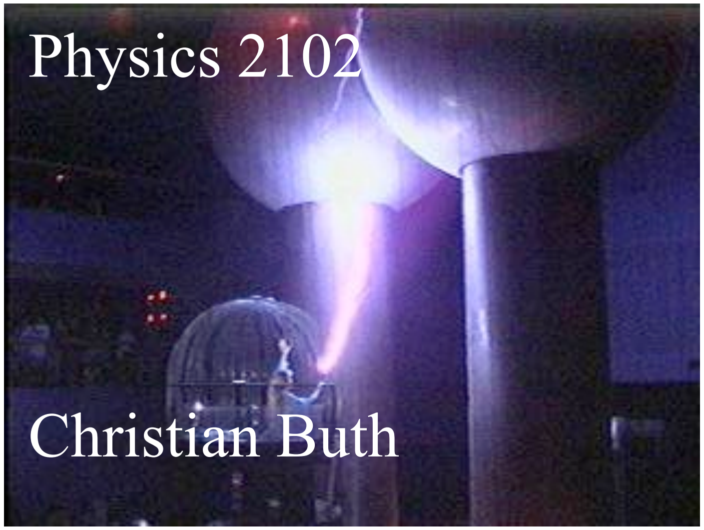
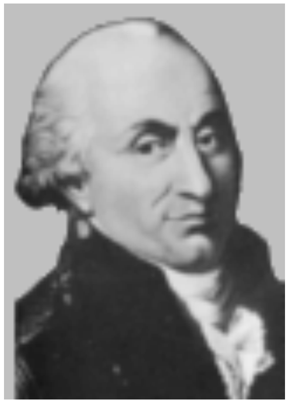
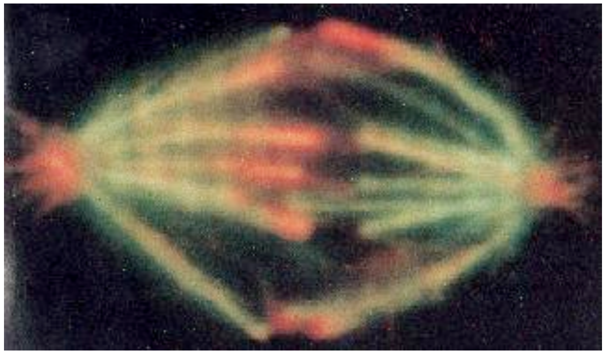


Physics 2102
Lecture 3

Electric Fields 1

Charles-Augustin
de Coulomb
(1736-1806)





Version: 01/16/2009

Review

- **Atoms** have a positive nucleus and a negative "electron cloud"
- In conductors, there are free **conduction electrons**
- In insulators, there are **no** free electrons
- Electrical charge is **conserved**, and **quantized**
- We can **charge objects** by transferring charge or by induction

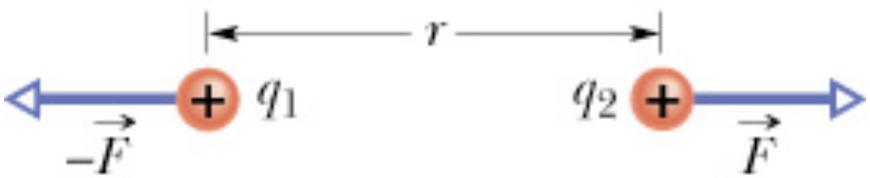
Concept of a Field

- New concept: **field**
- Every point in space has a certain value of a physical quantity
- Scalar field / vector field
- **Examples:**
  - Temperature field
  - Pressure field

Electric Field

- Coulomb's law: q_2 acts on q_1 at a distance r **instantaneously** ("action at a distance"):

q_1



$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

- How does q_2 know of q_1?

- How can we limit the **speed of interaction** to the speed of light?

- New concept: **electric field**

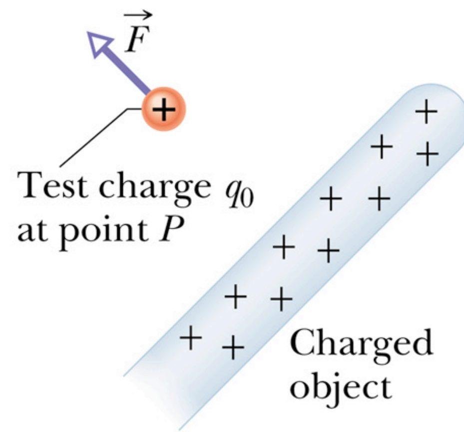
charge q_1 → generates electric field $\vec{E}$ → $\vec{E}$ exerts a force $\vec{F}$ on q_2

Measuring Electric Fields

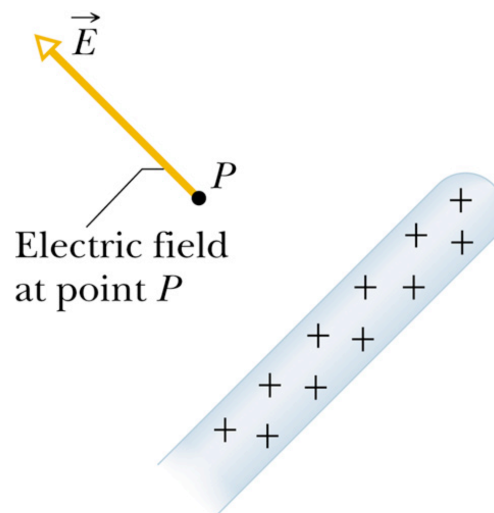
- **Electric field E in a point: force experienced by an *imaginary* point charge of q_0>0, divided by q_0:**

$$\vec{E} = \frac{\vec{F}}{q_0}$$

- **Note that E is a vector**
- **Since E is the force per unit charge, it is measured in units of N/C**
- **Measure with very small "test charges" q_0 to avoid distortion**



(a)

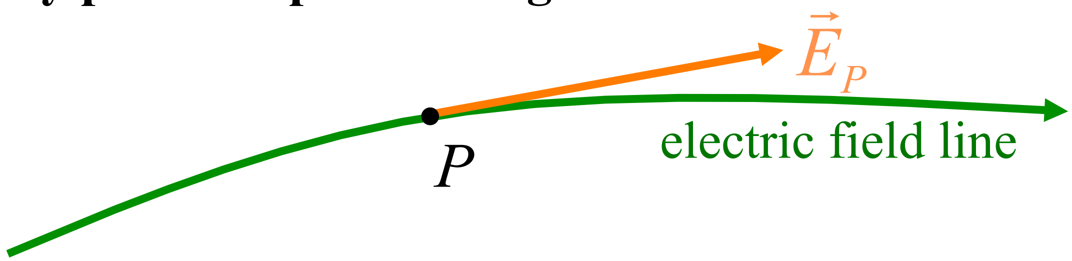


(b)

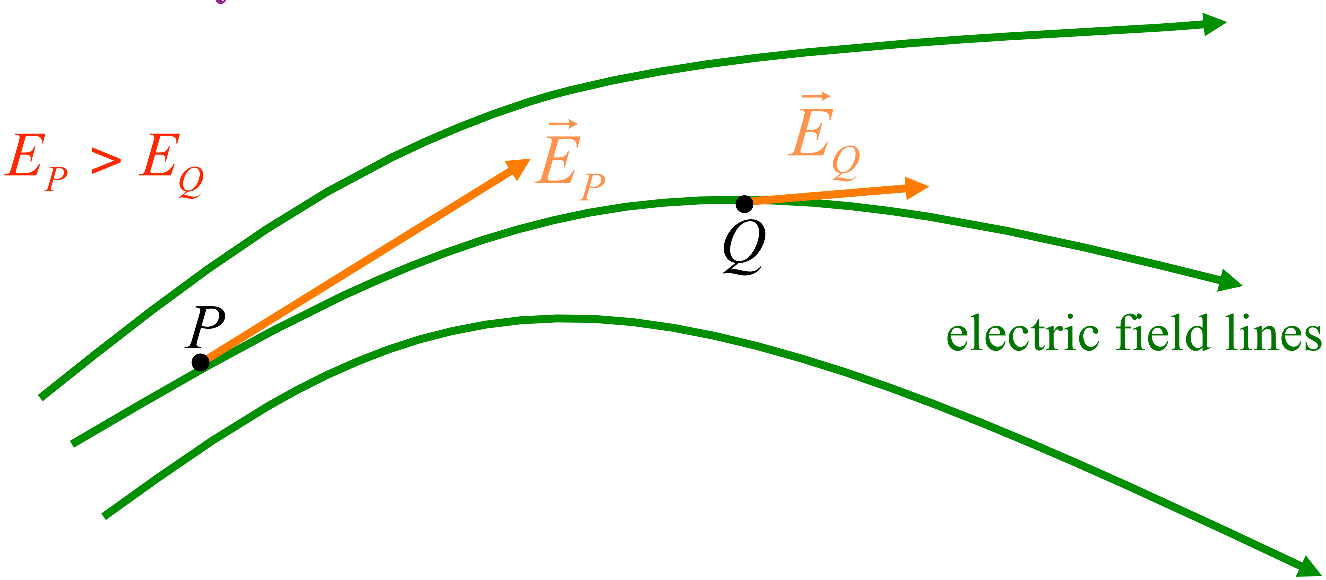
Electric Field Lines

Field lines: useful way to visualize electric field E

1. E at any point in space is tangential to field line

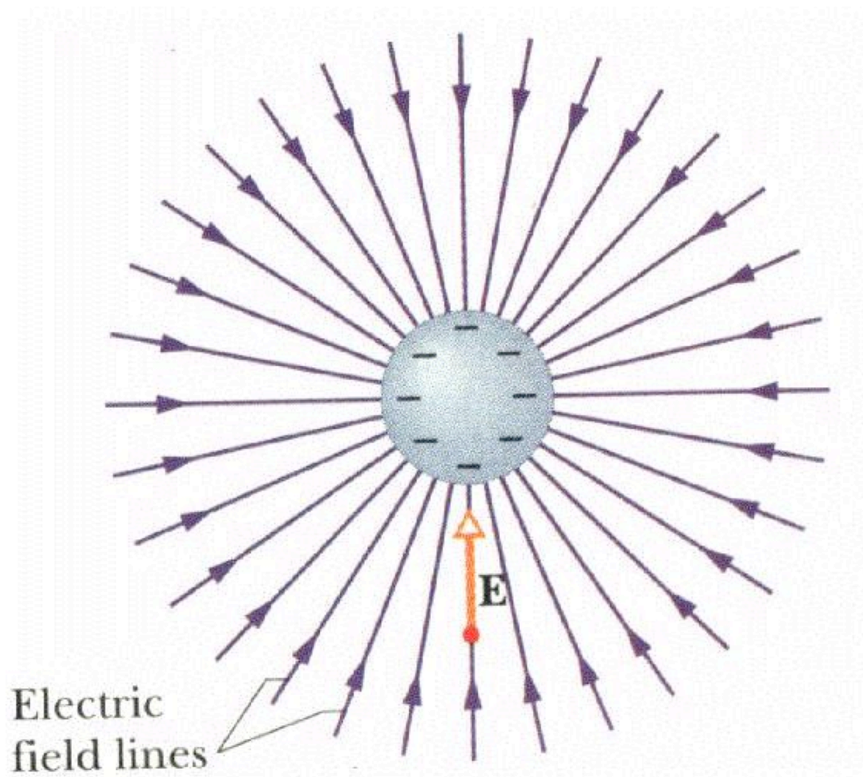


2. The magnitude of the electric field vector $\vec{E}$ is proportional to the density of the electric field lines.



Electric Field of a Point Charge

- Field lines **start** at a positive charges
- Field lines **end** at negative charge
- **Example:** a negative point charge — note spherical symmetry

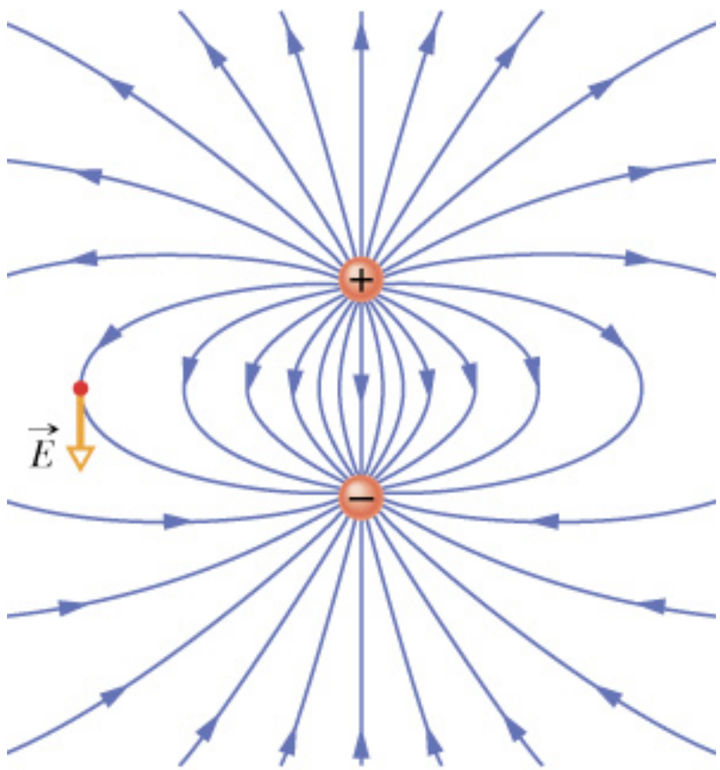


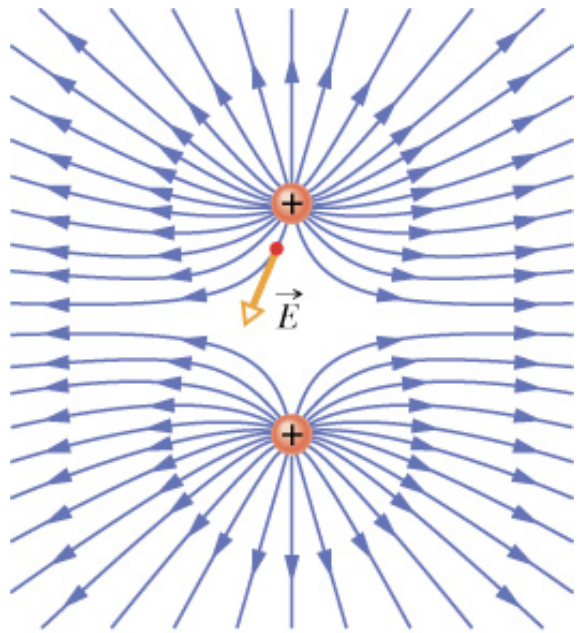
$$E = \frac{1}{q_0}\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_0}{r_{10}^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{10}^2}$$

Superposition

- **Question**: How do we figure out the field due to several point charges?
- **Answer**: consider one charge at a time, calculate the field (a vector!) produced by each charge, and then add all the vectors! ("superposition")

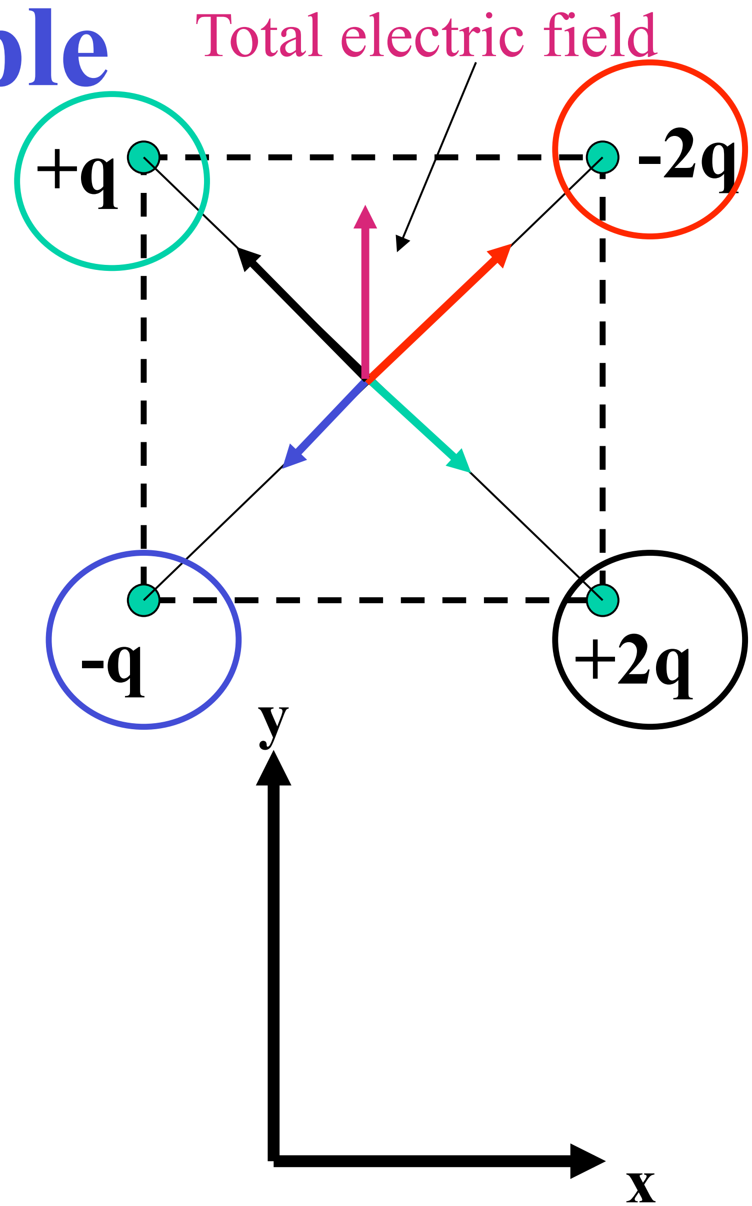
Field of two Point Charges





Example

- 4 charges are placed at the corners of a square as shown.
- What is the direction of the electric field at the center of the square?



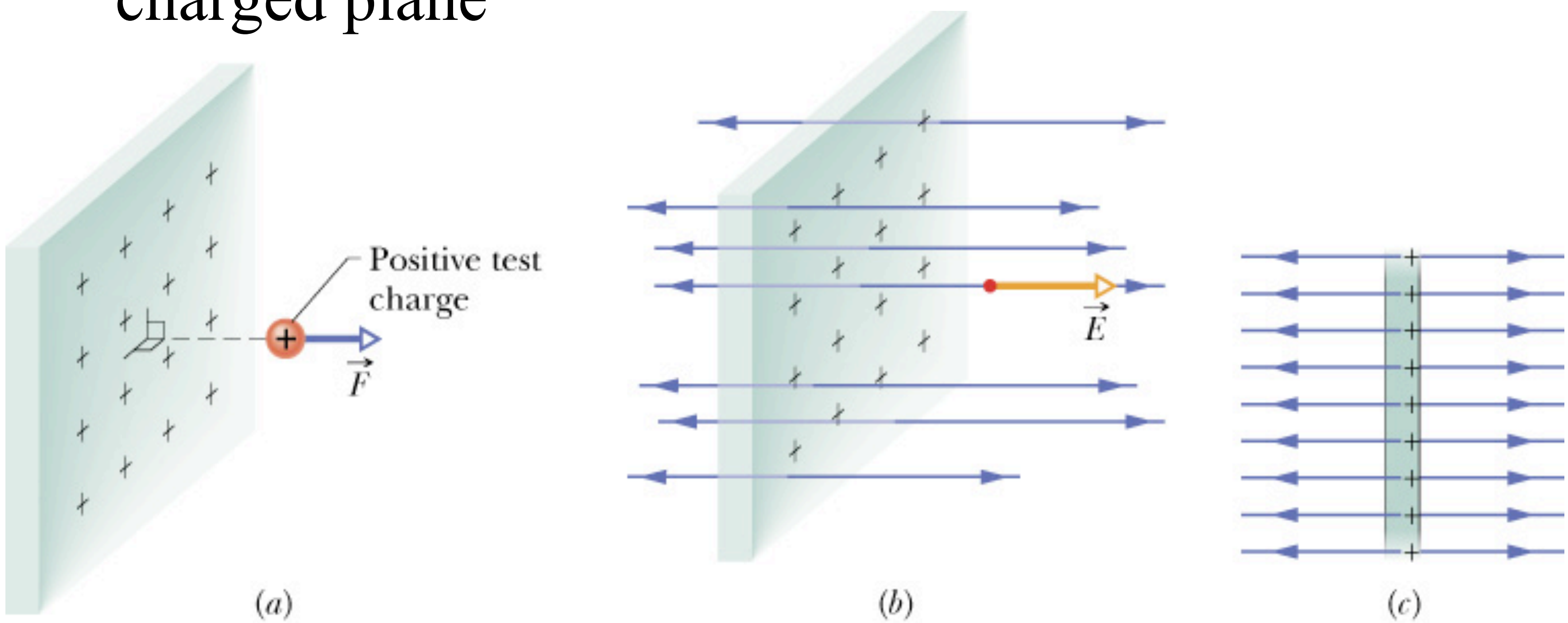
(a) Field is ZERO!

(b) Along +y

(c) Along +x

Electric Field of a Large Plane

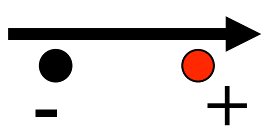
- The magnitude of the field is **constant** on both sides
- Field **vector is perpendicular** to plane
- Field **vector points away** from the positively charged plane

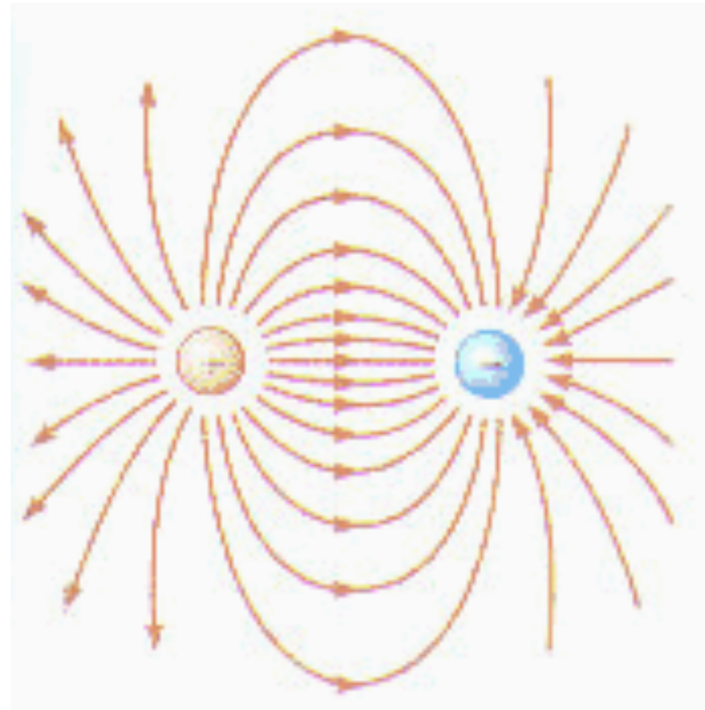


Electric Field of a Dipole

- Electric dipole: two point charges +q and –q separated by a distance d
- Common arrangement in Nature: molecules, antennae, …

p = qa
"dipole moment"
vector




(a)

$$\left|\vec{E}\right| \propto \frac{\left|\vec{p}\right|}{r^3}$$

Summary

- New concept **field**: a physical property is associated with every point in space
- **Electric field** $\vec{E} = \dfrac{\vec{F}}{q_0}$
- **Field lines** to visualize the direction and magnitude of an electric field
- Electric field of a point charge: $E=kq/r^2$
- Electric field of a dipole: $E \sim kp/r^3$