

Block 01 – Physical Quantities, Units, Charge & Current

Student Group

First Name	Surname	Matrikel Nr.

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Block 01 — Physical Quantities, Units, Charge & Current

Learning objectives

- Convert and compare values using SI base units and prefixes from atto (a) to exa (E).
- Explain electric charge as multiples of the elementary charge and compute total charge from particle count.
- Define electric current as time rate of charge flow, relate conventional current to electron flow, and use correct reference arrows.
- Apply unit analysis to check formulas and results.

90-minute plan

1. Warm-up (10 min): SI prefixes speed-drill; unit sanity checks (► quick quiz).
2. Core concepts & derivations (60 min): SI system & prefixes → charge and the elementary charge → current as charge per time; conventional vs electron flow; reference arrows in circuits.
3. Practice (15 min): 📖 Conversions & short calculations (prefixes; Q-I-t triangle); direction questions with mixed charge carriers.
4. Wrap-up (5 min): Recap key formulas and common mistakes; preview: voltage & potential (next block).

Conceptual overview

What's the game? In circuits we count **how much charge** moves (**Q**, coulombs) and **how fast** it moves (**I**, amperes). SI units and prefixes let us express tiny sensor signals and huge lightning currents on one common scale. Current direction is a **convention** (positive-charge movement) and must not be confused with the motion of electrons, which are negatively charged and usually move the other way.

Core definitions & formulas

SI base & derived (used today)

- Charge Q in coulomb (C); time t in second (s); current I in ampere (A).

Prefixes (selected)

- $1 \text{ mA} = 10^{-3} \text{ A}$, $1 \text{ }\mu\text{A} = 10^{-6} \text{ A}$, $1 \text{ nA} = 10^{-9} \text{ A}$, $1 \text{ kA} = 10^3 \text{ A}$.
- Tip: move powers of ten, not the decimal point “by feeling”.

Charge (discrete and continuous)

- $Q = n \cdot e$ with $e = 1.602 \times 10^{-19} \text{ C}$ (elementary charge).
- Typical values: single ion e ; small capacitor on a sensor: $Q \sim \text{pC}$ – nC .

Current (definition)

- $I = \frac{dQ}{dt}$ (or $I \approx \Delta Q / \Delta t$ for averages).
- Unit check: $[I] = \text{C/s} = \text{A}$.
- Typical values: biopotentials $\sim \mu\text{A}$; GPIO pin $\sim \text{mA}$; motor windings $\sim \text{A}$.

Conventional vs electron flow

- **Conventional current** points in the direction **positive charges** would move.
- Electron flow is opposite in direction to conventional current in metals.
- Reference arrows for later circuit work: choose arbitrarily **before** calculation, then interpret sign after.

Symbol	Meaning	SI unit	Typical values
Q	Electric charge	C	pC (sensors) ... mC
e	Elementary charge	C	$1.602 \times 10^{-19} \sim \mathrm{C}$
n	Number of charges/particles	-	$10^3 \dots 10^{20}$ (context dependent)
t	Time	s	ms ... s
I	Electric current ($\frac{dQ}{dt}$)	A	$\mu\mathrm{A}$... A

Tab. 1: Symbols, units, typical values

Worked example(s)

Example 1 — Prefix fluency & charge moved

A sensor draws $3.6 \sim \mathrm{mA}$ continuously. a) Express this in A and in $\mu\mathrm{A}$. b) How much charge passes in $250 \sim \mathrm{ms}$?

Solution. a) $3.6 \sim \mathrm{mA} = 3.6 \times 10^{-3} \sim \mathrm{A} = 3600 \sim \mu\mathrm{A}$. b) $Q = I \cdot t = 3.6 \times 10^{-3} \sim \mathrm{A} \cdot 0.250 \sim \mathrm{s} = 9.0 \times 10^{-4} \sim \mathrm{C} = 0.90 \sim \mathrm{mC}$.

Example 2 — From particles to current

A current in a thin gold wire is due to electrons. In $20 \sim \mathrm{ms}$, $n = 7.5 \times 10^{15}$ electrons pass a cross-section. What average current flows?

Solution. Total charge $Q = n e = 7.5 \times 10^{15} \cdot 1.602 \times 10^{-19} \sim \mathrm{C} \approx 1.20 \times 10^{-3} \sim \mathrm{C}$. $I \approx Q/t = (1.20 \times 10^{-3})/0.020 \approx 0.060 \sim \mathrm{A} = 60 \sim \mathrm{mA}$. **Direction:** electron motion $\text{right} \rightarrow \text{left}$ implies **conventional current** $\text{left} \rightarrow \text{right}$.

Example 3 — Mixed carriers & current direction

In an electrolyte between faces A_1 and A_2 , during $\Delta t = 1 \sim \mathrm{s}$, $\Delta Q_p = +40 \sim \mu\mathrm{C}$ moves from A_1 to A_2 and $\Delta Q_n = -25 \sim \mu\mathrm{C}$ (negative) moves from A_2 to A_1 . What is the algebraic current from A_1 to A_2 ?

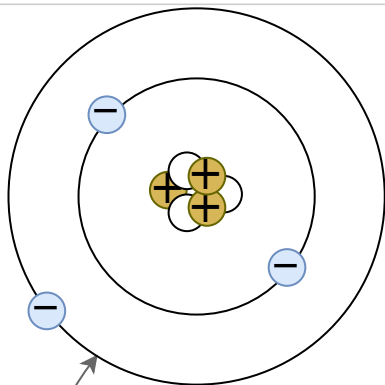
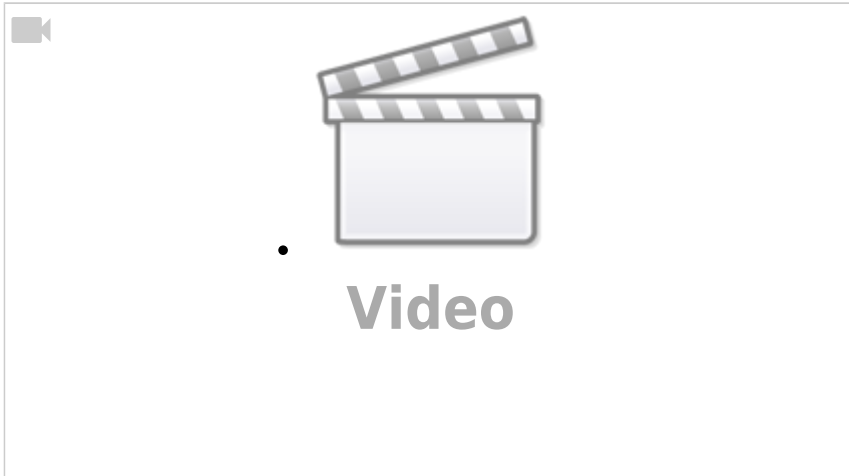
Solution. Total charge transfer $\Delta Q = \Delta Q_p - \Delta Q_n = 40 \sim \mu\mathrm{C} - (-25 \sim \mu\mathrm{C}) = 65 \sim \mu\mathrm{C}$. $I = \Delta Q / \Delta t = 65 \sim \mu\mathrm{A}$ **from A_1 to A_2** (positive).

Quick checks

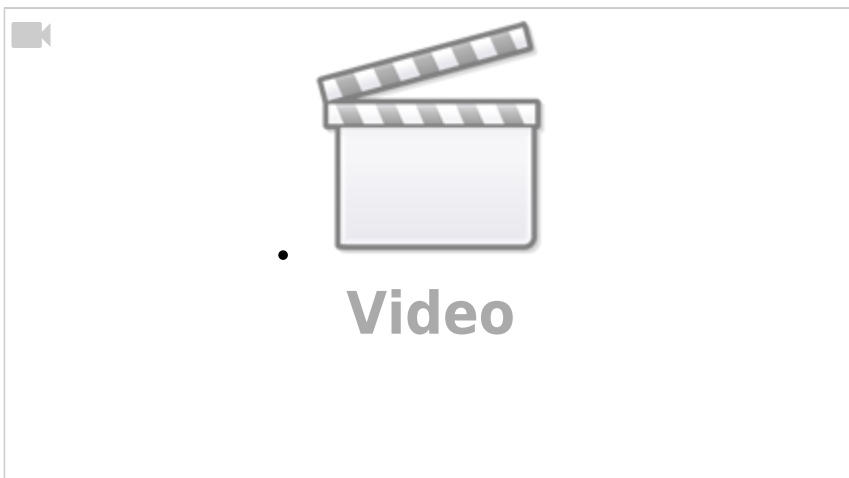
- What is the SI unit of charge? ++ Answer Coulomb (C). * Convert $47 \sim \mathrm{k}\Omega$ to

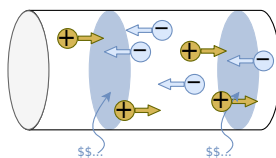
Ω . +++ Answer $k\Omega = 47,000\Omega$.
 * State the definition of I using charge and time. +++ Answer
 I flows if Q passes a cross-section in t . * If electrons drift to the right, which way is conventional current? +++ Answer To the **left** (opposite electron motion). * Compute the number of electrons in 1.0 nC . +++ Answer $n = Q/e \approx (1.0 \times 10^{-9}) / (1.602 \times 10^{-19}) \approx 6.24 \times 10^9$ electrons. ++

Embedded resources



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Common pitfalls & misconceptions

- Mixing up **quantity vs unit** (e.g., writing “mA” when you mean “m” as a prefix on amperes) or stacking prefixes (No: “ μ kA”).
- Confusing **charge** (C) with **current** (A) or **voltage** (V). Use unit analysis to catch errors early.
- Forgetting that **conventional current** follows positive charge flow; electrons go the opposite way in metals.
- Dropping sign information when interpreting reference arrows; always place arrows **before** calculation and read signs **after**.

Mini-assignment / homework (optional)

- Build a two-column “prefix ladder” from 10^{-18} to 10^{18} and place **five real-world examples** across it (e.g., biocurrent, USB device current, motor phase current). Bring it next time.
- Compute: A wearable draws $220 \mu\text{A}$ in standby for 18 h . How much charge (in mAh and in C) is used?

References & links

- Later: voltage & potential and ideal sources → [Block 02 — Voltage & Power](#).
- Later: resistance, conductance, and temperature dependence → [Block 03 — Resistance & Practical Resistors](#).
- Lab safety and measurement rules → [Laboratory regulations](#).

⚠ **Safety:** When measuring current, never put a multimeter in **voltage** mode across a source; use the **current** input and series connection to avoid a short circuit.

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