Chapter 2: The International System of Units (SI) (3 Weeks)

1 Overview

- Base quantities and their units of measurement;
- Supplementary quantities;
- Derived quantities.

2 Units of Measurement

- Rationale of the SI system – brief historical background;
- Base units and their definitions;
- Derived units (including dimensionless units);
- SI prefixes.

3 Rationale of the SI System – Brief Historical Background

Performing a measurement consists of comparing an unknown physical (or chemical) quantity with a reference quantity of the same nature using a measuring instrument.

Any measurement requires a reference system and, therefore, a unit. In the not-so-distant past, numerous units coexisted, often bearing little relation to one another. It was only during the French Revolution that the first coherent system of units emerged: the metric system. This system was internationally formalized through the Meter Convention of May 20, 1875, a diplomatic treaty.

In 1960, during the 11th General Conference on Weights and Measures (CGPM), the International System of Units (SI) was adopted. Today, the SI comprises two main classes of units:

- Seven base units;
- Derived units.

However, the SI should not be regarded as a fixed or immutable system. Advances in science and technology, along with evolving societal needs—particularly the demand for increased measurement accuracy—require national metrology institutes to continuously improve the practical realization of SI units. These efforts concern both reference standards and the dissemination of traceability to users. Consequently, it is sometimes necessary to update unit definitions or introduce new realizations.

4 Base Units and Their Definitions

The International System of Units (SI) is currently composed of seven base units (with their unique symbols):

- meter (m)
- kilogram (kg)
- second (s)
- ampere (A)
- kelvin (K)
- candela (cd)
- mole (mol)

Definitions

Meter (m) The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

Kilogram (kg) The kilogram is the mass of the platinum–iridium prototype sanctioned by the General Conference on Weights and Measures in Paris in 1889 and deposited at the International Bureau of Weights and Measures.

Second (s) The second is 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.

Ampere (A) The ampere is the constant electric current which, if maintained in two straight, parallel conductors of infinite length and negligible circular cross-section placed one meter apart in vacuum, would produce a force equal to 2×10^{-7} newton per meter of length between these conductors.

Kelvin (K) The kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Candela (cd) The candela is the luminous intensity, in a given direction, of a source emitting monochromatic radiation of frequency 540×10^{12} hertz and having a radiant intensity in that direction of 1/683 watt per steradian.

Mole (mol) The mole is the amount of substance containing as many elementary entities as there are atoms in 0.012 kilogram of carbon-12.

5 Derived Units (Including Dimensionless Units)

Derived units complement base units and may have special names (e.g., hertz, pascal, joule), but they can always be expressed in terms of base units. Some derived quantities are dimensionless.

All SI units are interrelated, forming a coherent system. Since physical quantities may span very wide ranges of values, SI prefixes are used to avoid excessive zeros, covering factors from 10^{24} to 10^{-24}.

6 Examples of Derived Quantities

6.1 Electricity and Magnetism

Potential difference	volt (V = W/A)
Capacitance	farad (F = C/V)
Resistance	ohm (Ω = V/A)
Inductance	henry (H = Wb/A)
Electric charge	coulomb (C = A·s)
Power	watt (W = J/s)
Energy	joule (J = N·m)
Magnetic induction	tesla (T = Wb/m^2)
Electric field	V/m
Magnetic field	A/m
Conductance	siemens (S = A/V)
Attenuation	decibel (dB)

6.2 Mass and Related Quantities

Density (ρ): kg·m^{-3}
Force: newton (N)
Pressure: pascal (Pa)
Dynamic viscosity: Pa·s
Kinematic viscosity: m^2·s^{-1}
Mass flow rate: kg·s^{-1}
Volumetric flow rate: m^3·s^{-1}

6.3 Length and Dimensional Quantities

Plane angle: radian (rad)
Solid angle: steradian (sr)

7 SI Prefixes

Factor	Prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y