Block 01 — Physical Quantities and SI System

Student Group

First Name	Surname	Matrikel Nr.

Table of Contents

Block 01 — Physical quantities and SI system

Learning objectives

- Use the SI base quantities, units, and symbols correctly; convert between units with prefixes.
- Distinguish base vs. derived quantities; express key EE units (e.g. $\rm V$, $\rm \Omega$) in SI base units.
- Apply quantity equations and perform unit (dimensional) checks; contrast with normalized (dimensionless) equations.
- Read and use common Latin/Greek letter symbols; distinguish uppercase/lowercase and instantaneous vs. constant quantities.

90-minute plan

1. Warm-up (10 min):
    1. “What is the unit of conductivity? of energy?”
2. Quick prefix quiz; everyday magnitude estimates ($\rm mA$, $\rm k\Omega$, $\rm \mu F$).
3. Core concepts & derivations (60 min):
    1. SI base set → derived units; prefix rules;
4. quantity vs. normalized equations;
5. dimensional checks.
    1. Prefix ladder ($\rm E$…$\rm a$) and best-practice rounding/checks.
    2. Symbols & Greek letters in EEE1; time-varying vs constant symbols.
6. Practice (15 min): Fast conversions and unit checks (individual → pair).
7. Wrap-up (5 min): Summary table; common pitfalls checklist.

Conceptual overview

1. Units are the grammar of engineering and physics.
2. The SI defines seven **base quantities** and units; all other (derived) units are built from these without extra numerical factors. The SI defines seven **base quantities** and units.
3. In EEE1 we work strictly in the SI system, combining **numerical value × unit** and tracking dimensions at every step (e.g., $I=2~\rm A$ means “two times one ampere”).
4. Derived units (e.g., $\rm V$, $\rm \Omega$, $\rm S$) must reduce to base units without hidden factors.
5. **Prefixes** scale units by powers of ten to keep numbers readable. Prefixes compress very large and very small numbers so we can compute and compare safely.
6. **Quantity equations** keep units; **normalized equations** cancel units to yield dimensionless ratios (e.g., efficiency).
7. In EE, symbol choices and letter case matter: U vs. $u(t)$, $\rm M$ (mega) vs. $\rm m$ (milli). We adopt a consistent symbol set (Latin + Greek), and distinguish **constants** (capital letters) from **time functions** (lowercase, e.g., $u(t)$).
8. Finally, we preview the three anchor quantities for the next blocks: **charge** (what moves), **current** (how fast charge moves), and **voltage** (energy per charge). Physics describes **quantities** with a **numerical value × unit** (e.g., $I=2~\rm{A}$).

SI base quantities and units

- For practical applications of physical laws of nature, **physical quantities** are put into mathematical relationships.
- There are basic quantities based on the SI system of units (French for Système International d'Unités), see below.
- In order to determine the basic quantities quantitatively (quantum = Latin for *how big*), **physical units** are defined, e.g. ${\rm metre}$ for length.
- In electrical engineering, the first three basic quantities (cf. table 1) are particularly important.
  Mass is important for the representation of energy and power.

- Each physical quantity is indicated by a product of **numerical value** and **unit**:
  e.g. $I = 2~{\rm A}$
  - This is the short form of $I = 2\cdot 1~{\rm A}$
  - I is the physical quantity, here: electric current strength
  - $\{I\} = 2 $ is the numerical value
  - $ [I] = 1~{\rm A}$ is the (measurement) unit, here: ${\rm Ampere}$

Base quantity	**Name**	**Unit**	**Definition**
Time	Second	${\rm s}$	Oscillation of Cs-Atom
Length	Meter	${\rm m}$	by s und speed of light
el. Current	Ampere	${\rm A}$	by s and elementary charge
Mass	Kilogram	${\rm kg}$	still by kg prototype
Temperature	Kelvin	${\rm K}$	by triple point of water
amount of substance	Mol	${\rm mol}$	via number of ^{12}C nuclides
luminous intensity	Candela	${\rm cd}$	via given radiant intensity

Tab. 1: SI base quantities (SI)

Common derived quantities

- Besides the basic quantities, there are also quantities derived from them, e.g. $[F] = [m]\cdot [a] \rightarrow 1~{\rm N} = 1 ~{\rm kg} \cdot {{1 ~{\rm m}}\over{1 ~{\rm s}^2}}$.
- SI units should be preferred for calculations. These can be derived from the basic quantities **without a numerical factor**.
  example:
  - The pressure unit bar (${\rm bar}$) is an SI unit.
  - BUT: The obsolete pressure unit “Standard atmosphere” ($=1.013~{\rm bar}$) is **not** an SI unit.
- To prevent the numerical value from becoming too large or too small, it is possible to replace a decimal factor with a prefix. These are listed in table ##.

We will see, that a lot of electrical quantities are derived quantities.

Prefixes

- Use prefixes to keep magnitudes practical

(see table 2 and table 3).
- Instead of writing zeroes for like in $0.000000004 ~\rm C $ is is easier to write $4 \rm ~nC $.
- For calculation it is often easier to write $4 ~\rm nC = 4 \cdot 10^{-9} ~C$ or the notation `\rm 4e-9 C`

Physical equations

- Physical equations allow a connection of physical quantities.
- There are two types of physical equations to distinguish:
    - Quantity equations (in German: *Größengleichungen*)
    - Normalized quantity equations (also called related quantity equations, in German *normierte Größengleichungen*)

Quantity Equations

The vast majority of physical equations result in a physical unit that does not equal 1.

Example: Force $F = m \cdot a$ with $[{\rm F}] = 1~\rm kg \cdot {{{\rm m}}\over{{\rm s}^2}}$

- A unit check should always be performed for quantity equations

normalized Quantity Equations

In normalized quantity equations, the measured value or calculated value of a quantity equation is divided by a reference value. This results in a dimensionless quantity relative to the reference value.

Example: The efficiency $\eta = {{P_{\rm O}}\over{P_{\rm I}}}$ is given as quotient between the outgoing power $P_{\rm

prefix	prefix symbol	meaning
Yotta	${\rm Y}$	10^{24}
Zetta	${\rm Z}$	10^{21}
Exa	${\rm E}$	10^{18}
Peta	${\rm P}$	10^{15}
Tera	${\rm T}$	10^{12}
Giga	${\rm G}$	10^{9}
Mega	${\rm M}$	10^{6}
Kilo	${\rm k}$	10^{3}
Hecto	${\rm h}$	10^{2}
Deka	${\rm de}$	10^{1}

Tab. 2: Prefixes I

prefix	prefix symbol	meaning
Deci	${\rm d}$	10^{-1}
Centi	${\rm c}$	10^{-2}
Milli	${\rm m}$	10^{-3}
Micro	${\rm u}$, $µ$	10^{-6}
Nano	${\rm n}$	10^{-9}
Piko	${\rm p}$	10^{-12}
Femto	${\rm f}$	10^{-15}
Atto	${\rm a}$	10^{-18}
Zeppto	${\rm z}$	10^{-21}
Yocto	${\rm y}$	10^{-24}

Tab. 3: Prefixes II

- Quantity equations should generally be preferred

O}$ and the incoming power $P_{\rm I}$.

As a reference the following values are often used:

- Nominal values (maximum permissible value in continuous operation) or
- Maximum values (maximum value achievable in the short term)

For normalized quantity equations, the units should **always** cancel out.

Letters for physical quantities

Latin/Greek letters are reused across physics.

In physics and electrical engineering, the letters for physical quantities are often close to the English term.

Thus explains C for ***C**apacity*, Q for ***Q**uantity* and ε_0 for the ***E**lectical Field Constant*. But, maybe you already know that C is used for the thermal capacity as well as for the electrical capacity. The Latin alphabet does not have enough letters to avoid conflicts for the scope of physics. For this reason, Greek letters are used for various physical quantities (see table 4).

Uppercase letters	Lowercase letters	Name	Application
A	α	Alpha	angles, linear temperature coefficient
B	β	Beta	angles, quadratic temperature coefficient, current gain
Γ	γ	Gamma	angles
Δ	δ	Delta	small deviation, length of a air gap

Especially in electrical engineering, **upper/lower case letters** are used to distinguish between

- a constant (time-independent) quantity,
  e.g. the period T
- or a time-dependent quantity,
  e.g. the instantaneous voltage $u(t)$
- EE relies on case and context (e.g., U vs. $u(t)$). Time-varying quantities often use lowercase, constants uppercase.

Uppercase letters	Lowercase letters	Name	Application
E	ϵ, ε	Epsilon	electrical field constant, permittivity
Z	ζ	Zeta	- (math function)
H	η	Eta	efficiency
Θ	θ, ϑ	Theta	temperature in Kelvin
I	ι	Iota	-
K	κ	Kappa	specific conductivity
Λ	λ	Lambda	- (wavelength)
M	μ	Mu	magnetic field constant, permeability
N	ν	Nu	-
Ξ	ξ	Xi	-
O	$\omicron$	Omicron	-
Π	π	Pi	math. product operator, math. constant
R	ρ, ϱ	Rho	specific resistivity
Σ	σ	Sigma	math. sum operator, alternatively for specific conductivity
T	τ	Tau	time constant
Υ	υ	Upsilon	-
Φ	ϕ, φ	Phi	magnetic flux, angle, potential
X	χ	Chi	-
Ψ	ψ	Psi	linked magnetic flux
Ω	ω	Omega	unit of resistance, angular frequency

Tab. 4: greek letters

Common pitfalls & misconceptions

- **Case matters:** $\rm M$ (mega, 10^6) vs. $\rm m$ (milli, 10^{-3});
- **Micro symbol:** use $\rm \mu$ (or u only when typing constraints exist);
- **usage of prefixes** never stack prefixes (no “$\rm mµF$”).
- **Mixed units:** keep SI consistently; avoid mixing $\rm hours$/$\rm Wh$ inside SI derivations.
- **Units vs. variables:** don’t confuse W (work) with $\rm W$ (Watt = unit of power $\rm P$ = work per second).
  Don’t confuse C (capacity = charge per voltage) with $\rm C$ (Coulomb = unit of charge $\rm Q$).
- **Units vs. prefixes:** don’t confuse $\rm mN$ (Millinewton) with $\rm Nm$ (Newton meter).
- **Normalized vs. quantity equations:** dimensionless ratios should cancel units; if not, something’s wrong.

Exercises

Worked example(s)

1) Unit check (quantity equation): Show that $P=U\cdot I$ has unit watt.

1. $[U]=\rm{V}=\rm{kg}\,\rm{m}^2\,\rm{s}^{-3}\,\rm{A}^{-1}$, $[I]=\rm{A}$.
2. $[P]=[U][I]=\rm{kg}\,\rm{m}^2\,\rm{s}^{-3}=\rm{W}$.

> **2) Prefix conversion:** $3.3~\rm{mA}=3.3\times10^{-3}~\rm{A}=3300~\rm{\mu A}$.

> **3) Work from lifting (quantity equation):** $W=mgs$ with $m=100~\rm{kg},\,g=9.81~\rm{m/s^2},\,s=2~\rm{m}$. $W=100\cdot9.81\cdot2~\rm{Nm}=1962~\rm{J}$.

Quick checks

> Convert $47~\rm{k\Omega}$ to $\rm{M\Omega}$ and Ω.
>
> Answer
>
> $47~\rm{k\Omega}=0.047~\rm{M\Omega}=47{,}000~\Omega$.

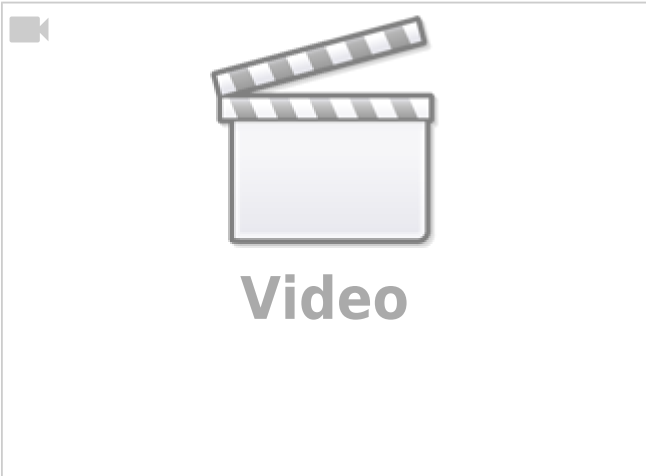
> Is $\eta=\dfrac{P_\rm{O}}{P_\rm{I}}$ dimensionless?
>
> Answer
>
> Yes. Units cancel (W/W); normalized equation.

> Which is larger: $5~\rm{mA}$ or $4500~\rm{\mu A}$?
>
> Answer
>
> $5~\rm{mA}=5000~\rm{\mu A}$, so $5~\rm{mA}$ is larger.

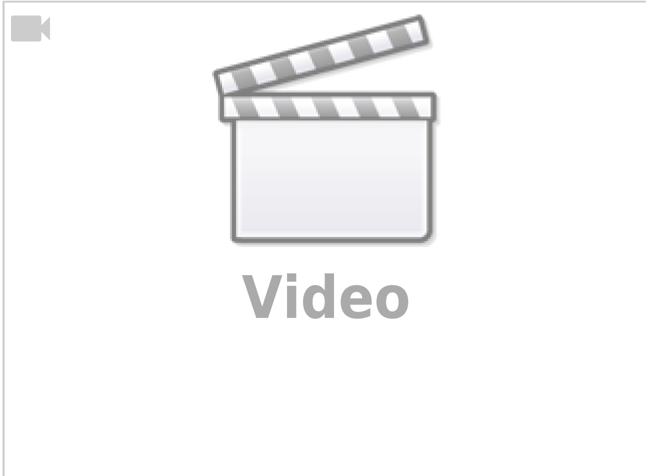
> True/False: $1~\rm{V}=1~\rm{Nm/As}$.
>
> Answer
>
> True (from $W=UQ$).

Embedded resources

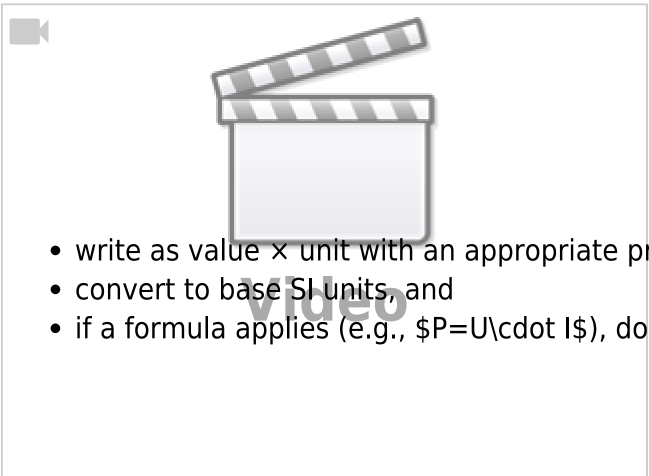
A nice 10-minute intro into some of the main topics of this chapter



Short presentation of the SI units



Orders of magnitude and why prefixes matter.



Mini-assignment / homework (optional)

List 10 everyday EE-relevant quantities (e.g., USB current, phone battery energy, LED forward voltage). For each:

- write as value × unit with an appropriate prefix,
- convert to base SI units, and
- if a formula applies (e.g., $P=U\cdot I$), do a unit check.