that define the reference points and divisions for measuring temperature.

1. Kelvin (K):

- **Description:** The SI base unit of thermodynamic temperature. It's an *absolute* temperature scale, meaning 0 K (absolute zero) is the theoretical point

where all molecular motion ceases. There are no "degrees" in Kelvin.

- **Reference Points:** Defined by the triple point of water (273.16 K) and absolute zero (0 K).
- **Usage:** Primarily used in science, engineering, and for very low (cryogenic) temperatures.

2. Celsius ($^{\circ}C$):

- **Description:** The most used temperature scale worldwide for everyday purposes. It's a derived unit in the SI system.
- **Reference Points:** Water freezes at $0^{\circ}C$ and boils at $100^{\circ}C$ at standard atmospheric pressure.
- **Relationship to Kelvin:** $K = ^{\circ}C + 273.15$
- **Usage:** Widely used in most countries for weather, cooking, and general scientific work.

3. Fahrenheit ($^{\circ}F$):

- **Description:** Primarily used in the United States, its territories, and a few other specific contexts.
- **Reference Points:** Water freezes at $32^{\circ}F$ and boils at $212^{\circ}F$ at standard atmospheric pressure.
- **Relationship to Celsius:** $^{\circ}C = (^{\circ}F - 32) / 1.8$ or $^{\circ}C = (^{\circ}F - 32) \times 5/9$
- **Usage:** Everyday use in the USA.

4. Rankine ($^{\circ}R$ or $^{\circ}Ra$):

- **Description:** An absolute temperature scale, similar to Kelvin, but based on the Fahrenheit degree. 0 $^{\circ}R$ is absolute zero.
- **Relationship to Fahrenheit:** $^{\circ}R = ^{\circ}F + 459.67$



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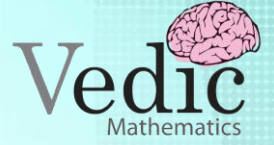
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- **Usage:** Mainly in engineering fields in the USA, particularly when dealing with thermodynamic calculations that involve Fahrenheit.

Less Common/Historical Scales:

- **Réaumur (°Re):** Water freezes at 0°Re and boils at 80°Re. Used historically in parts of Europe.
- **Newton (°N):** Water freezes at 0°N and boils at 33°N. (Isaac Newton's scale).
- **Delisle (°D):** A "backward" scale where higher numbers meant colder temperatures. Water freezes at 150°D and boils at 0°D.
- **Rømer (°Rø):** One of the earliest scales. Water freezes at 7.5°Rø and boils at 60°Rø.

II. Temperature Measuring Devices (Thermometers)

These are the instruments that utilize various physical principles to convert temperature into a readable value.

1. Liquid-in-Glass Thermometers:

- **Principle:** Thermal expansion of a liquid (mercury or alcohol) confined in a glass tube.
- **Types:**
 - **Clinical Thermometer:** Designed for body temperature, often with a constriction to hold the mercury/alcohol level.
 - **Laboratory Thermometer:** Wider range, no constriction.
 - **Alcohol Thermometer:** Uses colored alcohol, safer than mercury, good for lower temperatures.

- **Mercury Thermometer:** Very accurate, wide range, but mercury is toxic (phasing out).

- **Usage:** Common household, medical, and laboratory use for direct readings.

2. Bimetallic Strip Thermometers:

- **Principle:** Two different metals bonded together, which expand at different rates when heated, causing the strip to bend. This bending is linked to a pointer.
- **Usage:** Ovens, home thermostats, industrial temperature gauges. Relatively inexpensive and robust.

3. Thermocouples:

- **Principle:** Based on the Seebeck effect, where a voltage is generated when two dissimilar metals are joined at two junctions held at different temperatures. The voltage is proportional to the temperature difference.

- **Usage:** Wide range of industrial applications, high temperatures, quick response time, robust.

4. Resistance Temperature Detectors (RTDs):

- **Principle:** The electrical resistance of a metal (typically platinum) changes predictably with temperature. The change in resistance is measured to infer temperature.
- **Usage:** High accuracy and stability, industrial processes, laboratory, often for moderate to high temperatures.

5. Thermistors:

- **Principle:** A type of resistor whose resistance changes significantly and



predictably with temperature. Often made from semiconductor materials.

- **Types:** NTC (Negative Temperature Coefficient - resistance decreases with increasing temperature), PTC (Positive Temperature Coefficient - resistance increases with increasing temperature).
- **Usage:** Sensitive, fast response, good for narrow temperature ranges, electronic circuits, digital thermometers, automotive applications.

6. Infrared Thermometers (Pyrometers / Non-contact Thermometers):

- **Principle:** Detects the infrared radiation emitted by an object. All objects with a temperature above absolute zero emit thermal radiation.
- **Types:**
 - **Handheld Infrared Thermometers (IR Guns):** Common for quick surface temperature checks.
 - **Thermal Imagers (Infrared Cameras):** Create visual images based on temperature differences.
- **Usage:** Measuring temperature of hot, moving, or inaccessible objects, fever screening, industrial process control, electrical troubleshooting, building inspection.

7. Gas Thermometers:

- **Principle:** Based on the relationship between temperature, pressure, and volume of a gas (e.g., ideal gas law). Either constant volume or constant pressure.
- **Usage:** Highly accurate, often used as primary standards for calibrating other thermometers, but bulky and slow.

8. Change-of-State Devices:

- **Principle:** Materials that change color or state (melt) at specific temperatures.
- **Types:** Temperature labels, crayons, pellets, liquid crystals.
- **Usage:** Indicating if a certain temperature threshold has been exceeded (e.g., for shipping, cooking). Generally less accurate.

9. Silicon Diode Temperature Sensors:

- **Principle:** The forward voltage drop across a silicon diode changes predictably with temperature.
- **Usage:** Integrated into electronic circuits, good for measuring cryogenic temperatures, simple to interface with microcontrollers.

D. SI Prefixes (for Multiples and Submultiples)

Prefix	Symbol	Factor
Yotta	Y	10^{24}
Zetta	Z	10^{21}
Exa	E	10^{18}
Peta	P	10^{15}
Tera	T	10^{12}
Giga	G	10^9
Mega	M	10^6
Kilo	k	10^3
Hecto	h	10^2
Deka	da	10^1



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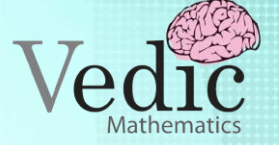
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Prefix	Symbol	Factor
(none)		10^0 (1)
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}
Atto	a	10^{-18}
Zepto	z	10^{-21}
Yocto	y	10^{-24}

- **pound (lb)** (1 lb = 16 oz)
- **stone (st)** (UK only, 1 st = 14 lb)
- **short ton (US ton)** (1 short ton = 2000 lb)
- **long ton (Imperial ton)** (1 long ton = 2240 lb)

C. Volume (Liquid)

- **fluid ounce (fl oz)**
- **pint (pt)** (1 pint = 16 fl oz US, 20 fl oz Imperial)
- **quart (qt)** (1 qt = 2 pints)
- **gallon (gal)** (1 gal = 4 quarts)

D. Volume (Dry) - US Customary only

- **pint (dry pt)**
- **quart (dry qt)**
- **peck (pk)**
- **bushel (bu)**

E. Area

- **square inch (in²)**
- **square foot (ft²)**
- **acre (ac)** (1 acre = 43,560 ft²)
- **square mile (mi²)**

II. Imperial and US Customary Units

These systems are still in use in some countries (notably the United States, and to some extent the UK for certain purposes). Conversions to SI are often necessary in scientific contexts.

A. Length

- **inch (in)**
- **foot (ft)** (1 ft = 12 in)
- **yard (yd)** (1 yd = 3 ft)
- **mile (mi)** (1 mi = 1760 yd = 5280 ft)
- **nautical mile (nmi)** (used for sea/air navigation, approx 1.852 km)

B. Mass/Weight

- **ounce (oz)**

