Chapter 16

Electric Charge and Electric Field

Electric Charge: Why Important

- Many natural phenomena (static shock, lightning,…)
- Huge application in the distribution and use of electricity (not really electrostatic)
- Ultimately responsible for the interactions between matter (other than gravity)

Properties of Electric Charges

- There are only two types of electric charge: positive and negative
  - like charges attract, opposite charges repel
- Charges are neither created nor destroyed – they are redistributed
  - the net amount of electric charge produced in any process is zero

Electric Charge in the Atom

- Electron: $-e$
- Proton: +e
- Neutron: no charge
- Atoms: nucleus of protons/neutrons surrounded by electrons
- Atoms are neutral, so the number of protons = the number of electrons

Elementary Charge

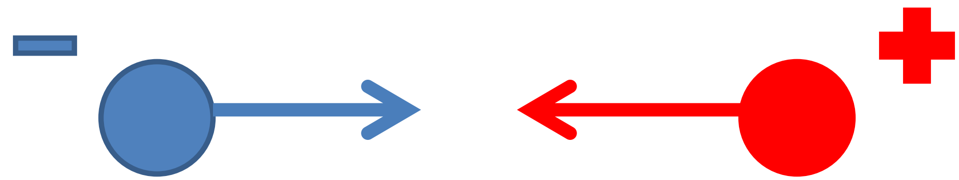
- Electrons and protons have charge $e=1.602\times10^{-19}$ C
  - by convention, the charge of the electron is negative
- Electric charge is quantized
  - any amount of charge must be a multiple of e (unless we want to discuss quarks, that is)
- A neutral particle can decay into charged particles ($n \rightarrow p+e$) and two particles can annihilate their charges ($e^{+}+e^{-} \rightarrow \gamma\gamma$), but the total amount of charge in the system never changes

Insulators and Conductors

- Some materials allow charges to move freely within them → conductors
  - examples: metals, salt water
  - in metals, electrons are nearly free and can easily move from one atom to another
  - in salt water, molecules of salt (NaCl) are dissolved into charged ions which move freely in the liquid
- In other materials, charges cannot move or can only move with great difficulty → insulators
  - examples: glass, pure water
- There are semiconductors, too

Coulomb's Law

$$F = k\frac{Q_1 Q_2}{r^2}$$



2.0000000000000000…

$$k = 8.988\times 10^9\ \mathrm{N\cdot m^2/C^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

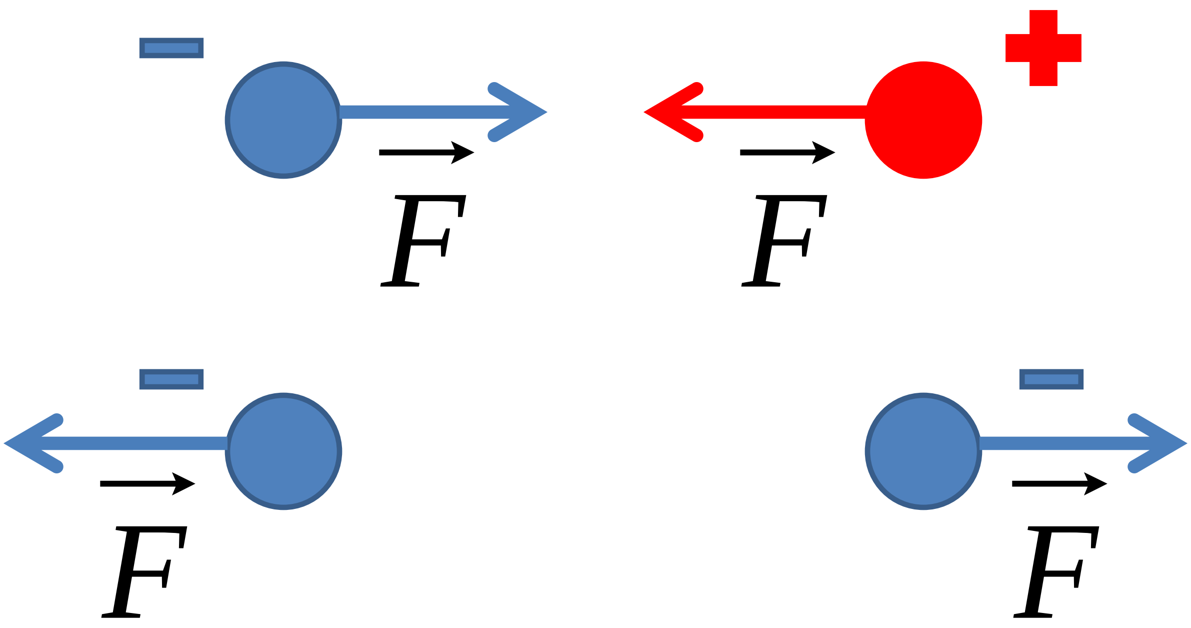
$$\varepsilon_0 = 8.85\times 10^{-12}\ \mathrm{C^2/N\cdot m^2}$$

"permittivity of free space"

denominator!

Electric Force is a Vector

… like any other force



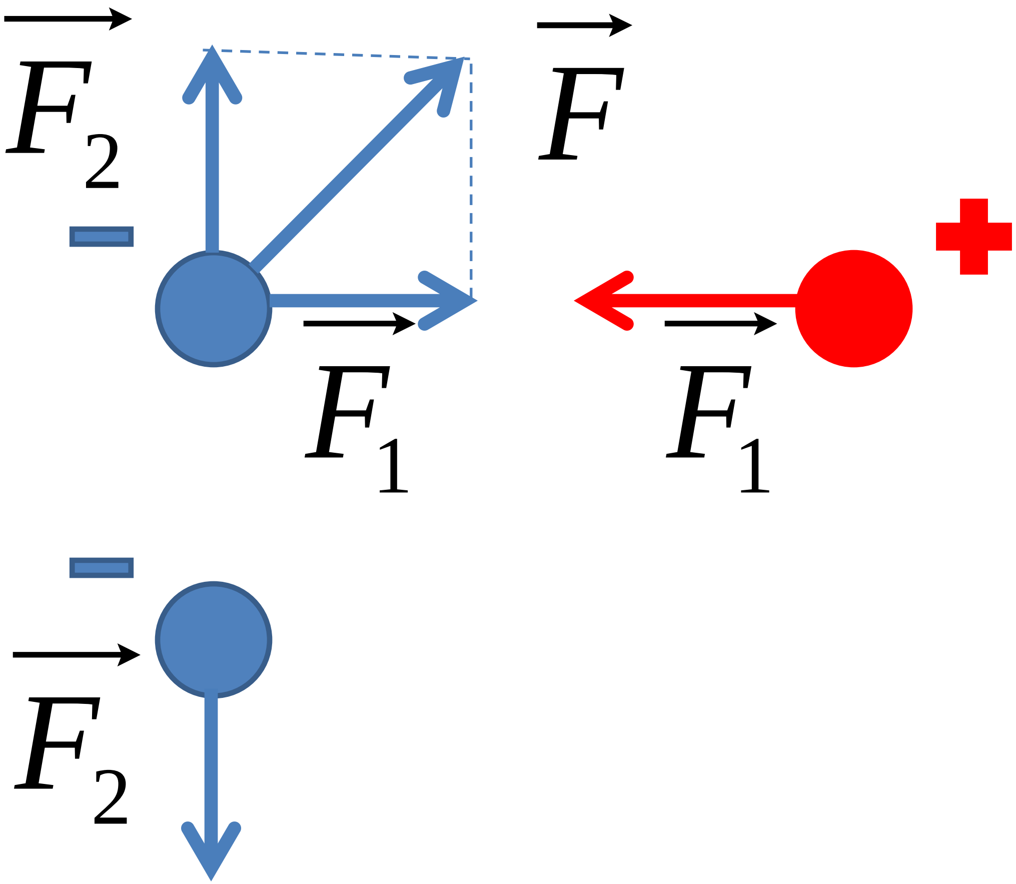
trivial if there are two charges

what if there are more than two?

Adding Electric Forces

- Everybody is affected by everybody else
  - if there are n charges, there are (n-1) forces acting on each charge
- Like charges repel, opposite charges attract
- When solving a problem, first figure out the number of dimensions
- Remember: forces are vectors!
- Cross check: sum of all forces acting on all charges is zero

Vector Sum of Forces



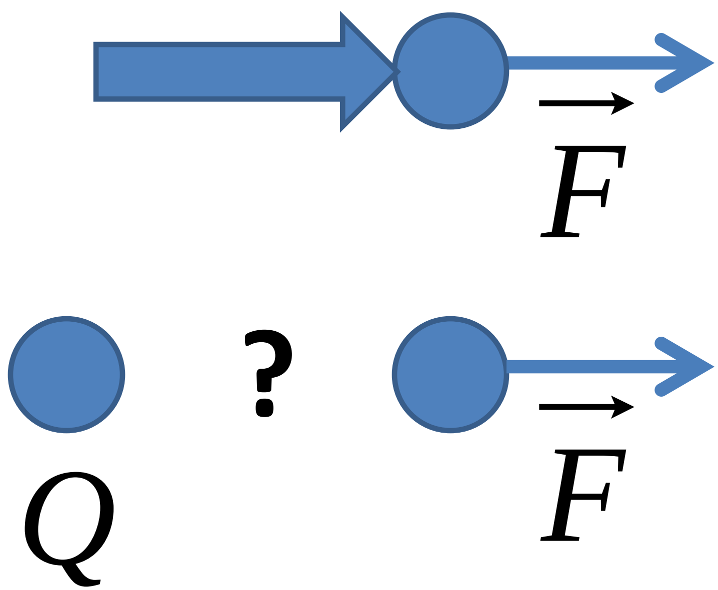
$$\vec{F} = \vec{F_1} + \vec{F_2}$$

$$F_x = F_{1x} + F_{2x}$$

$$F_y = F_{1y} + F_{2y}$$

Electric Field

- How come that one electric charge pushes (or pulls) another electric charge without touching it?



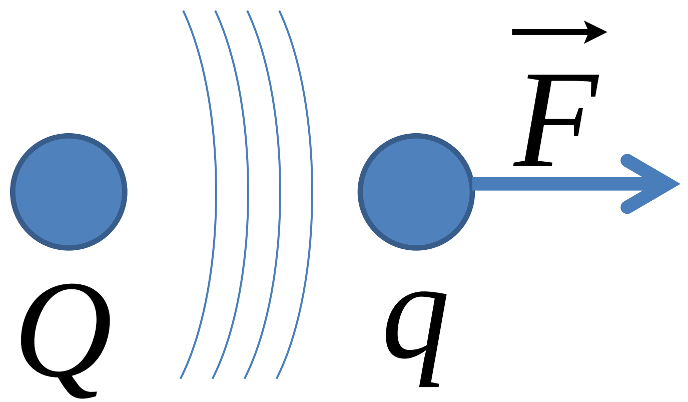
The answer (M. Faraday): there is **field**

- ➢ It extends outwards the charge and penetrates the whole space
- ➢ Fields from multiple charges add up ("superposition")

Electric Field and Electric Force

- Electric field is a property of the charge that emits it, but does not depend on the probe charge

$$E = \frac{F}{q} = k\frac{Q}{r^2}$$



- Electric field is a vector

$$\vec{E} = \frac{\vec{F}}{q}$$

two similar types of problems:

➢ find the force acting on a charge

➢ find electric field at a given point

make sure you understand the question!

Field Lines

- Field lines are drawn so that they indicate the direction of the force on a positive probe charge
- More on them when we'll talk about potential

Electric Fields and Conductors

- In electrostatics, the electric field inside a conductor is zero
  - otherwise the charges would experience a force and move – not static anymore
- Outside the conductor, the electric field is always perpendicular to the conductor surface
  - otherwise the charges would move along the surface
- Electric field inside a hollow metal box is zero
  - a person inside such a box (e.g. in a car) is protected against a strong electric discharge (e.g. lightining)