Electric Circuits

AP Physics C: E&M ▪ Unit 11

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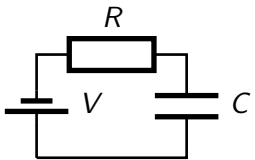
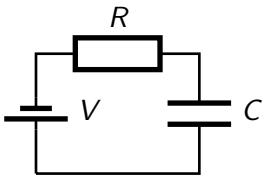


What we will cover

1. Electric current
2. Ohm's law and power
3. Compound circuits and internal resistance
4. Kirchhoff's rules
5. RC circuits



Electric current and Ohm's law

Rate of charge flow

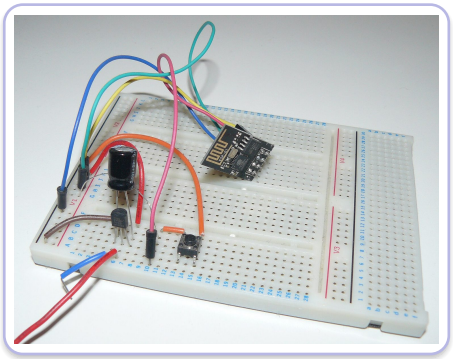
$$I = \frac{dQ}{dt}$$

Conventional current 常规电流 is opposite to the electron **drift** 漂移速度.

Ohm's law

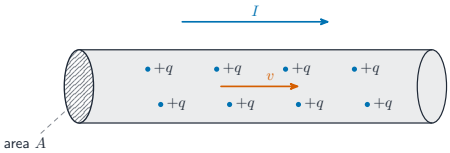
$$V = IR, \qquad R = \frac{\rho L}{A}$$

Resistivity 电阻率 ρ is a material property; R is the object's.

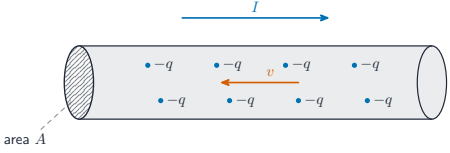


breadboard

Electric current and Ohm's law



(a) positive carriers drift with I



(b) electrons drift against I

Compound circuits and internal resistance

Reduce series/parallel resistors to one **equivalent resistance** 等效电阻. A real battery is an ideal **emf** 电动势 plus a small **internal resistance** 内阻 r:

Terminal voltage

$$V_{term} = \varepsilon - Ir$$

Worked example

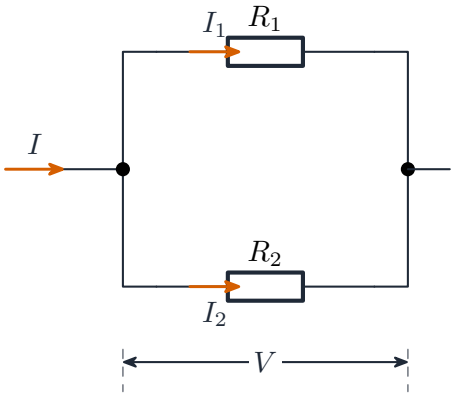
$\varepsilon = 12\,\mathrm{V}$, $r = 1\ \Omega$, load $5\ \Omega$:

$$I = \frac{12}{6} = 2\,\mathrm{A}$$

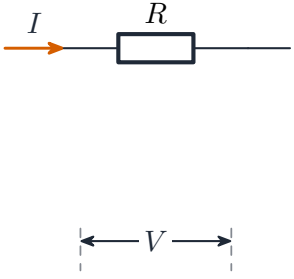
$$V_{term} = 12 - 2(1) = 10\,\mathrm{V}$$

$2\,\mathrm{V}$ lost inside the battery.

Compound circuits and internal resistance



equivalent to



Kirchhoff's rules

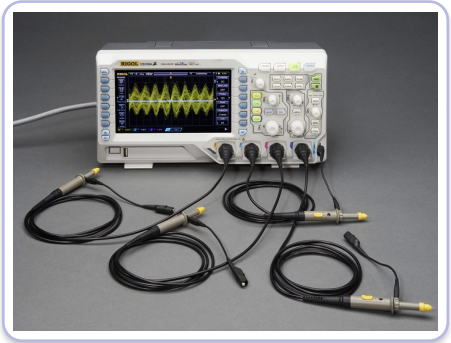
Loop rule (energy)

$$\sum \Delta V = 0 \quad \text{around a loop}$$

A rise across an emf, a drop $-IR$ across a resistor.

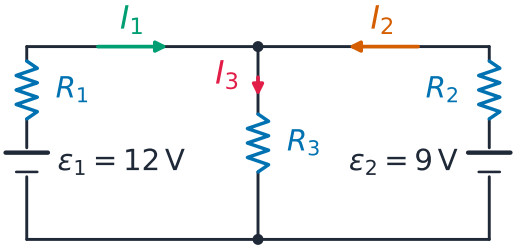
Junction rule (charge)

$$\sum I_{in} = \sum I_{out}$$



oscilloscope

Kirchhoff's rules



RC circuits

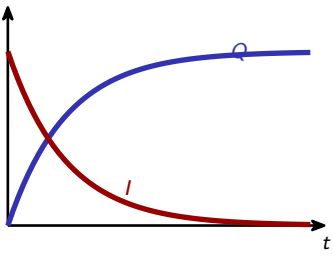
A capacitor charges through a resistor with **time constant** 时间常数 $\tau = RC$:

Charging

$$Q(t) = C\varepsilon\left(1 - e^{-t/\tau}\right)$$

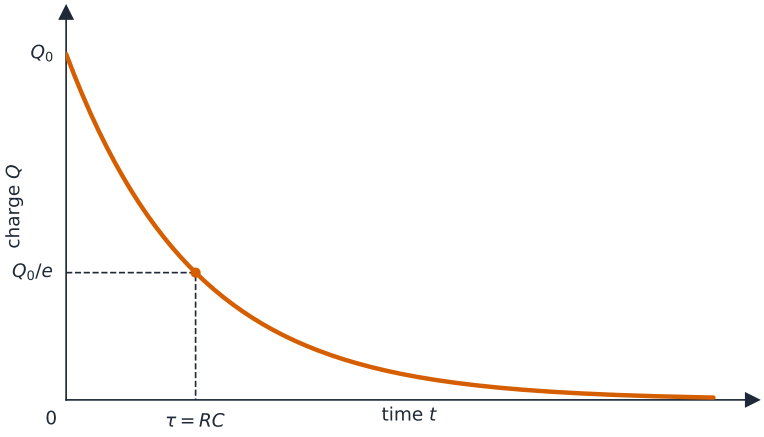
$$I(t) = \frac{\varepsilon}{R}\, e^{-t/\tau}$$

Empty capacitor = a wire at first; full = blocks steady current.



$R = 2$, $C = 3$: $\tau = 6\,\mathrm{s}$.

RC circuits



Unit 11 – key takeaways

1 Current & Ohm

$I = dQ/dt$; $V = IR$; $P = IV = I^2R = V^2/R$

2 Real battery

$V_{term} = \varepsilon - Ir$; small internal resistance

3 Kirchhoff

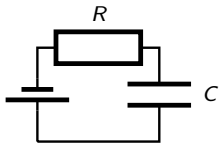
loop $\sum \Delta V = 0$; junction $\sum I_{in} = \sum I_{out}$

4 RC

$\tau = RC$; charge and current decay exponentially

Check yourself

1. Write current as a derivative of charge.
2. What conservation law is Kirchhoff's loop rule?
3. At $t = 0$, how does an empty capacitor behave?
4. After a long time, how much current flows through a charged capacitor?



Answers **1.** $I = dQ/dt$ **2.** conservation of energy **3.** like a plain wire **4.** zero