Block 01 — Physical Quantities, Units, Charge & Current

Student Group

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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)

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

Charge (discrete and continuous)

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

Current (definition)

- $I = \dfrac{\mathrm{d}Q}{\mathrm{d}t}$ (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	pC (sensors) … mC
e	Elementary charge	C	$1.602\times 10^{-19}~\mathrm{C}$
n	Number of charges/particles	–	$10^3 \ldots 10^{20}$ (context dependent)
t	Time	s	ms … s
I	Electric current ($\mathrm{d}Q/\mathrm{d}t$)	A	$\mathrm{\mu A}$ … A

Tab. 1: Symbols, units, typical values

Worked example(s)

Example 1 — Prefix fluency & charge moved

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

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

Example 2 — From particles to current

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

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

Example 3 — Mixed carriers & current direction

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

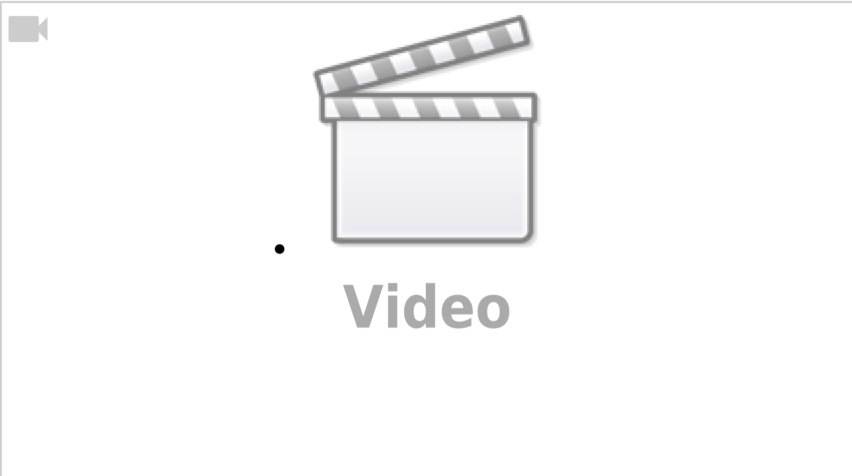
Solution. Total charge transfer $\Delta Q=\Delta Q_p-\Delta Q_n = 40~\mathrm{\mu C}-(-25~\mathrm{\mu C})=65~\mathrm{\mu C}$. $I=\Delta Q/\Delta t=65~\mathrm{\mu A}$ **from A_1 to A_2** (positive).

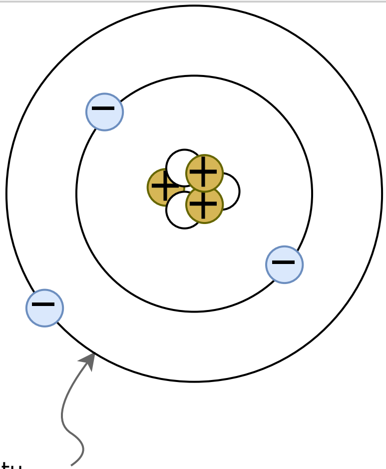
Quick checks

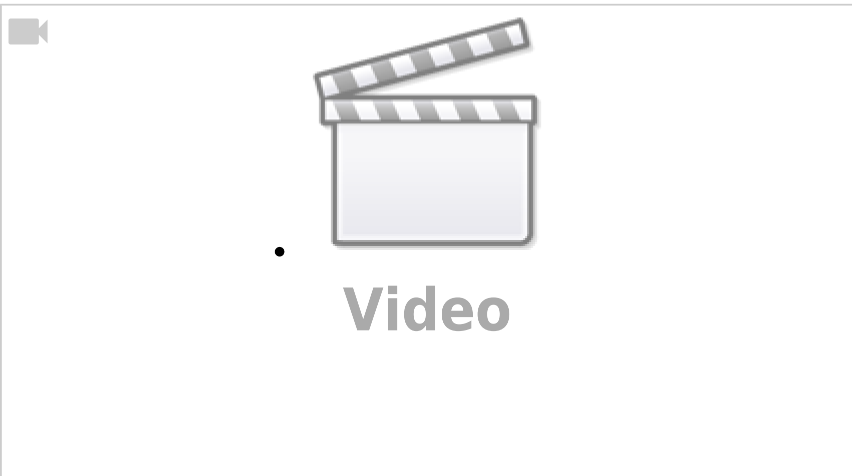
- What is the SI unit of charge? ++ Answer Coulomb (C). * Convert $47~\mathrm{k\Omega}$ to

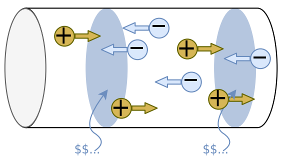
$\mathrm{\Omega}$. ++++ Answer $47~\mathrm{k\Omega}=47\,000~\mathrm{\Omega}$. * State the definition of $1~\mathrm{A}$ using charge and time. ++++ Answer $1~\mathrm{A}$ flows if $1~\mathrm{C}$ passes a cross-section in $1~\mathrm{s}$. * If electrons drift to the right, which way is conventional current? ++++ Answer To the **left** (opposite electron motion). * Compute the number of electrons in $1.0~\mathrm{nC}$. ++++ Answer $n=Q/e \approx (1.0\times10^{-9})/(1.602\times10^{-19})\approx 6.24\times10^{9}$ electrons. ++

Embedded resources

- 

- quantu... 

- 

- 

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: “μkA”).
- 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 $220~\mathrm{\mu A}$ in standby for $18~\mathrm{h}$. 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.