PHYSICS 1B – Fall 2007

Electricity

&

Magnetism

Wednesday October 3, 2007

Course Week 1

Professor Brian Keating

SERF Building. Room 333

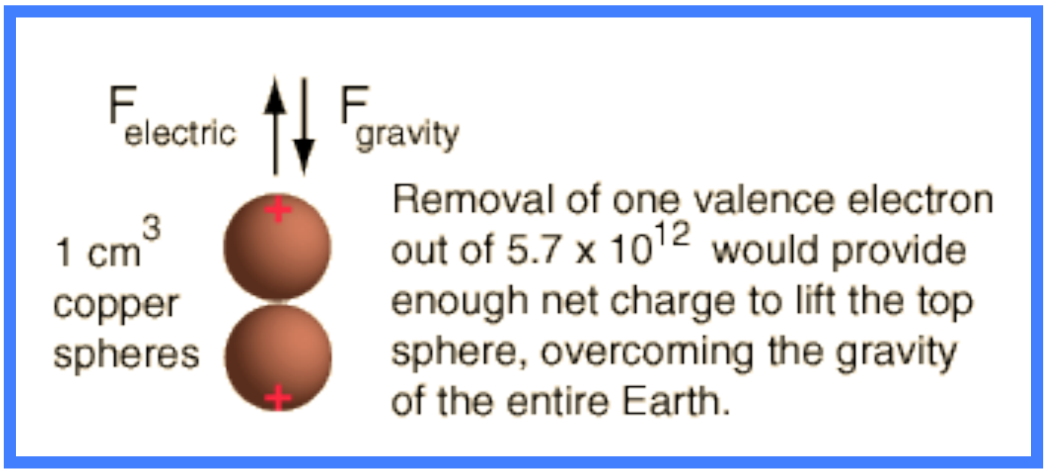
UCSD

UCSD

Today

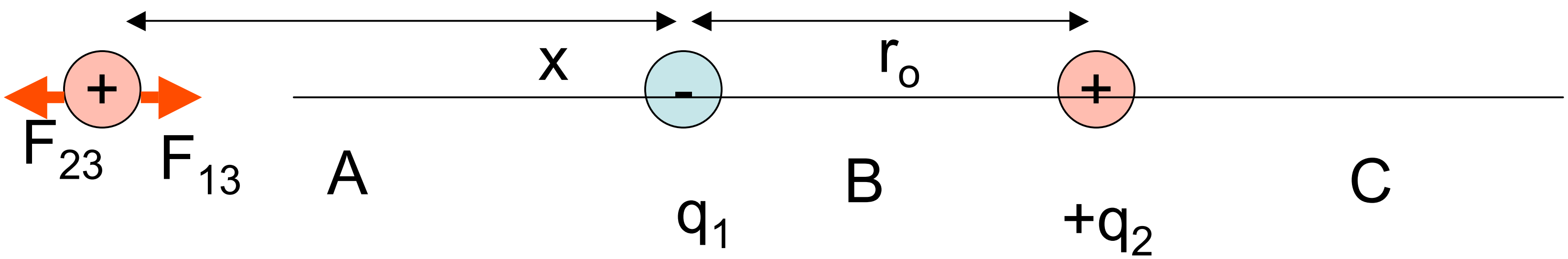
- No Problem Session Tomorrow.
- First problem session will be next Thursday night.
- Jon, the TA has office hours today.
- Lecture notes for lecture 1 and 2 on web. Lectures will be posted a within a few days after each class, but ***never*** before lecture.
- Finish electric forces and Electric fields

Example



- Let's examine the amount of charge in a sphere of copper of volume one cubic centimeter.
- Cu has one valence electron outside of closed shells in its atom, and that electron is free to move.
- The density of metallic Cu = 9 g/cm^3 and one mole of Cu = 63.5 grams so the cubic centimeter of Cu = 1/7th of a mole or about 8.5×10^{22} Cu atoms.
- With one mobile electron per atom, and with the electron charge of 1.6×10^{-19} C, so there are ~ 13,600 C/cm^3.
- Suppose we remove enough of the electrons from two spheres of Cu so that there is enough net positive charge on them to suspend one of them over the other. What fraction of the electron charge must we remove?
- The force to lift one of the spheres of copper would be its weight, 0.088 N.
- Radius of a 1cm^3 = 0.62 cm, separation= 2.48 cm Using Coulomb's law, this requires a charge of 7.8×10^{-8} Coulombs.
- This amounts to removing just one valence electron out of every 5.7×10^{12} from each copper sphere.

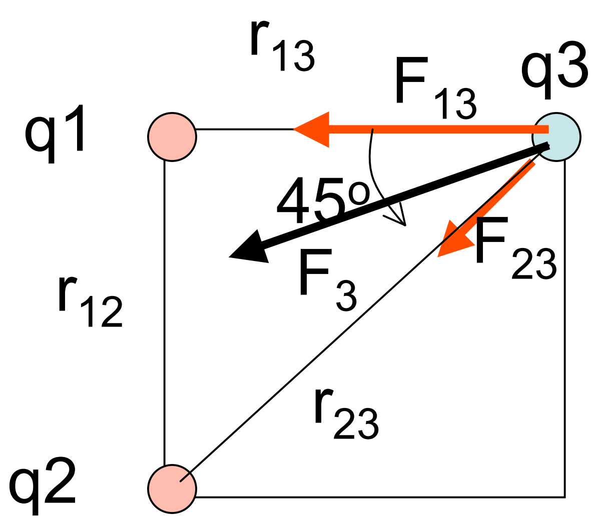
Two charges are in a line. q_1= -1μC, q_2 =2μC Is there a position along the line through the centers where the force on a + charge,q_3 is zero?



A. Yes

B. No

Three charges are placed a the corners of a square with the length of each side =2.0 cm. Find the force on q3. q3= -2x10^{-6} C q1=q2=1x10^{-6} C



Forces acting on q3

F_{13} =

F_{23}=

F_3=

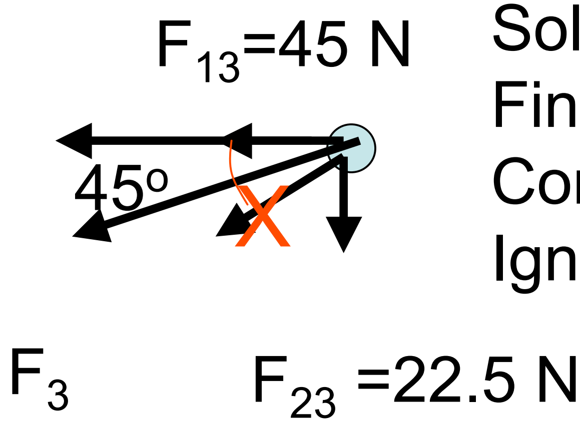
$$r_{23}^2 = r_{13}^2 + r_{12}^2$$

$$r_{23}^2 = 2r_{13}^2$$

$$r_{23} = \sqrt{2}r_{13}$$

$$F_{13} = \frac{k_e q_1 q_3}{r_{13}^2} = \frac{9x10^9(10^{-6})(2x10^{-6})}{(2x10^{-2})^2} = 45N$$

$$F_{23} = \frac{k_e q_2 q_3}{r_{23}^2} = \frac{9x10^9(10^{-6})(2x10^{-6})}{2(2x10^{-2})^2} = 22.5N$$



Solve

Find x and y components.

Consider only the relative magnitudes

Ignore the minus sign

$$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2}$$

$$F_{3x} = 45 + 22.5(\cos 45) = 61N$$

$$F_{3y} = 22.5(\sin 45) = 16N$$

$$F_3 = \sqrt{61^2 + 16^2} = 63N$$

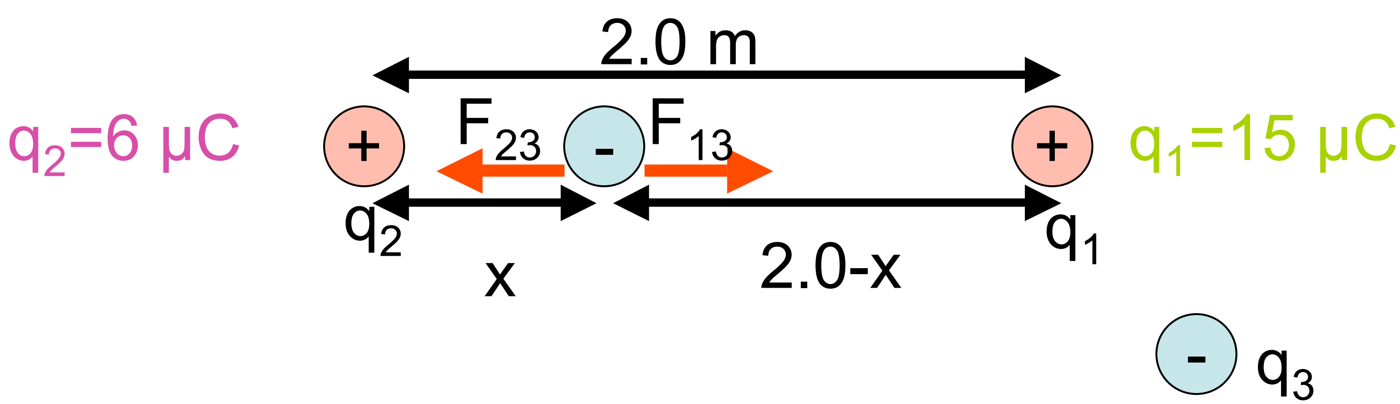
Example 15.3 Where is the resultant force zero?

Two charges are in a line

$q_1=15\mu C$, $q_2=6.0\mu C$.

A negative charge q_3 must be placed in between them at a position where the net force is zero.

Where should it be placed: closer to q1 or q2 ?

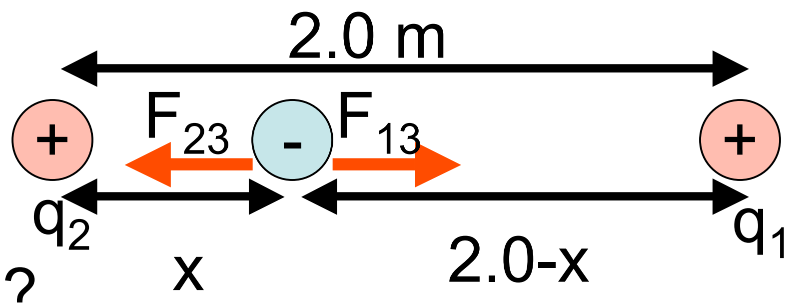


A. Closer to q_1

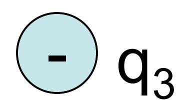
B. Closer to q_2

Example 15.3 Where is the resultant force zero?

Two charges are in a line
q_1=15μC , q_2=6.0μC a negative charge q_3 must be placed in between them at a position where the net force is zero. Where should it be placed?



closer to q_1 or q_2 ?



Magnitudes of forces are equal

$$F_{13} = F_{23}$$

$$\frac{kq_1q_3}{(2-x)^2} = \frac{kq_2q_3}{x^2}$$

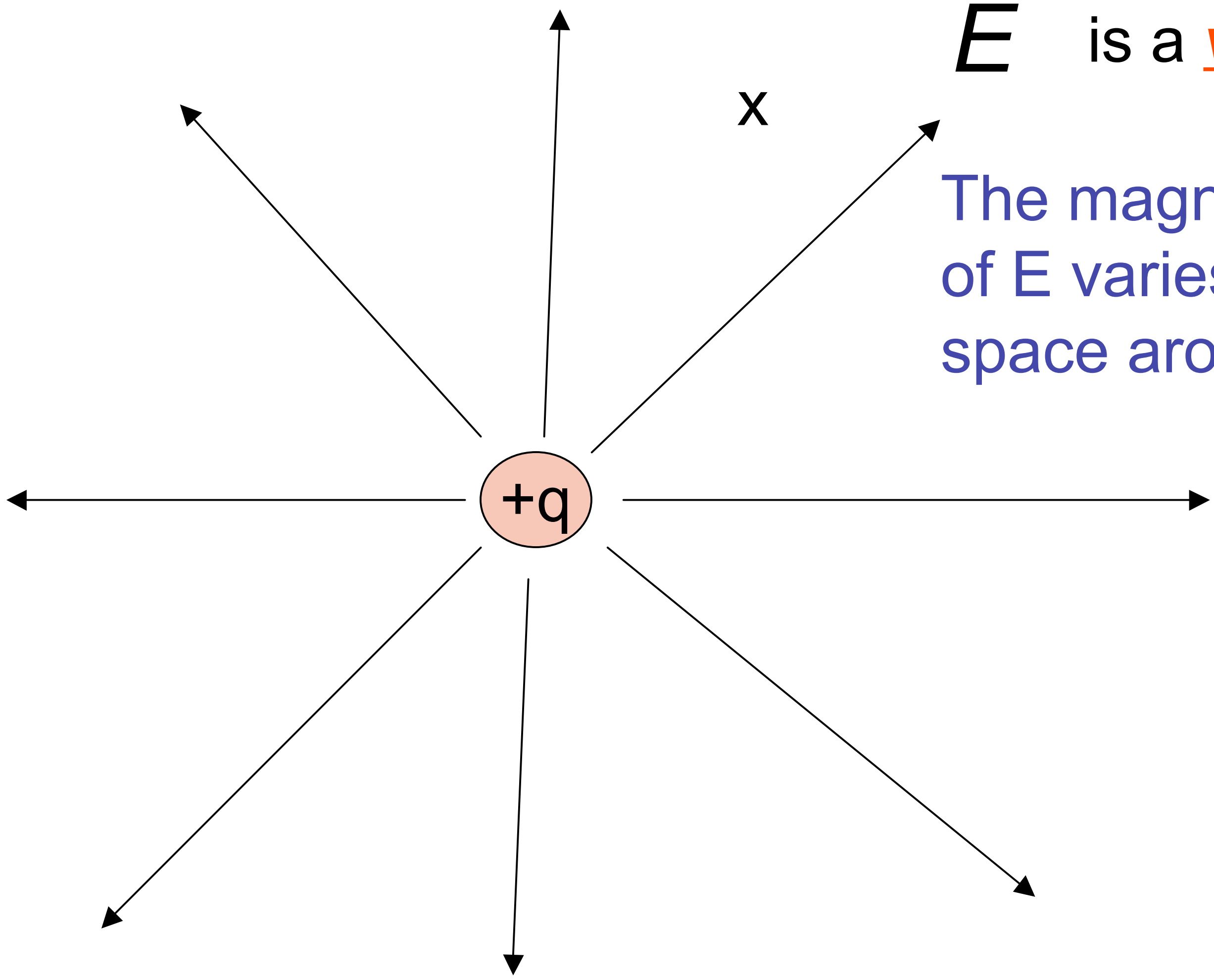
$$\frac{q_1}{(2-x)^2} = \frac{q_2}{x^2}$$

Chapter 15.3
Electric Fields / Electric Field Lines

- Definition of electric field
- Interaction of electric fields with charges
- Electric field lines
- Electric field from a point charge
- Electric field from several point charges.

The Electric Field exists in space surrounding a charge

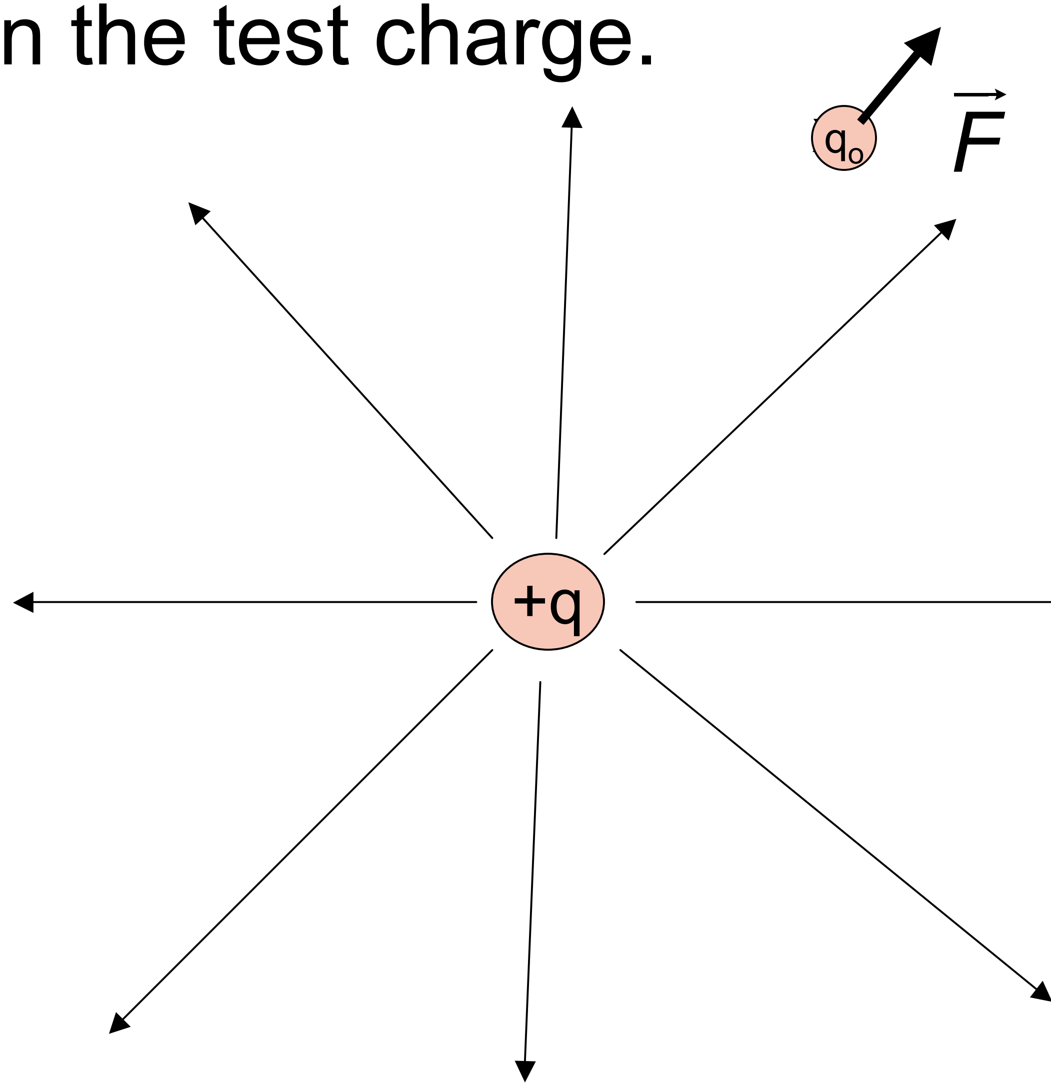
$\vec{E}$ is a ***vector quantity***



The magnitude and direction of E varies with position in space around a charge.

Lines are a way of visualizing how strong, and in what direction, an Electric Force will act on a test charge.

To determine E at position r place a test charge q_o at this position and measure the force on the test charge.



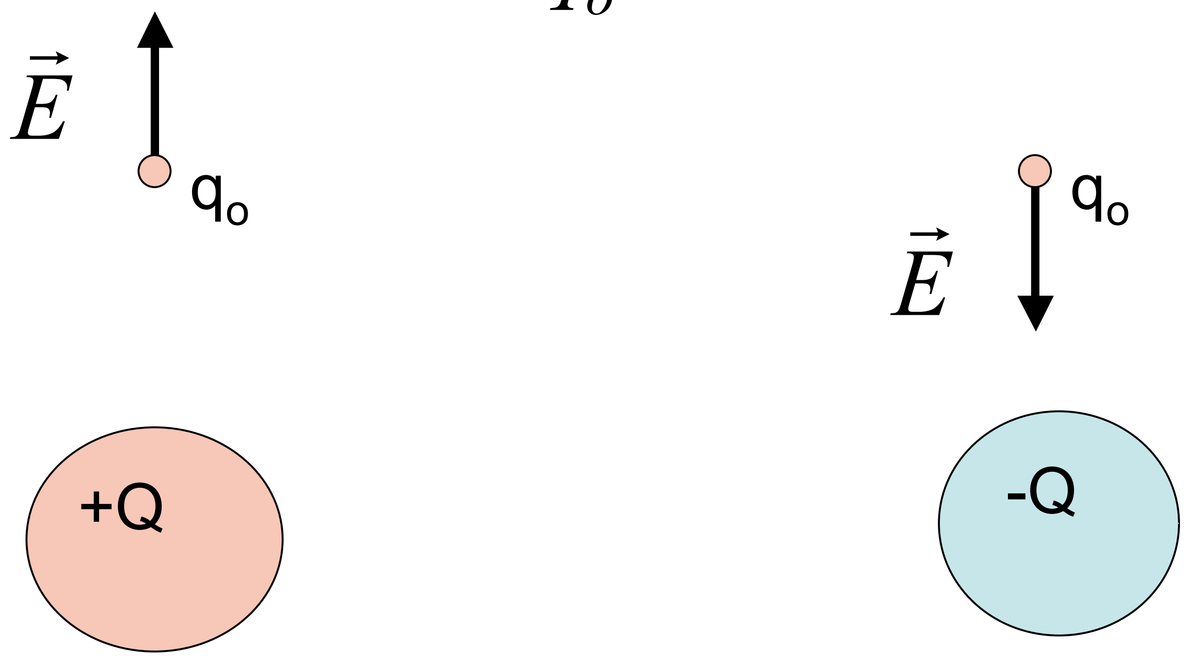
$$\vec{E} = \frac{\vec{F}}{q_o}$$

units N/C
also Volts/m
(volt is a unit of electrical potential)

Electric field due to positive and negative charges at the position of the test charge

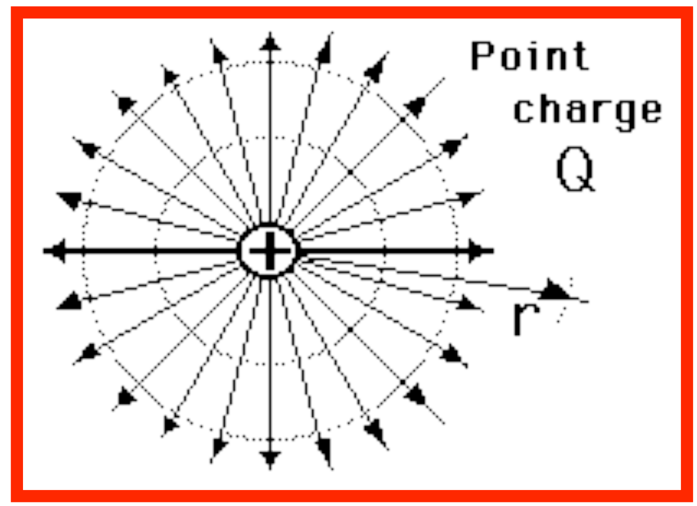
$$\vec{E} = \frac{\vec{F}}{q_o}$$

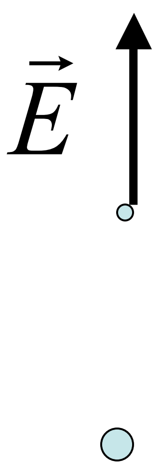
q_o positive test charge



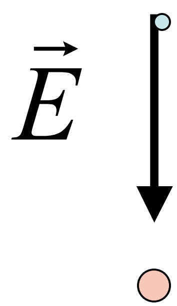
Electric field due to a point charge q at distance r, Coulomb's Law

$$\vec{E} = \frac{\vec{F}}{q_o} = \frac{k_e q}{r^2}$$





+q



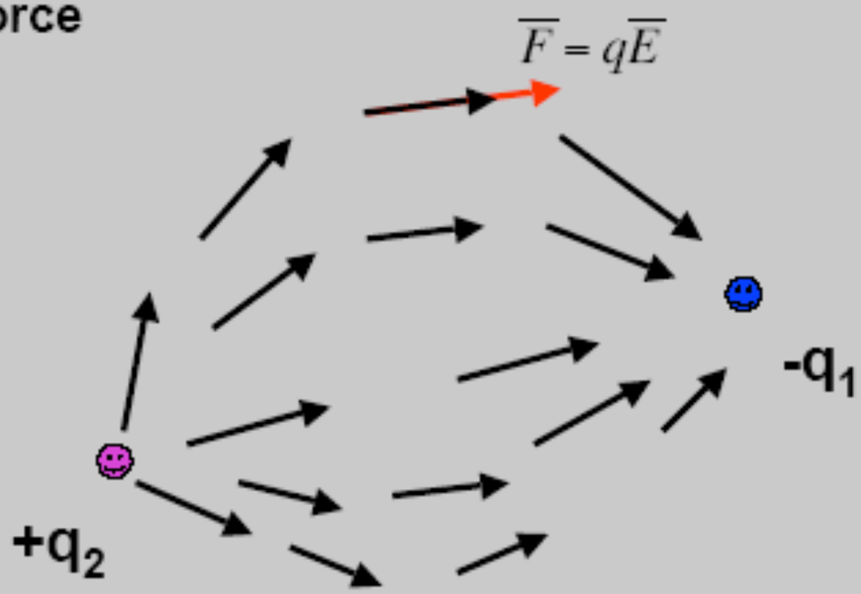
-q

Find the electric field at a distance of 10 cm from a point charge of 10^{-9}C

$$E = k_e \frac{q}{r^2} = 9\text{x}10^9 \frac{10^{-9}}{(0.1)^2} = 9\text{x}10^2\, N/C$$

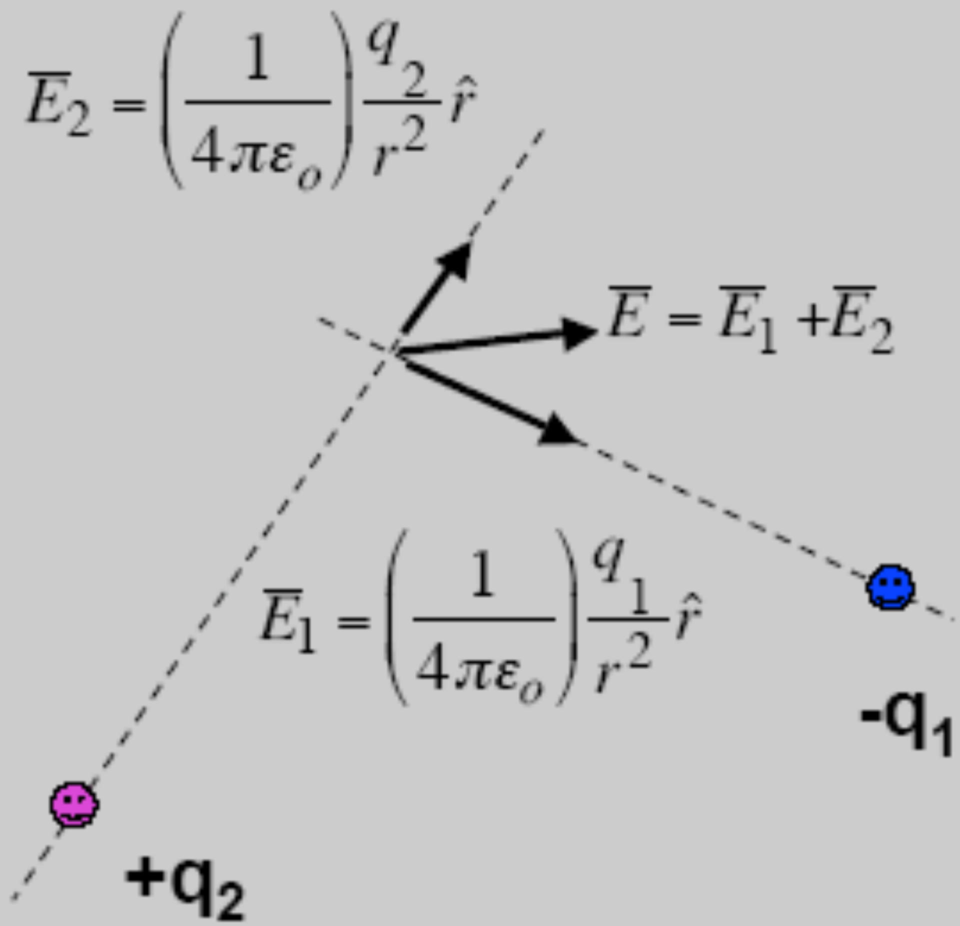
Electric Field

- **Vector valued function**
- **Aligned with force**



Physics Background

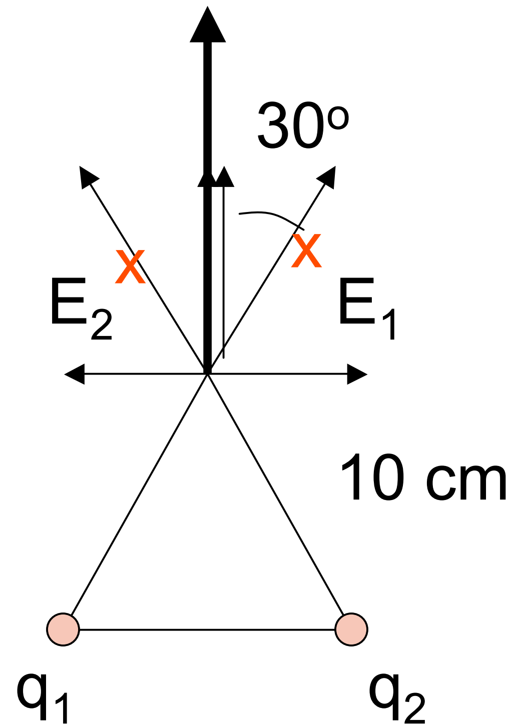
Superposition of Electric Field



Two charges of 10^{-9}C are placed at two corners of an equilateral triangle with sides of 10 cm. Find E at the third corner.

$$E_1 = E_2 = \frac{kq}{r^2} = \frac{9x10^9(10^{-9})}{(0.1)^2} = 900 N/C$$

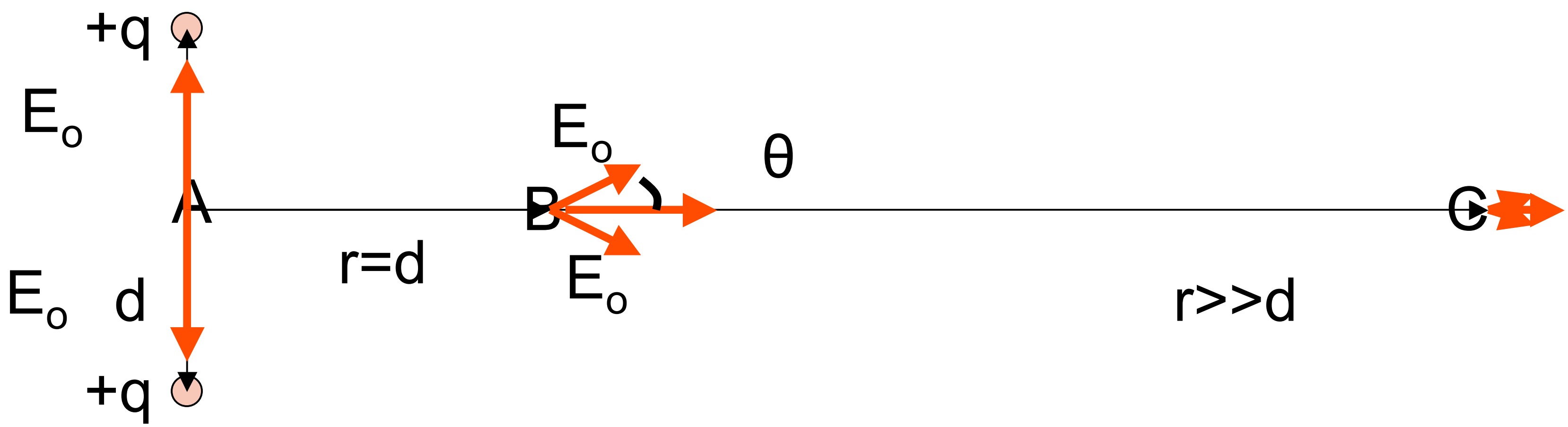
$$E = 2E_1 \cos 30 = 1.56x10^3 N/C$$



What is the direction of E?

A. Left
B. Right
C. Up
D. Down

Electric field due to 2 + charges



E_A

E_B

$E_A = 0$

$E_B = 2E_o \cos\theta$

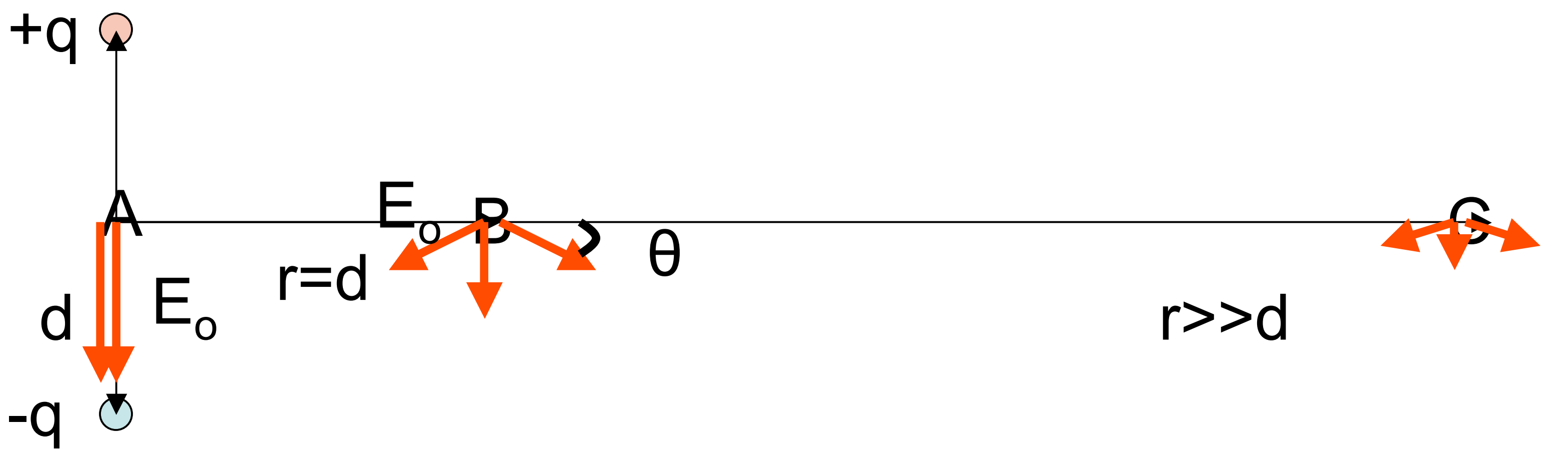
$E_C = 2E_o \cos\theta \Rightarrow 2E_o$

as θ->0

looks like a point charge of 2q

Electric field due to a dipole

dipole moment $qd=\mu$



Far field

as $\theta \to 0$

E_A

E_B

$E_A=2E_o$

$$E_B = 2E_o \sin\theta$$

$$E_C = 2E_o \sin\theta \Rightarrow 2E_o \frac{d/2}{r}$$

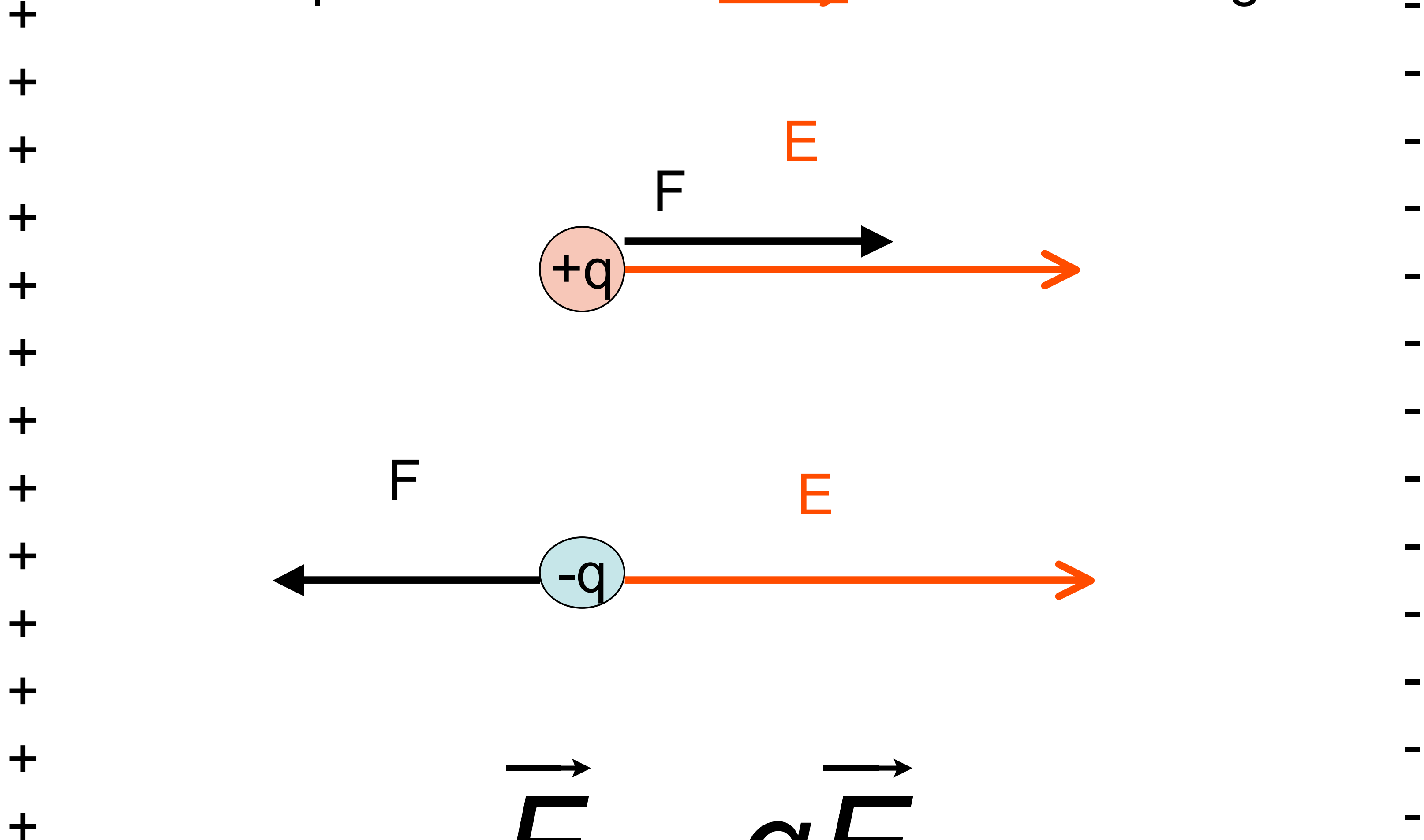
$$E_o = \frac{k_e q}{r^2}$$

E falls off as $1/r^3$

$$E_c = \frac{k_e qd}{r^3} = \frac{k_e \mu}{r^3}$$

The Electric Field exerts a Force on a Charge

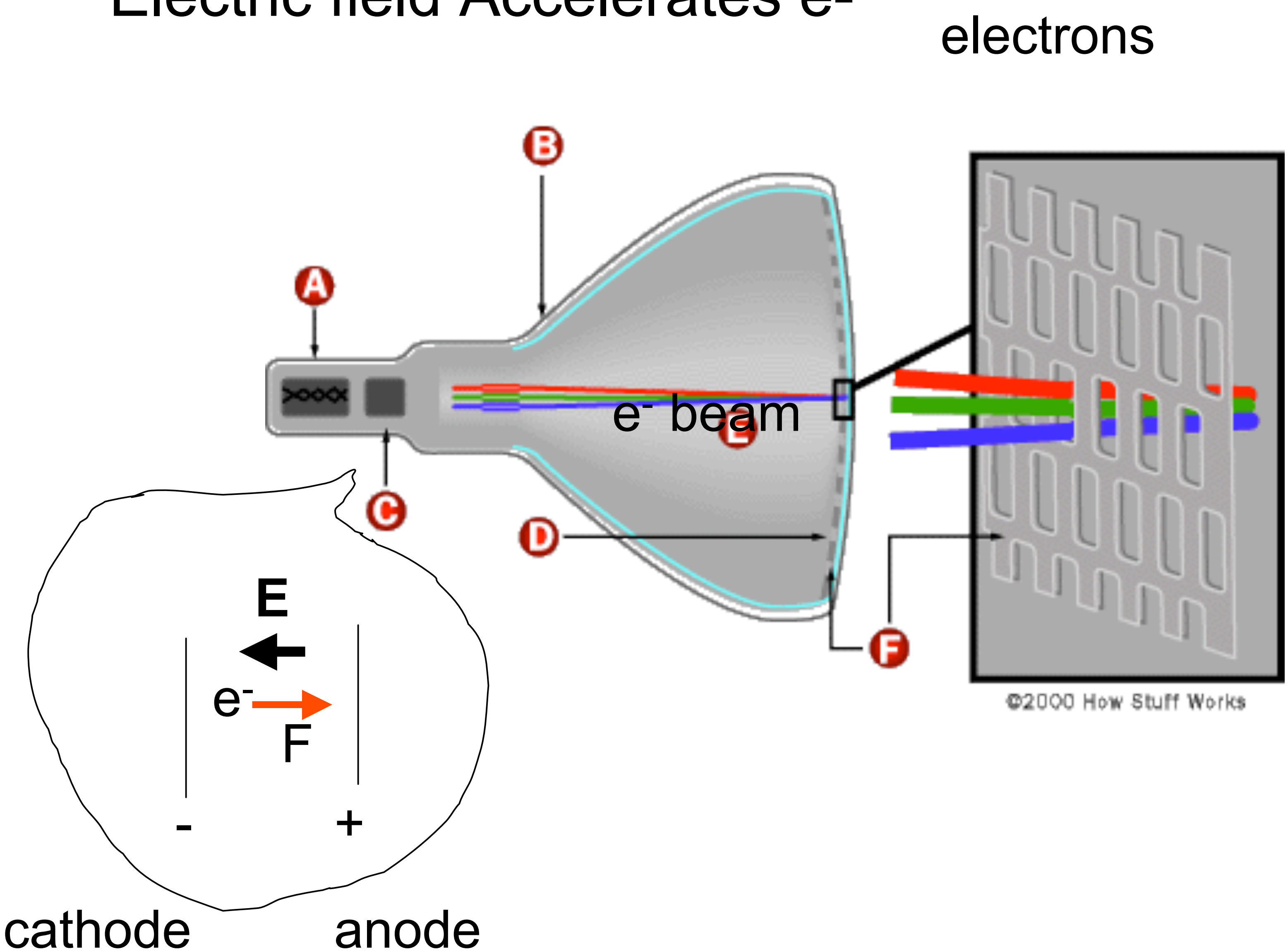
E field in space- due to an *array* of + and - charge



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

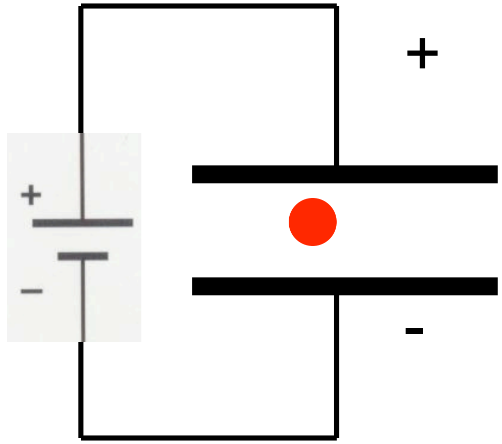
Cathode ray tube

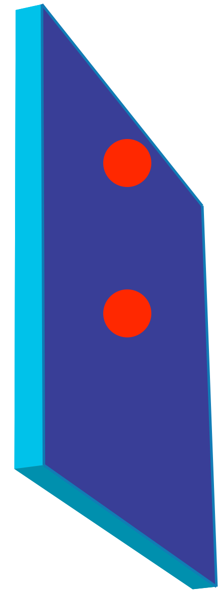
Electric field Accelerates e-



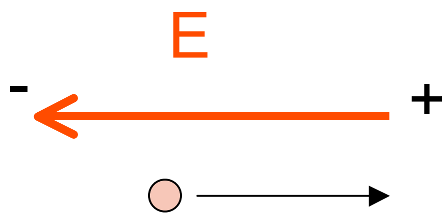
Oscilloscope

J.J.Thomson
N.P. physics 1906





An electron is accelerated from rest in a constant electric field of 1000 N/C through a distance of 3 cm. Find the force on the electron. Find the velocity of the electron. $m_e = 9x10^{-31}$ kg.



$$F = qE = 1.6x10^{-19}(1000) = 1.6x10^{-16} N$$

F=ma

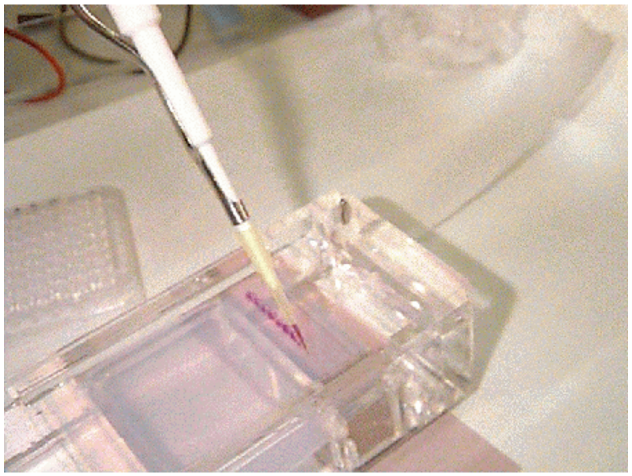
$$a = \frac{F}{m}$$

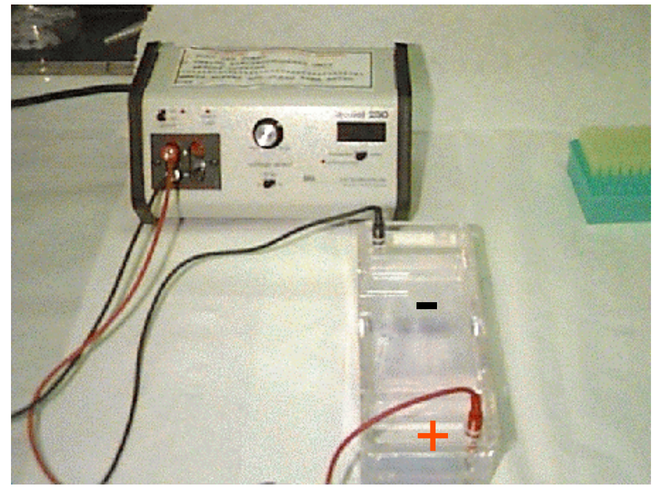
$$v^2 = v_o^2 + 2ax$$

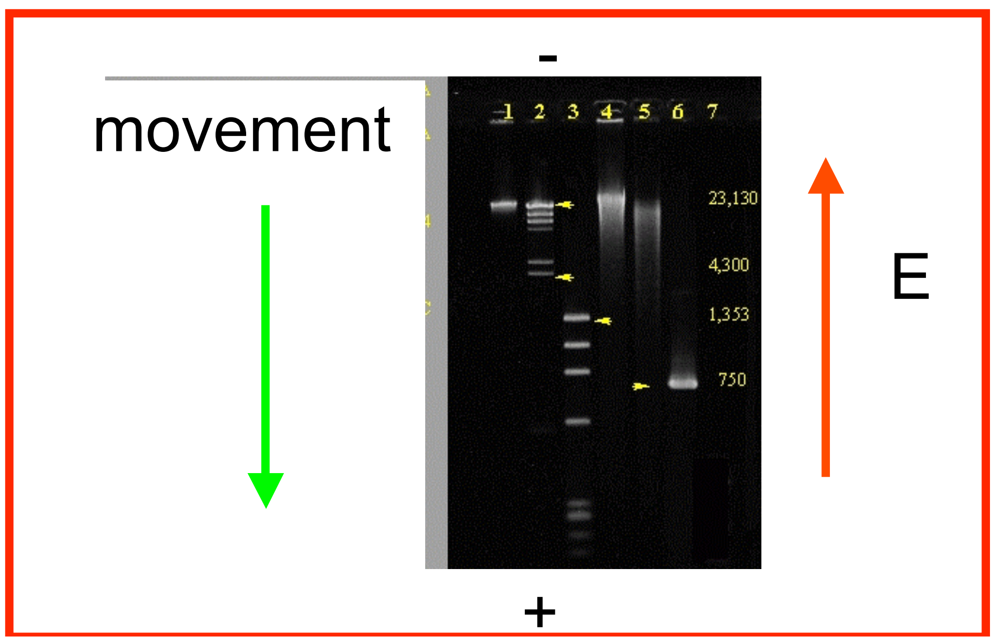
$$v = \sqrt{2ax} = \sqrt{2\frac{qE}{m}x} = \sqrt{2\frac{1.6x10^{-19}(1000)}{9x10^{-31}}(0.03)}$$

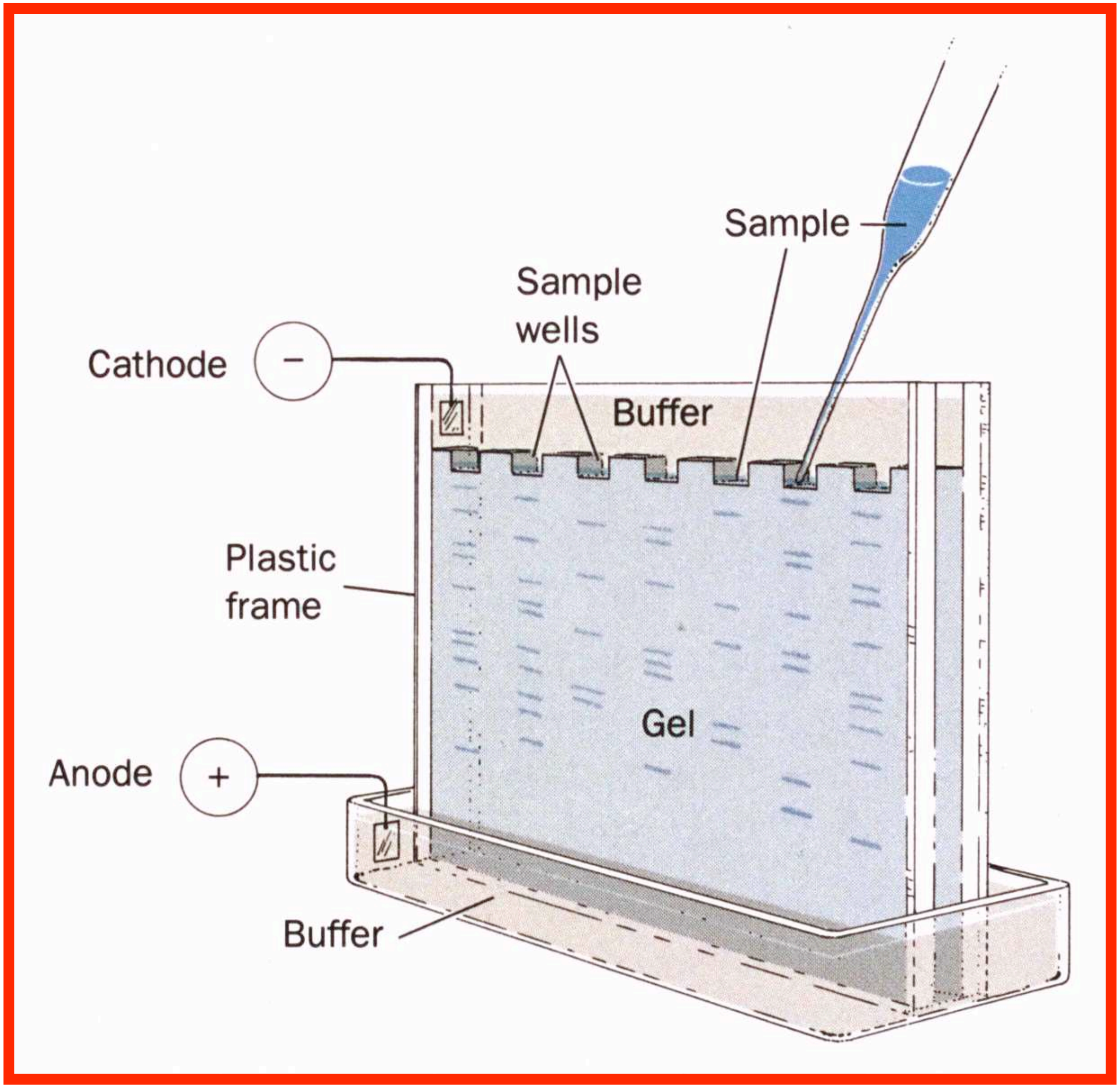
$$v = 3.3x10^6 m/s$$

Electrophoresis- Separation of DNA (Negatively charged ~ -1000 e) In an Electric field ~1000 N/C,

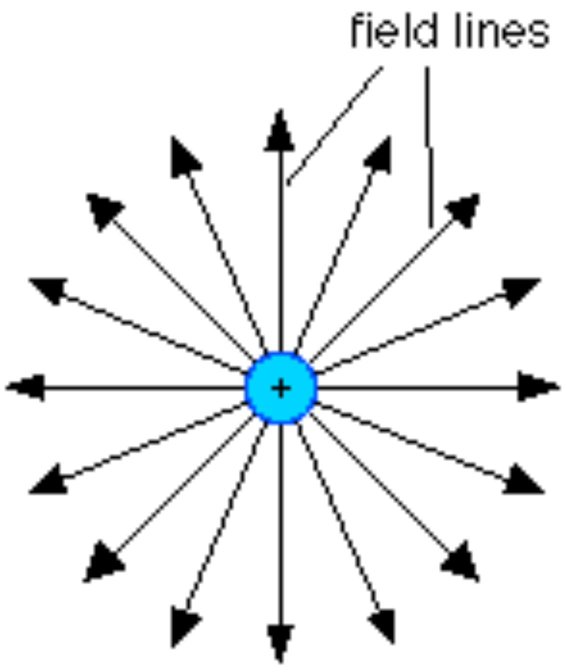







Sample
Sample
wells
Cathode
−
Buffer
Plastic
frame
Gel
Anode
+
Buffer

Electric field lines

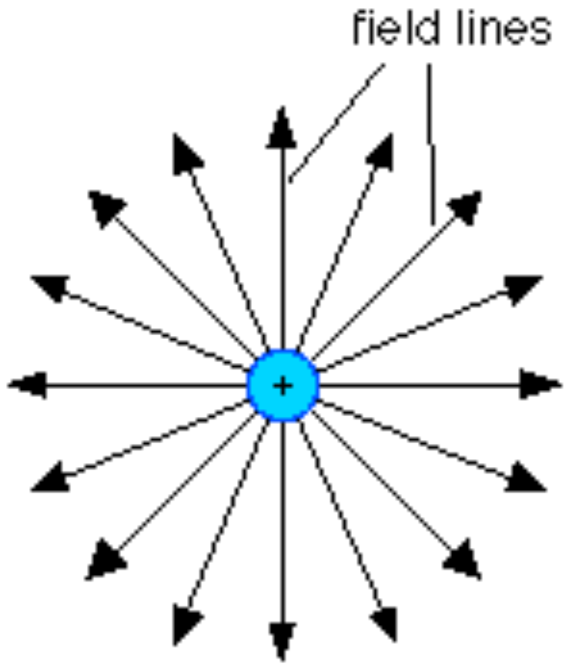


The electric field vector **E** is tangent to the electric field line

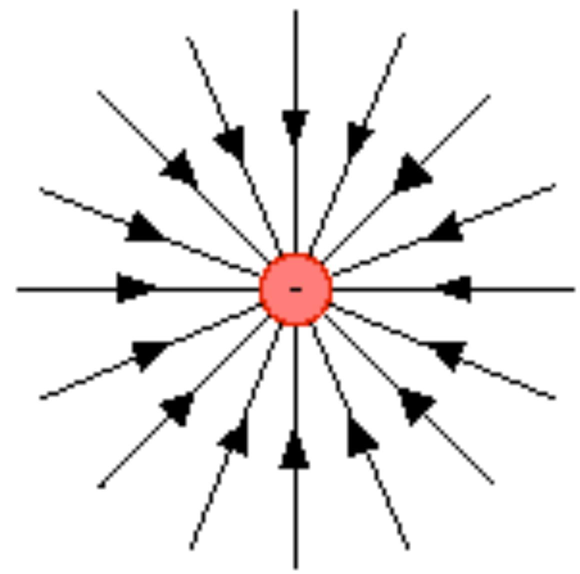
The number of electric field lines per unit area through a surface perpendicular to the lines is proportional to the strength of the electric field in a given region

Rules:

1. Electric Field Lines Begin at + charge and terminate on – charge (some lines can begin or end at infinity)
2. Number of lines leaving + charge or ending at – charge is proportional to the charge
3. No two lines can cross

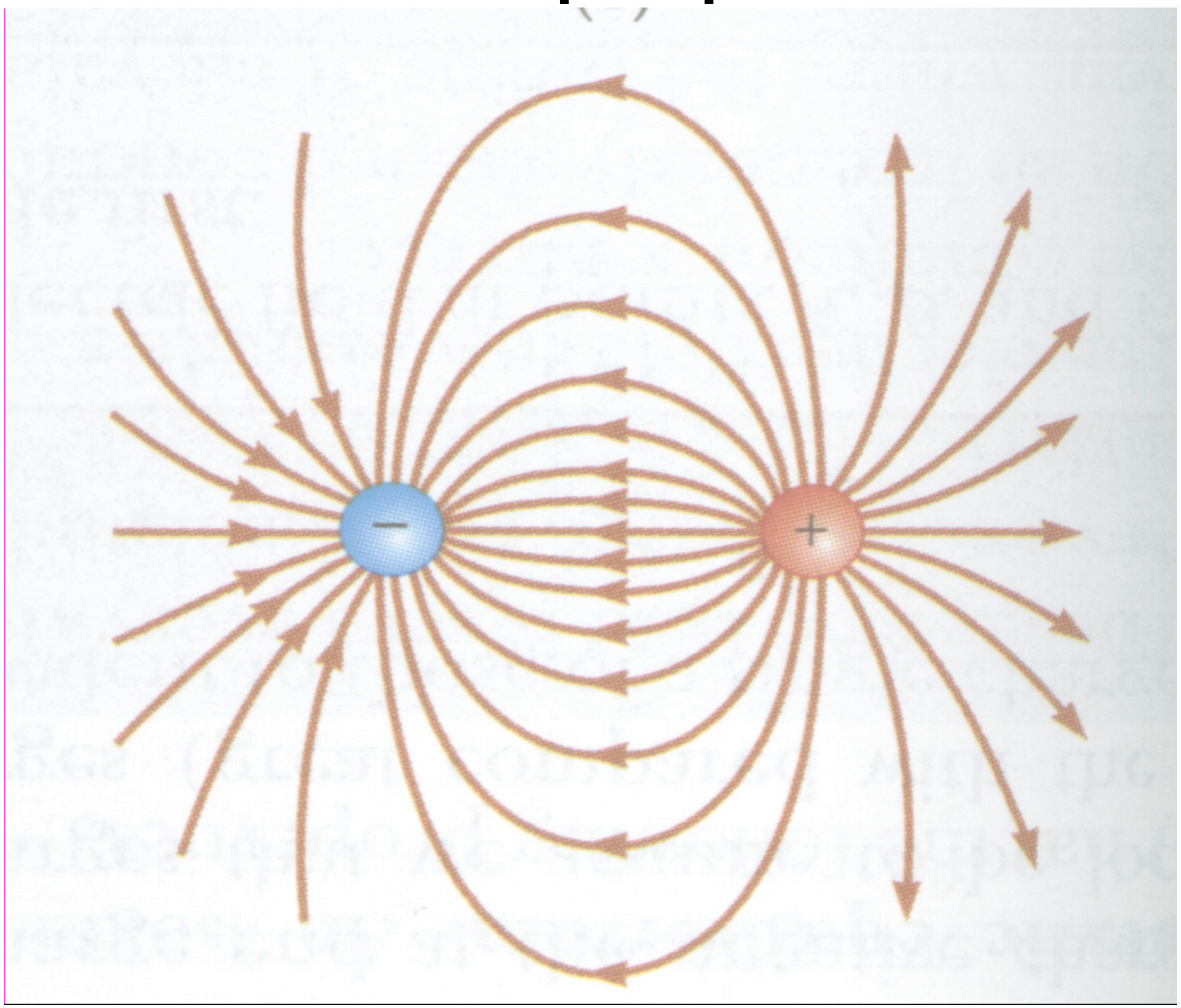


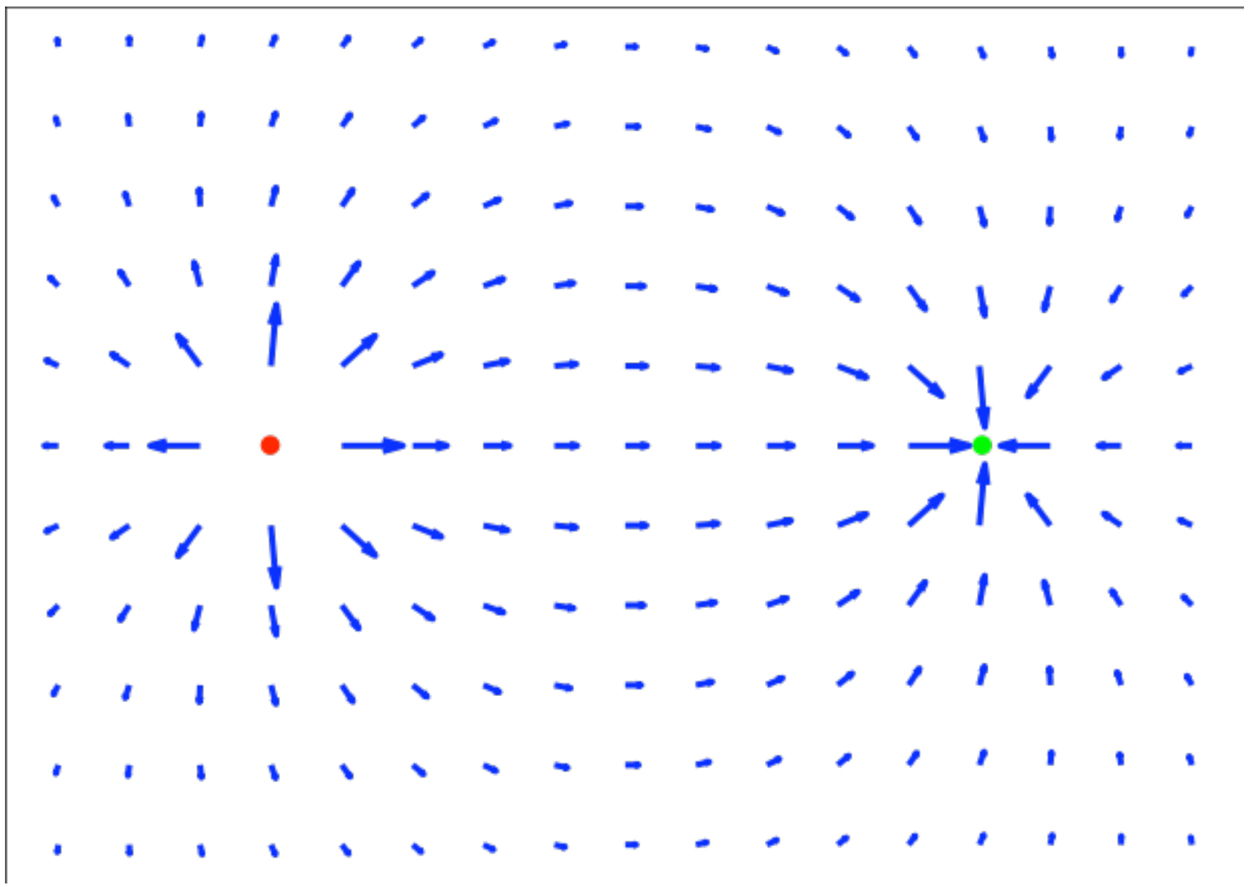
The electric field from an isolated positive charge



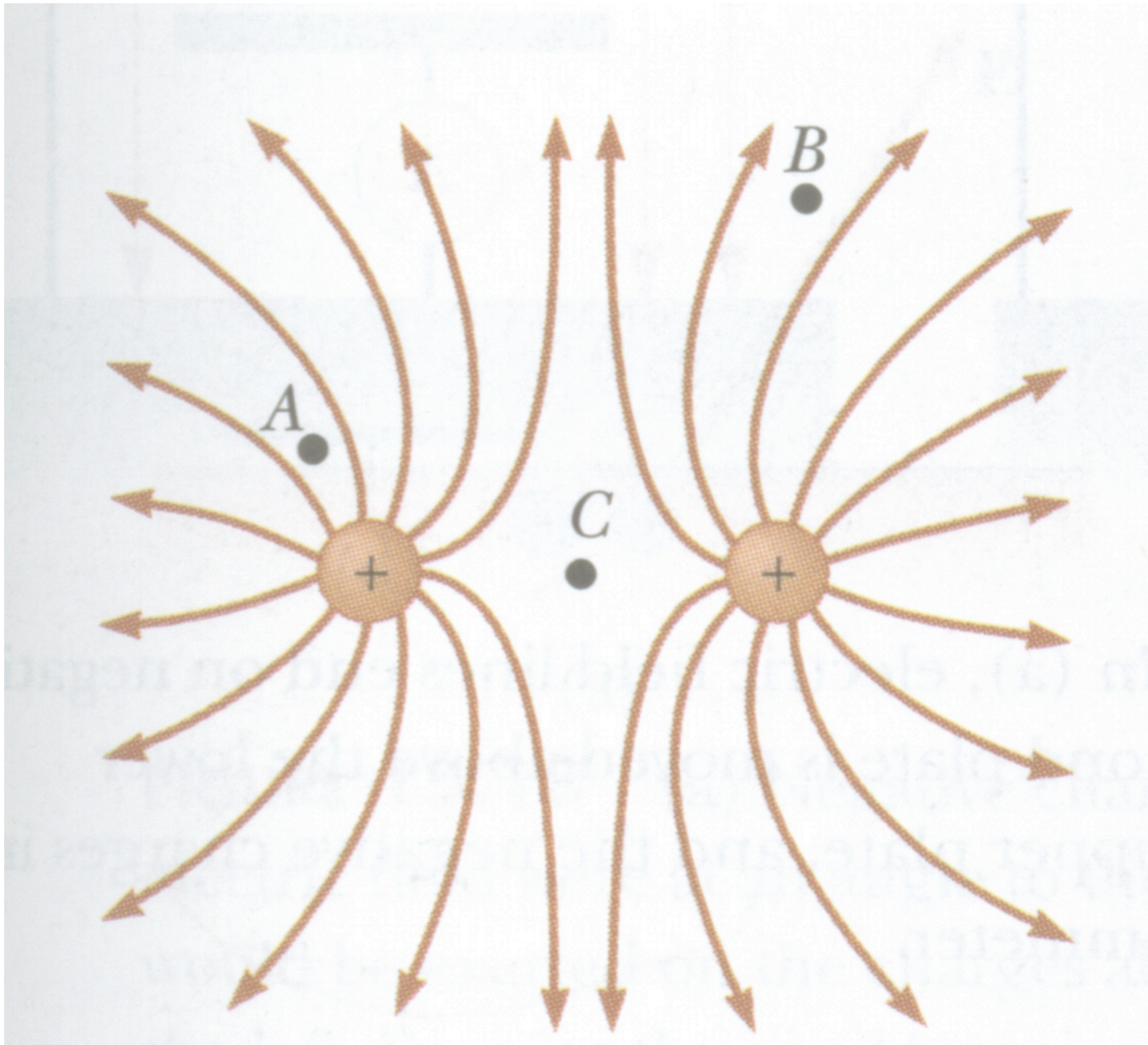
The electric field from an isolated negative charge

Electric field lines from a dipole +q, -q





Electric field lines from 2 + q charges



Electric field lines due to unequal charges +2q and -q