SI Units

International System of Units

SI Units

The International System of Units (SI) is the globally accepted standard for measurement. Established to provide a consistent framework for scientific and technical measurements, SI units facilitate clear communication and data comparison across various fields and countries. The system is based on seven fundamental units: the meter for length, the kilogram for mass, the second for time, the ampere for electric current, the kelvin for temperature, the mole for substance, and the candela for luminous intensity.

Table 1: Base SI units.

Physical Quantity	SI Base Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere	A
Temperature	Kelvin	K
Amount of Substance	Mole	mol
Luminous Intensity	Candela	cd

Table 2: Derived SI units.

Physical Quantity	Derived SI Unit	Symbol
Area	Square meter	m^2
Volume	Cubic meter	m^3
Speed	Meter per second	m/s
Acceleration	Meter per second squared	m/s^2
Force	Newton	N
Pressure	Pascal	Pa
Energy	Joule	J
Power	Watt	W
Electric Charge	Coulomb	C
Electric Potential	Volt	V
Resistance	Ohm	Ω
Capacitance	Farad	F
Frequency	Hertz	Hz
Luminous Flux	Lumen	lm
Illuminance	Lux	lx
Specific Energy	Joule per kilogram	J/kg
Specific Heat Capacity	Joule per kilogram Kelvin	$J/(kg \cdot K)$

Table 3: Common multiples and submultiples for SI units.

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10^1	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ

SI System Rules and Common Mistakes

Using the SI system correctly is crucial for clear communication in science and engineering. Below are common mistakes in using the SI system, examples of incorrect usage, and how to correct them.

Table 4: SI system rules and common mistakes

Concept	**Mistake**	**Correct Usage**	**Notes**
Use of SI Unit Symbols	`m./s`	`m/s`	Use the correct format without additional punctuation.
Spacing Between Value & Unit	`10kg`	`10 kg`	Always leave a space between the number and the unit symbol.
Incorrect Unit Symbols	`sec`, `hrs`, `°K`	`s`, `h`, `K`	Use the proper SI symbols; symbols are case-sensitive.
Abbreviations for Units	`5 kilograms (kgs)`	`5 kilograms (kg)`	Avoid informal abbreviations like “kgs”; adhere to standard symbols.
Multiple Units in Expressions	`5 m/s/s`, `5 kg/meter²`	`5 m/s²`, `5 kg/m²`	Use compact, standardized formats for derived units.

Concept	Mistake	Correct Usage	Notes
Incorrect Use of Prefixes	`0.0001 km`	`100 mm`	Choose prefixes to keep numbers in the range (0.1 x < 1000).
Misplaced Unit Symbols	`5/s`, `kg10`	`5 s` ^{1}, `10 kg`	Symbols must follow numerical values, not precede them.
Degrees Celsius vs. Kelvin	`300°K`	`300 K`	Kelvin is written without "degree"
Singular vs. Plural Units	`5 kgs`, `1 meters`	`5 kg`, `1 meter`	Symbols do not pluralize; full unit names follow grammar rules.
Capitalization of Symbols	`Kg`, `S`, `Km`, `MA`	`kg`, `s`, `km`, `mA`	Symbols are case-sensitive; use uppercase only where specified (e.g., `N`, `Pa`).
Capitalization of Unit Names	`Newton`, `Pascal`, `Watt`	`newton`, `pascal`, `watt`	Unit names are lowercase, even if derived from a person's name, unless starting a sentence.
Prefix Capitalization	`MilliMeter`, `MegaWatt`	`millimeter`, `megawatt`	Prefixes are lowercase for (10^{-1}) to (10^{-9}), uppercase for (10^6) and larger (except `k` for kilo).
Formatting in Reports	`5`, `Temperature: 300`	`5 kg`, `Temperature: 300 K`	Always specify units explicitly.

Unity Fraction

The **unity fraction** method, or **unit conversion using unity fractions**, is a systematic way to convert one unit of measurement into another. This method relies on multiplying by fractions that are equal to one, where the numerator and the denominator represent the same quantity in different units. Since any number multiplied by one remains the same, unity fractions allow for seamless conversion without changing the value.

The principle of unity fractions is based on:

1. **Setting up equal values**: Write a fraction where the numerator and denominator are equivalent values in different units, so the fraction equals one. For example, $\frac{1km}{1000m}$ is a unity fraction because 1 km equals 1000 m.

2. **Multiplying by unity fractions**: Multiply the initial quantity by the unity fraction(s) so that the undesired units cancel out, leaving only the desired units.

Classwork

Example 0.1. Suppose we want to convert 5 kilometers to meters.

1. Start with 5 kilometers:
$$5\,\mathrm{km}$$

2. Multiply by a unity fraction that cancels kilometers and introduces meters. We use $(\frac{1000\,\mathrm{m}}{1\,\mathrm{km}}), since\ 1\,\mathrm{km} = 1000\,\mathrm{m}$:
$$5\,\mathrm{km} \times \frac{1000\,\mathrm{m}}{1\,\mathrm{km}} = 5000\,\mathrm{m}$$

3. The kilometers km cancel out, leaving us with meters m:
$$5\,\mathrm{km} = 5000\,\mathrm{m}$$

This step-by-step approach illustrates how the unity fraction cancels the undesired units and achieves the correct result in meters.

Unity fractions can be extended by using multiple conversion steps. For example, converting hours to seconds would require two unity fractions: one to convert hours to minutes and another to convert minutes to seconds. This approach ensures accuracy and is widely used in science, engineering, and other fields that require precise unit conversions.

Example 0.2. Convert $15\,\mathrm{m/s}$ to km/h.

1. Start with $15\,\mathrm{m/s}$.
2. To convert meters to kilometers, multiply by $\frac{1\,\mathrm{km}}{1000\,\mathrm{m}}$.
3. To convert seconds to hours, multiply by $\frac{3600\,\mathrm{s}}{1\,\mathrm{h}}$.

$$15\,\mathrm{m/s} \times \frac{1\,\mathrm{km}}{1000\,\mathrm{m}} \times \frac{3600\,\mathrm{s}}{1\,\mathrm{h}} = 54\,\mathrm{km/h}$$

The meters and seconds cancel out, leaving kilometers per hour: $54\,\mathrm{km/h}$.

Problem Set

Instructions:

1. Use unity fraction to convert between derived SI units.
2. Show each step of your work to ensure accuracy.
3. Simplify your answers and include correct units.

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1. **Speed**
   Convert $72\,\text{km/h}$ to m/s.
2. **Force**
   Convert $980\,\text{N}$ (newtons) to $\text{kg}\cdot\text{m/s}^2$.
3. **Energy**
   Convert $2500\,\text{J}$ (joules) to kJ.
4. **Power**
   Convert $1500\,\text{W}$ (watts) to kW.
5. **Pressure**
   Convert $101325\,\text{Pa}$ (pascals) to kPa.
6. **Volume Flow Rate**
   Convert $3\,\text{m}^3/\text{min}$ to L/s.
7. **Density**
   Convert $1000\,\text{kg/m}^3$ to g/cm^3.
8. **Acceleration**
   Convert $9.8\,\text{m/s}^2$ to cm/s^2.
9. **Torque**
   Convert $50\,\text{N}\cdot\text{m}$ to $\text{kN}\cdot\text{cm}$.
10. **Frequency**
    Convert $500\,\text{Hz}$ (hertz) to kHz.
11. **Work to Energy Conversion**
    A force of $20\,\text{N}$ moves an object $500\,\text{cm}$. Convert the work done to joules.
12. **Kinetic Energy Conversion**
    Calculate the kinetic energy in kilojoules of a $1500\,\text{kg}$ car moving at $72\,\text{km/h}$.
13. **Power to Energy Conversion**
    A machine operates at $2\,\text{kW}$ for 3 hours. Convert the energy used to megajoules.

14. **Pressure to Force Conversion**
    Convert a pressure of $200\,\mathrm{kPa}$ applied to an area of $0.5\,\mathrm{m}^2$ to force in newtons.
15. **Density to Mass Conversion**
    Convert $0.8\,\mathrm{g/cm}^3$ for an object with a volume of $250\,\mathrm{cm}^3$ to mass in grams.

Answer Key

1. $72\,\mathrm{km/h} = 20\,\mathrm{m/s}$
2. $980\,\mathrm{N} = 980\,\mathrm{kg}\cdot\mathrm{m/s}^2$
3. $2500\,\mathrm{J} = 2.5\,\mathrm{kJ}$
4. $1500\,\mathrm{W} = 1.5\,\mathrm{kW}$
5. $101325\,\mathrm{Pa} = 101.325\,\mathrm{kPa}$
6. $3\,\mathrm{m}^3/\mathrm{min} = 50\,\mathrm{L/s}$
7. $1000\,\mathrm{kg/m}^3 = 1\,\mathrm{g/cm}^3$
8. $9.8\,\mathrm{m/s}^2 = 980\,\mathrm{cm/s}^2$
9. $50\,\mathrm{N}\cdot\mathrm{m} = 5\,\mathrm{kN}\cdot\mathrm{cm}$
10. $500\,\mathrm{Hz} = 0.5\,\mathrm{kHz}$
11. $20\,\mathrm{N} \times 5\,\mathrm{m} = 100\,\mathrm{J}$
12. Kinetic energy $= 1500\,\mathrm{kg} \times (20\,\mathrm{m/s})^2/2 = 300\,\mathrm{kJ}$
13. $2\,\mathrm{kW} \times 3\,\mathrm{hours} = 21.6\,\mathrm{MJ}$
14. $200\,\mathrm{kPa} \times 0.5\,\mathrm{m}^2 = 100,000\,\mathrm{N}$
15. $0.8\,\mathrm{g/cm}^3 \times 250\,\mathrm{cm}^3 = 200\,\mathrm{g}$

Further Reading

Read Chapter 1 in @russell2022 and complete the end of chapter problems.