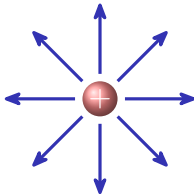


Electric Force, Field, and Potential

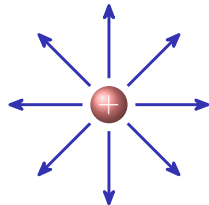
AP Physics 2 ■ Unit 10

AP Physics 2



What we will cover

- 1 Electric charge and Coulomb's law
- 2 The process of charging
- 3 Electric fields and field lines
- 4 Electric potential energy
- 5 Electric potential (voltage)
- 6 Capacitors
- 7 Conservation of electric energy



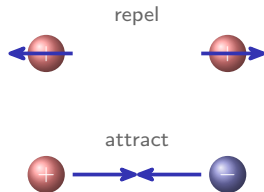
Electric charge and Coulomb's law

Electric charge 电荷 comes in two kinds;
it is **conserved** 守恒 and
quantized 电荷量子化 ($q = ne$).

Coulomb's law

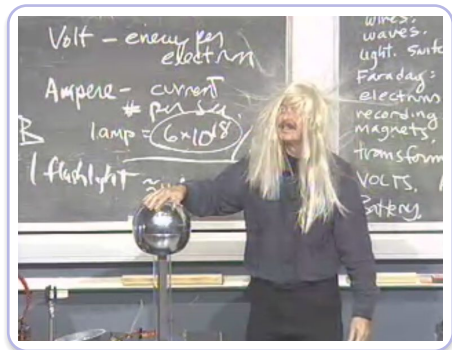
$$F = k \frac{q_1 q_2}{r^2}$$

An **inverse-square** 反平方 law – double r ,
quarter the force.



The process of charging

- a **conductor** 导体 lets charge move; an **insulator** 绝缘体 holds it fixed
- **friction** 摩擦起电 – electrons scraped across
- **conduction** 传导 – touch: **same** sign
- **induction** 感应起电 – near + ground: **opposite** sign



Static charge can be stored and transferred

Electric fields and field lines

The **electric field** 电场 is force per unit positive charge:

Field of a point charge

$$\vec{E} = \frac{\vec{F}}{q}, \quad E = k \frac{q}{r^2}$$

- lines leave +, enter -; denser = stronger
- a **uniform field** 匀强电场 sits between parallel plates



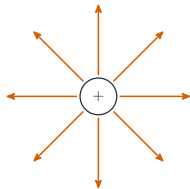
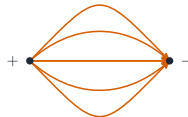
Charges create electric fields in space

Electric fields and field lines

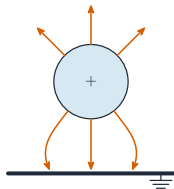
a) parallel plates (uniform field)



b) dipole (+ and -)



c) point charge (radial)



d) sphere above earthed plate

Energy, potential, and voltage

Potential energy of a pair

$$U = k \frac{q_1 q_2}{r}$$

Like charges: $U > 0$ (fly apart). Unlike: $U < 0$ (bound). Note r , not r^2 .

Potential (voltage)

$$V = \frac{U}{q} = k \frac{q}{r}$$

A **scalar** – just add the numbers.

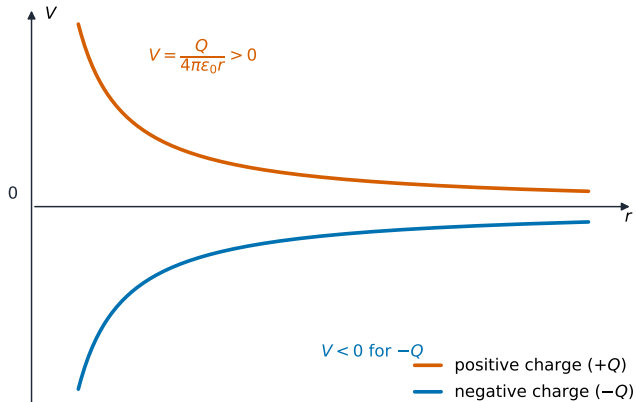
The field points **downhill** on the potential – toward lower V .

Between parallel plates

$$E = \frac{\Delta V}{d}, \quad W = q \Delta V$$

100 V over 0.02 m: $E = 5000 \text{ V/m}$.

Energy, potential, and voltage



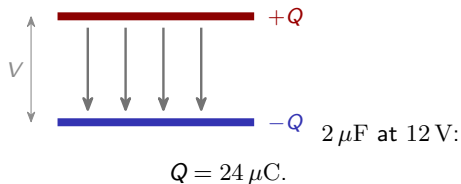
Capacitors

A **capacitor** 电容器 stores charge on two plates ($+Q$ and $-Q$).

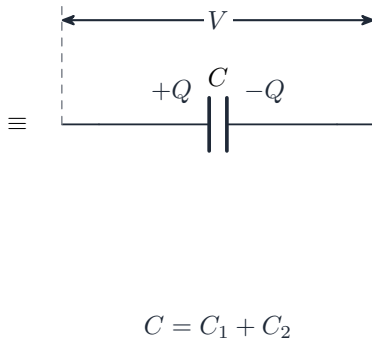
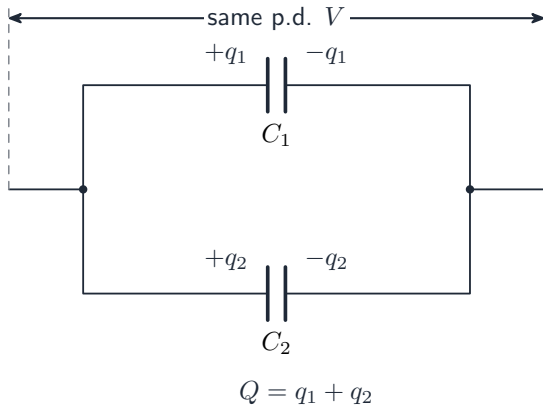
Capacitance and stored energy

$$C = \frac{Q}{V} = \frac{\epsilon_0 A}{d}, \quad U = \frac{1}{2} CV^2$$

Bigger plates or a smaller gap $\Rightarrow$ more capacitance. Energy $\propto V^2$.



Capacitors



Conservation of electric energy

A charge **accelerated** 加速 through a potential difference turns field work into kinetic energy:

Accelerating a charge

$$\Delta KE = q \Delta V = \frac{1}{2}mv^2$$

A capacitor stores $\frac{1}{2}CV^2$, then hands it back – energy borrowed, not lost.

Worked example

An electron through 200 V:

$$\begin{aligned}\Delta KE &= (1.6 \times 10^{-19})(200) \\ &= 3.2 \times 10^{-17} \text{ J}\end{aligned}$$

$$v = \sqrt{\frac{2\Delta KE}{m}} \approx 8.4 \times 10^6 \text{ m/s}$$

Unit 10 – key takeaways

1

Coulomb

$F = kq_1q_2/r^2$; like repel, unlike attract

2

Field

$E = F/q = kq/r^2$; lines leave +, enter –

3

Potential

$V = U/q = kq/r$, a scalar; $E = \Delta V/d$

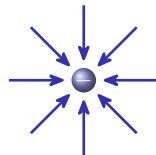
4

Capacitor

$C = Q/V$; stores $U = \frac{1}{2}CV^2$

Check yourself

- 1 Double the distance between two charges – what happens to the force?
- 2 Which way do field lines point around a negative charge?
- 3 Is electric potential a scalar or a vector?
- 4 Double a capacitor's voltage – what happens to its stored energy?



Answers 1. it drops to one quarter 2. inward (toward the charge) 3. a scalar 4. it quadruples