

# Block 01 — Physical Quantities, Units, Charge & Current

## Student Group

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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)

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

### Charge (discrete and continuous)

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

### Current (definition)

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

## 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	$\mathrm{pC}$ (sensors) ... $\mathrm{mC}$
$e$	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	$\mathrm{ms}$ ... $\mathrm{s}$
$I$	Electric current ( $\frac{dQ}{dt}$ )	A	$\mu\mathrm{A}$ ... $\mathrm{A}$

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  $\mathrm{A}$  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  $A_2$ ?

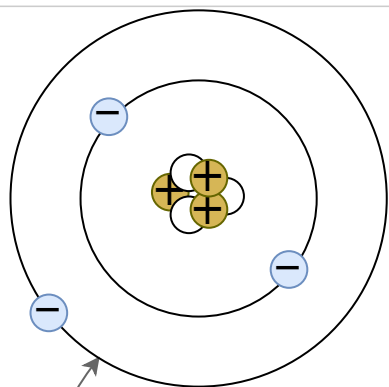
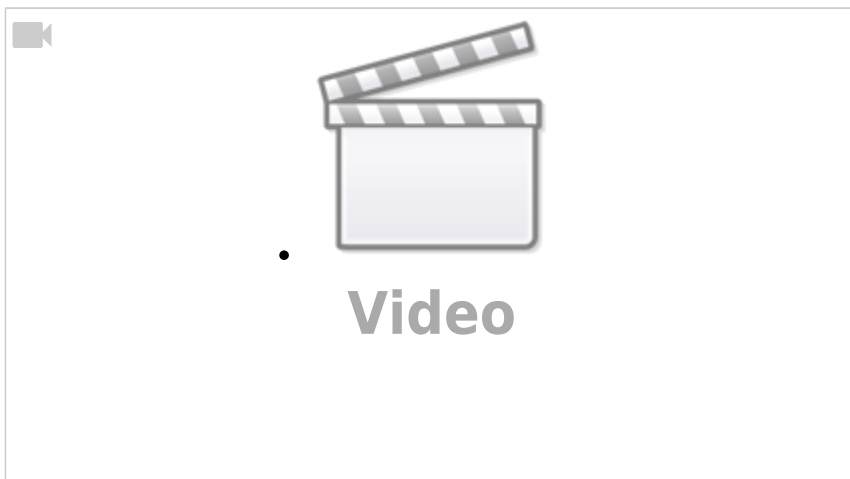
**Solution.** Total charge transfer  $\Delta Q = \Delta Q_p - \Delta Q_n = 40 \sim \mu\mathrm{C} - (-25 \sim \mu\mathrm{C}) = 65 \sim \mu\mathrm{C}$ .  $I = \Delta Q / \Delta t = 65 \sim \mu\mathrm{A}$  **from  $A_1$  to  $A_2$**  (positive).

## Quick checks

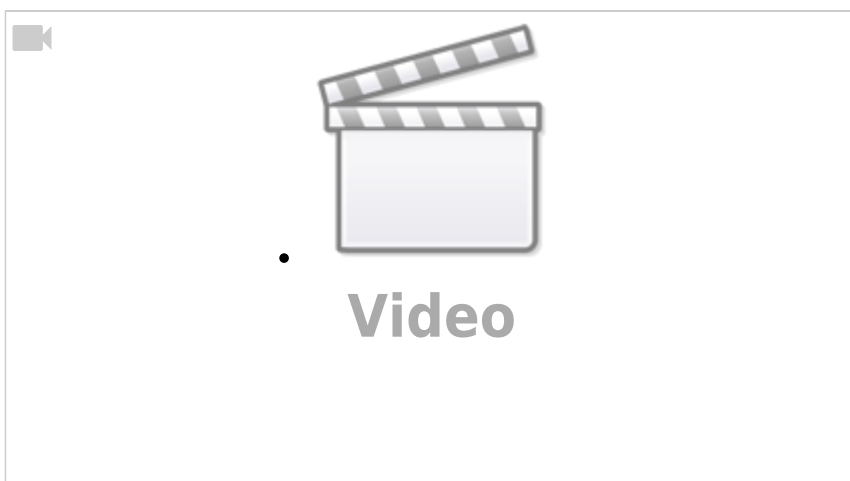
- What is the SI unit of charge? ++ Answer Coulomb (C). \* Convert  $47 \sim \mathrm{k}\Omega$  to

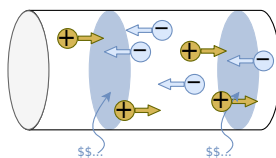
$\Omega$ . +++ Answer  $k\Omega = 47,000\Omega$ .  
 \* State the definition of  $I$  using charge and time. +++ Answer  
 $I$  flows if  $Q$  passes a cross-section in  $t$ . \* If electrons drift to the right, which way is conventional current? +++ Answer To the **left** (opposite electron motion). \* Compute the number of electrons in  $1.0\text{ nC}$ . +++ 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: “ $\mu$  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  $220 \sim \mu\text{A}$  in standby for  $18 \sim \text{h}$ . 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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