Electric Circuits

AP Physics C: E&M ▪ Unit 11

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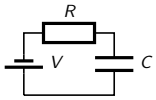
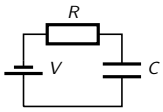


What we will cover



1 Current

Electric current and Ohm's law

Rate of charge flow

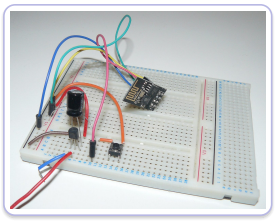
$$I = \frac{dQ}{dt}$$

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

2 Internal resistance

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 $5\ \Omega$:

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

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

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

3 Kirchhoff

Kirchhoff's rules

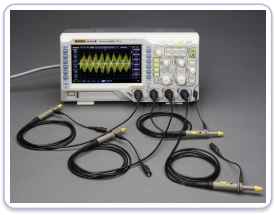
Loop rule (energy)

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

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

Junction rule (charge)

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



Oscilloscope

4 RC

RC circuits

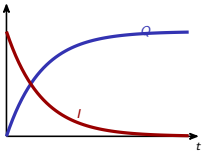
A capacitor charges through a resistor with **time constant** 时间常数 $\tau = RC$:

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.



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

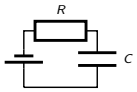
5 Recap

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