PHYSICS 1B – Fall 2009

Electricity
&
Magnetism

Wednesday Sept 30, 2009

Course Week 1

Professor Brian Keating

SERF Building. Room 333

UCSD

UCSD

Announcements

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- **You can register your clickers using your PID number, including the "A" in front.**

Solis Hall?


College Upper Apartments
345
Ridge
375
Hopkins L
Marshall College Field
Thurgood Marshall College Lower Apartments
386
P309
Economics
P308
370
Thurgood Marshall College
350
380
Sequoyah Hall
360
Thurgood Marshall College Administration
Media Center/ Communication
390
Eucalyptus Point
391
392
Book Drop
P501
Geisel Library
900
P302
Scholars Drive North
361
V
P207
B
A
P301
Chemistry Research
393
Cognitive Science
397
University C
Peterson Hall
399
P
P
Muir Lane
Mandler Hall
245
P205
249
P206
McGill Hall
246
Applied Physics and Mathematics
Faculty Club
270
P415
Student Health and Wellness
999
Library Walk
Boo
Chancellor

Your questions via email

- I was wondering if I need to answer the questions correctly in order to
- obtain extra credit points. Thank you.

- I was wondering if you were going to post the lecture slides for Monday'slecture? Physics helproom isn't open until next week and there is a slide from Monday's lecture that would help me with my pre-lab that's due tomorrow for the 1BL class..

- I am currently enrolled in your 1B physics class that meets on Mon, Wed and Friday at 1pm. I am concerned about the way that the example problems are presented. I noticed that all the equations and work are presented in power point format which is very difficult to follow. I know that I would better understand the examples if they were worked out on the board and explained rather than quickly flashed on the screen while I scratch my head trying to figure out how we went from point A to point B. I don't think that I am alone in feeling this as a number of people around me today in class also expressed frustration. consider this request, to work out problems on the board rather than present them on the power point slides.

•

- I was reading over the syllabus and it states that homework will be not be collected. However, I feel like you stated in class last week that HW will be collected. Can you please clarify this for me?

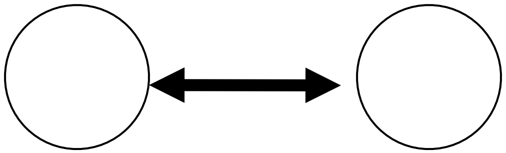
Dear Prof. Keating,

I'm studying for your physics 1B class and noticed there are example problems within the reading chapters. I was wondering if you would recommend also doing these problems in addition to your assigned homework. The reason why I'm asking was my 1A physics prof said that those problems were not helpful and made the material more confusing. I just wanted to see your opinion. Thanks!

Similarity with the gravitational force (1/r^2 dependence)

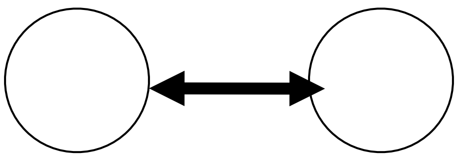
$$F_G = G\frac{M_1 M_2}{r^2}$$

$$G = 7\text{x}10^{-11}\frac{Nm^2}{kg^2}$$



$$F_e = k_e\frac{q_1 q_2}{r^2}$$

$$k_e = 9\text{x}10^{9}\frac{Nm^2}{C^2}$$



Similarity with the gravitational force ($1/r^2$ dependence)

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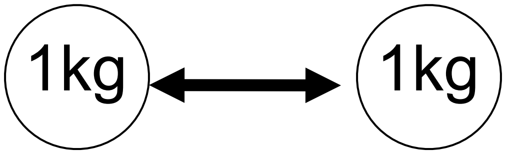

r=1m

$F_G = 7\text{x}10^{-11}$ N

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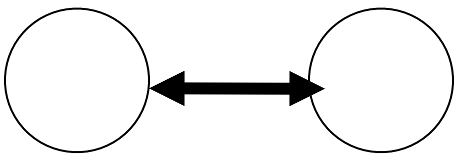

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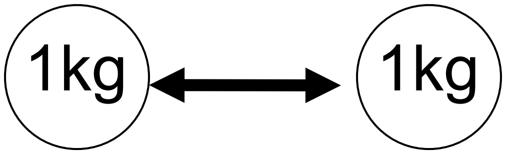

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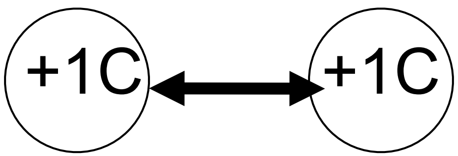
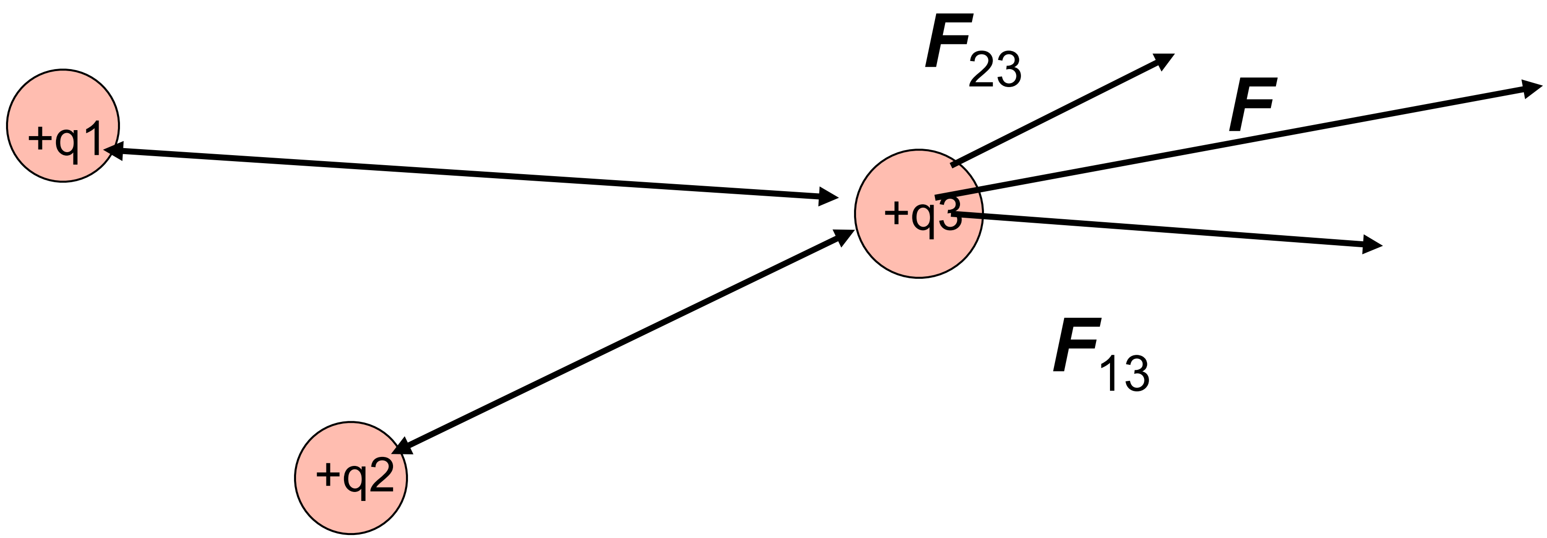


r =1m

$F_e = 9\text{x}10^{9}$ N

10^{20} times more than F_G

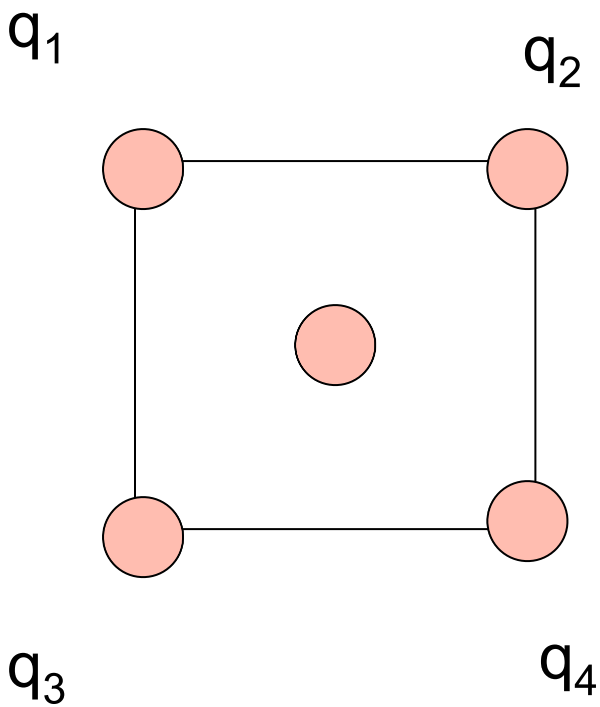
Force between several point charges



Force acting on q3 $\vec{F} = \vec{F}_{13} + \vec{F}_{23}$

Net force = vector sum of forces

Suppose you had a charge q at the center of a square having Charges of q at each corner. What is the force on the charge In the center?



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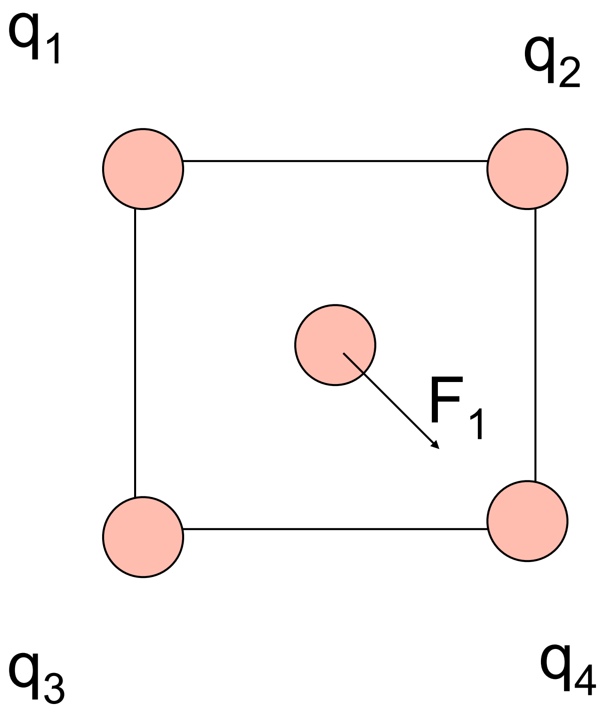

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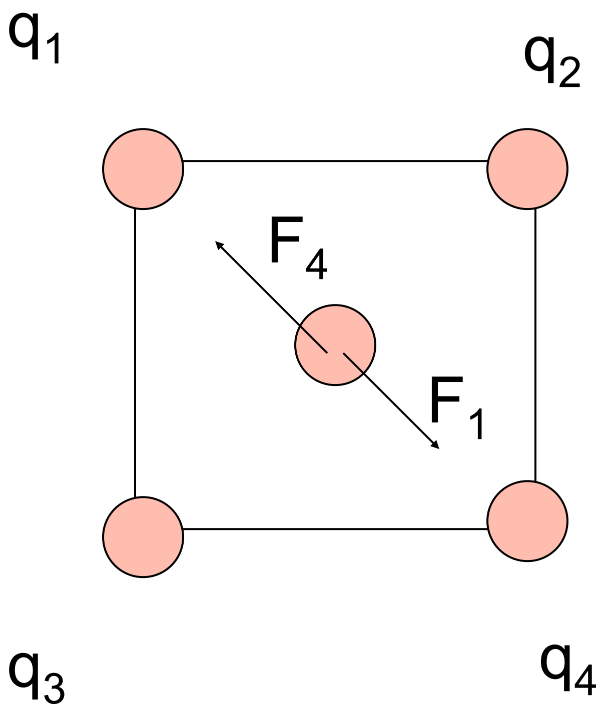

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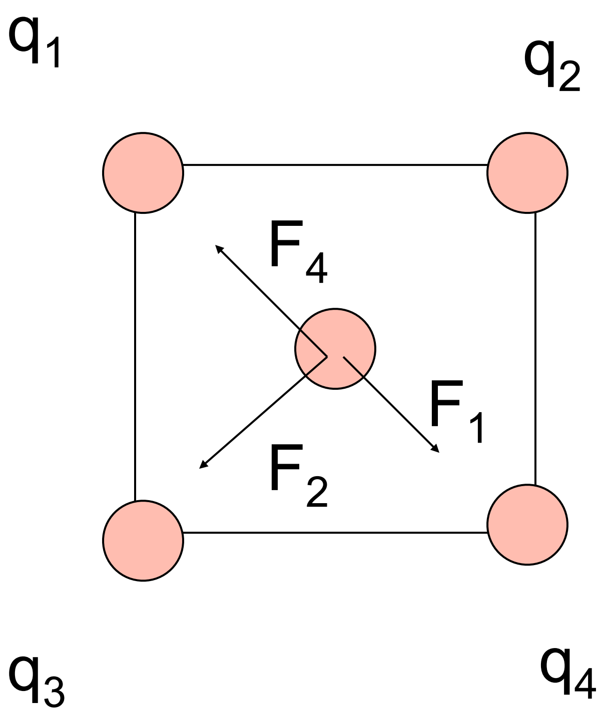

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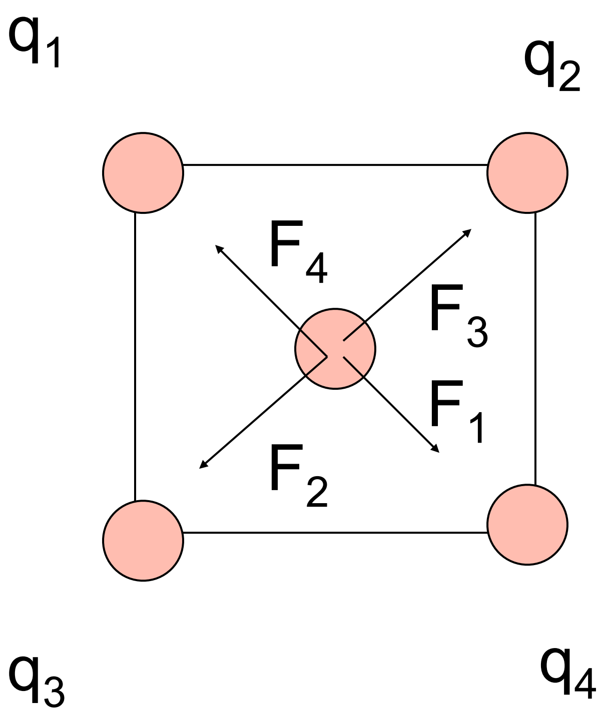

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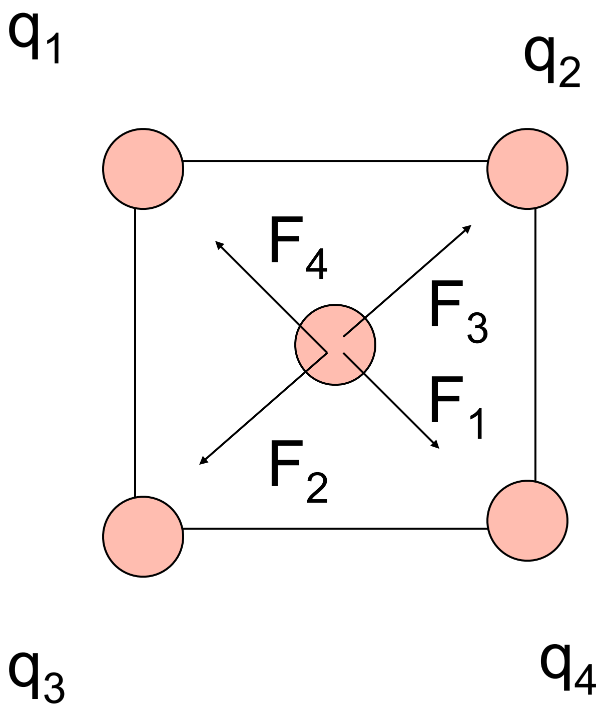

$$F_1 + F_4 = 0$$

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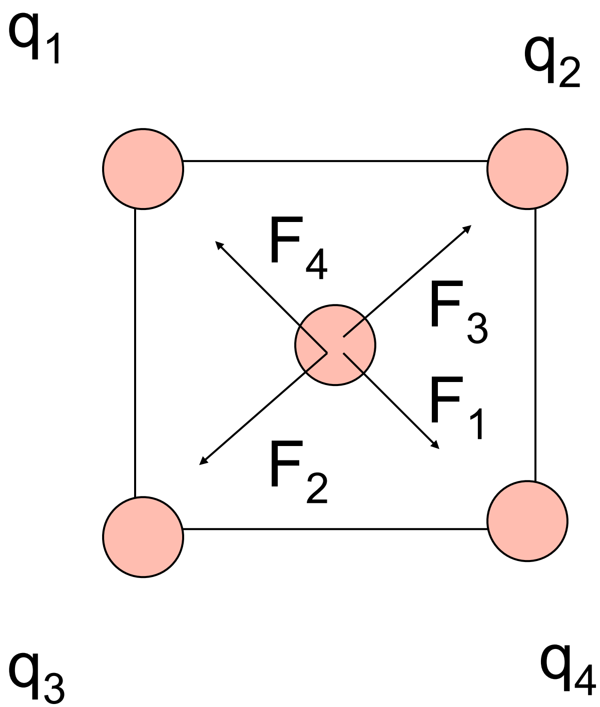

$$F_1 + F_4 = 0$$

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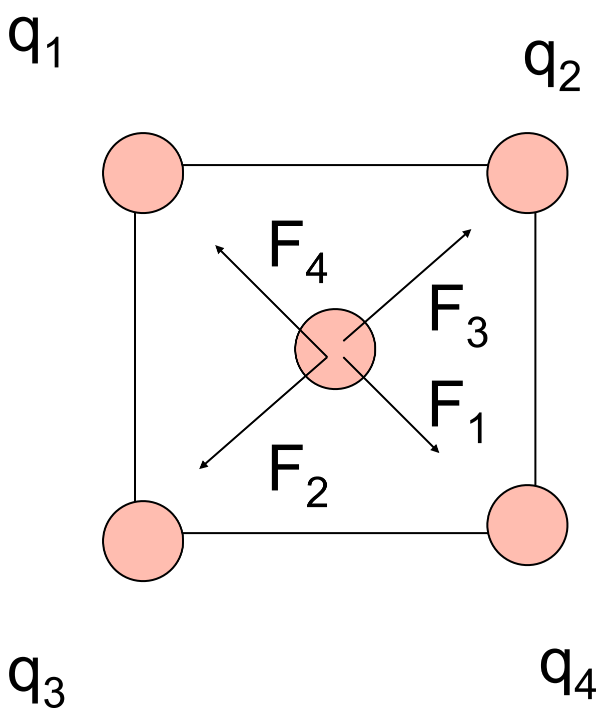


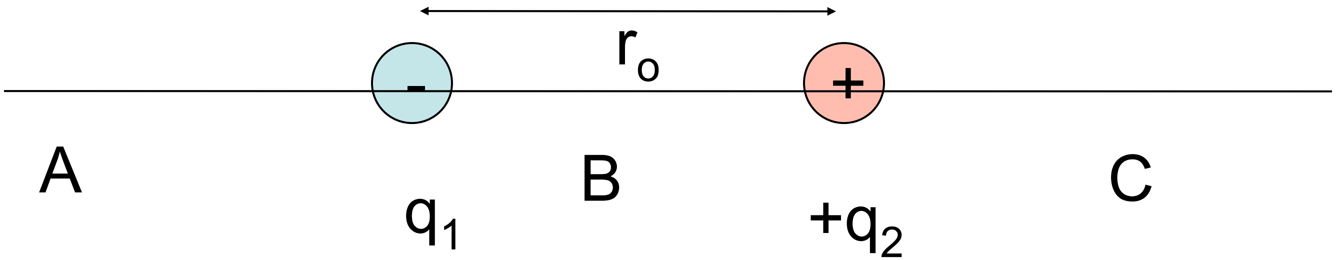
$$F_1 + F_4 = 0$$

$$F_2 + F_3 = 0$$

$$\sum F = 0$$

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?

Is it in the A, B or C region?



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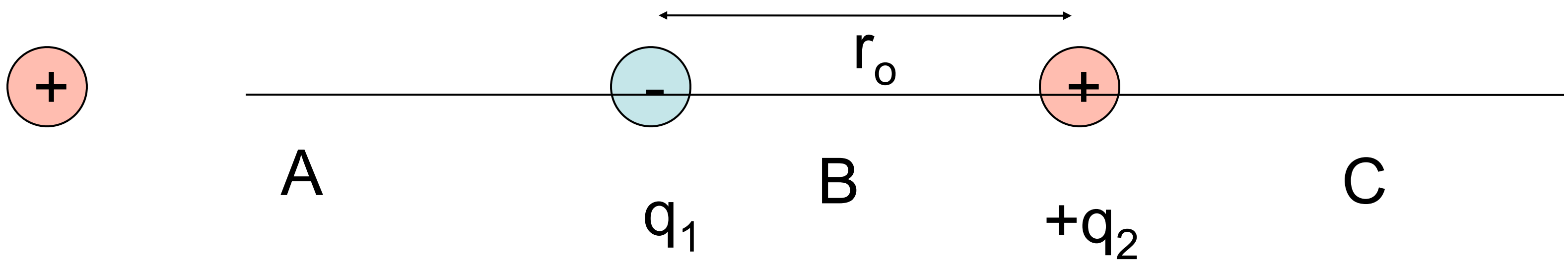

It must be in the A region. The force from the smaller –charge can be increased by a smaller distance

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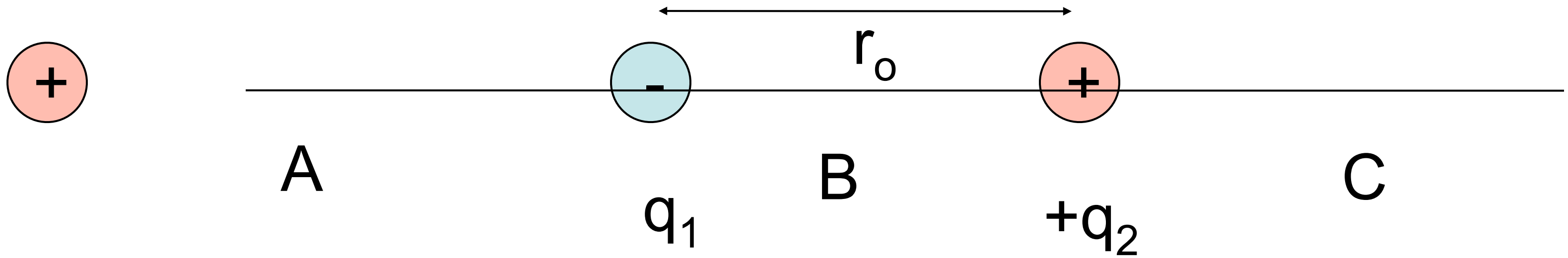

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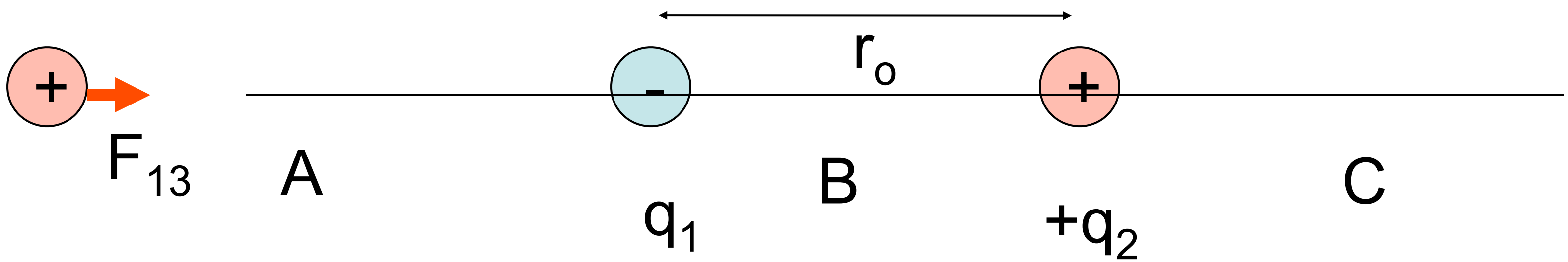

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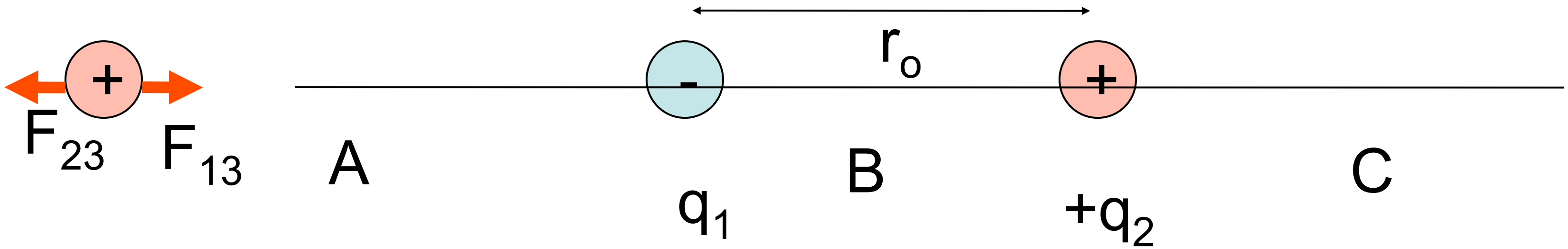

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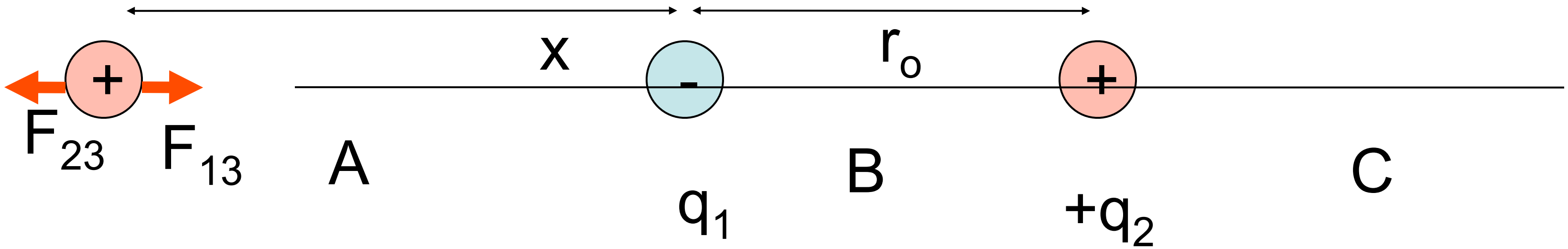

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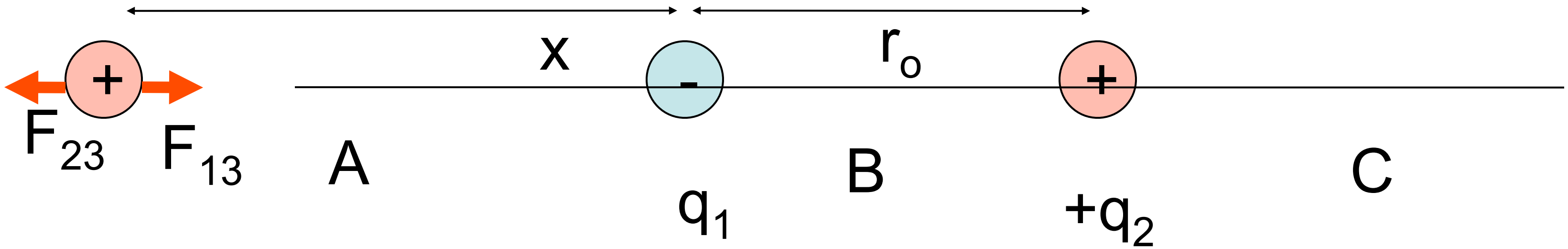

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$$|F_{13}| = |F_{23}|$$

$$\frac{k_e |q_1||q_3|}{x^2} = \frac{k_e |q_2||q_3|}{(r_o + x)^2}$$

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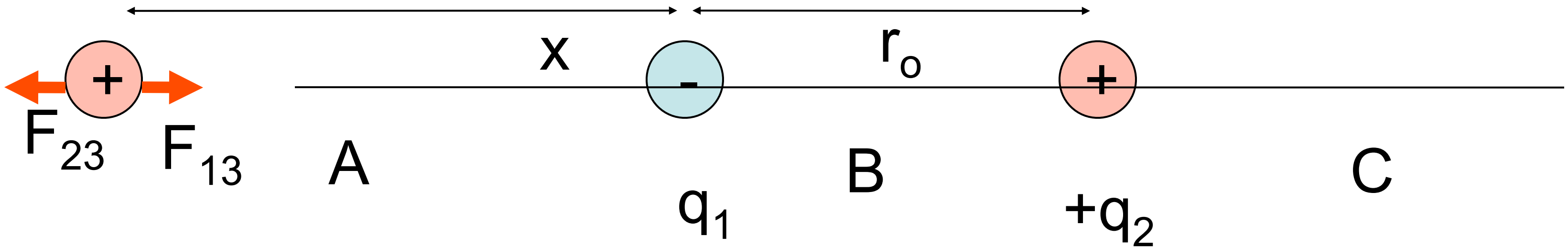

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$$(r_o + x)^2 |q_1| = x^2 |q_2|$$

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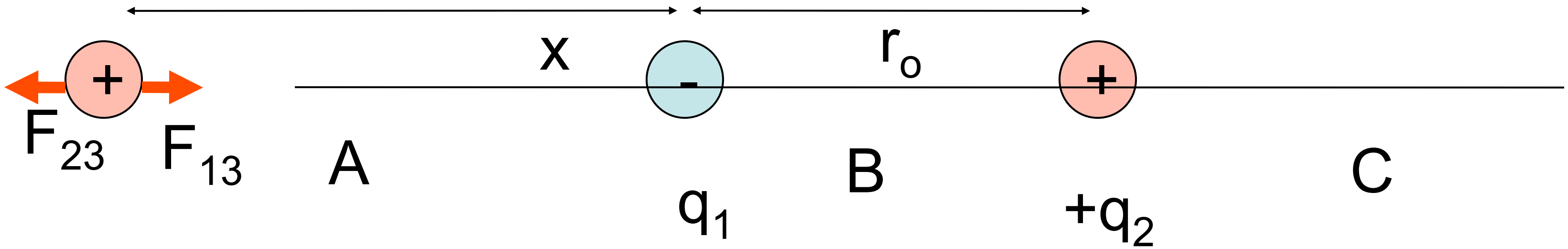

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$$(r_o + x)^2\left|q_1\right| = x^2\left|q_2\right|$$

$$(r_o + x)\sqrt{\left|q_1\right|} = x\sqrt{\left|q_2\right|}$$

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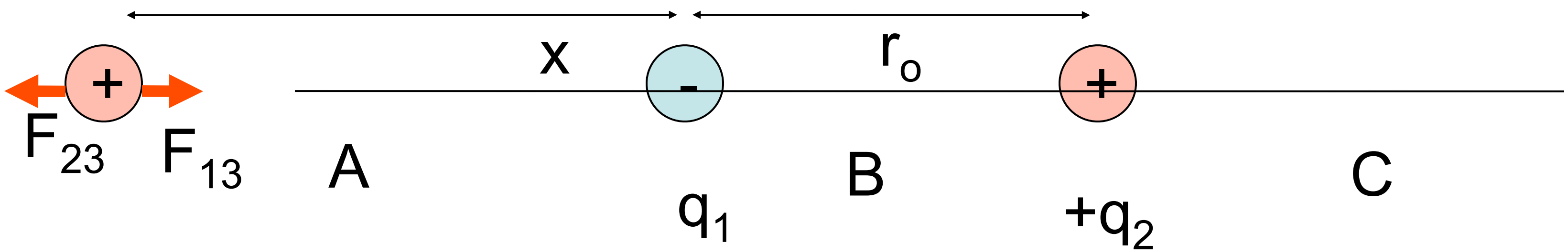

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$$(r_o + x)^2|q_1| = x^2|q_2|$$

$$(r_o + x)\sqrt{|q_1|} = x\sqrt{|q_2|}$$

$$x = \frac{\sqrt{|q_1|}}{\sqrt{|q_2|} - \sqrt{|q_1|}}r_o = \frac{\sqrt{1}}{\sqrt{2} - \sqrt{1}}r_o = 2.41r_o$$

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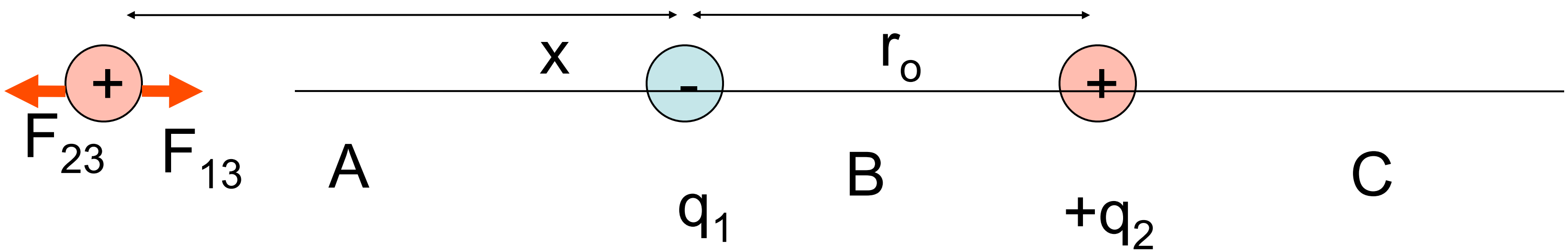

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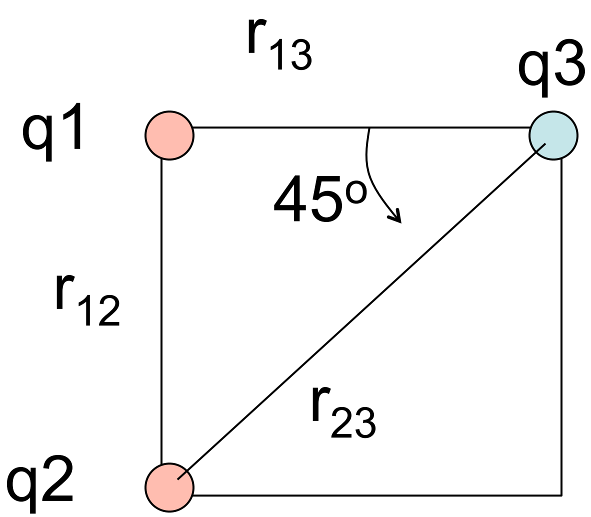
$$(r_o + x)^2 |q_1| = x^2 |q_2|$$

$$(r_o + x)\sqrt{|q_1|} = x\sqrt{|q_2|}$$

$$x = \frac{\sqrt{|q_1|}}{\sqrt{|q_2|} - \sqrt{|q_1|}} r_o = \frac{\sqrt{1}}{\sqrt{2} - \sqrt{1}} r_o = 2.41 r_o$$

$$r_o + x = 3.41 r_o$$

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=

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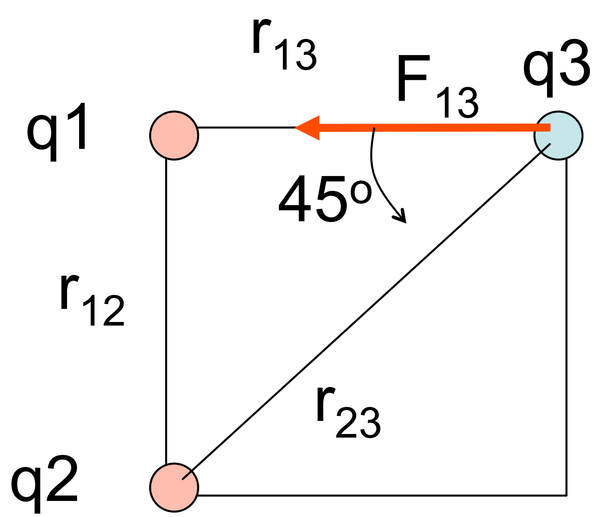

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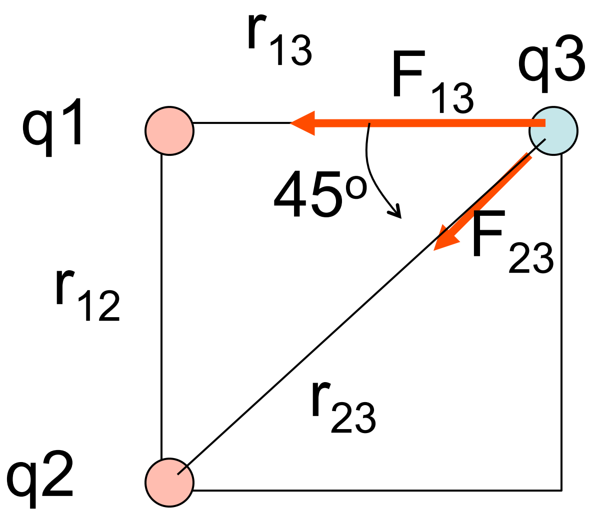

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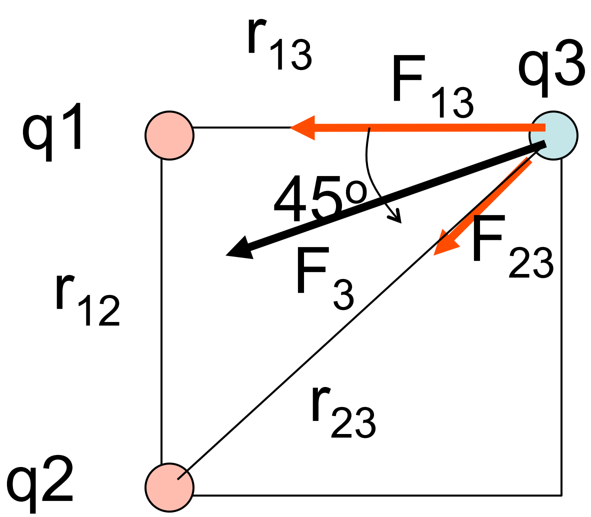

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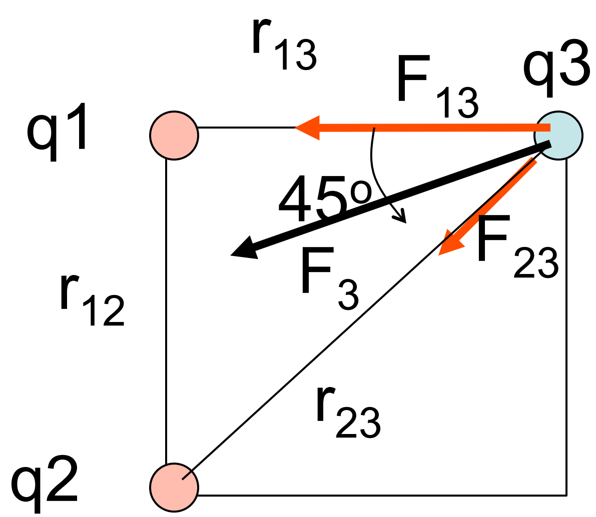


Forces acting on q3

F_{13} =

F_{23}=

F_3=

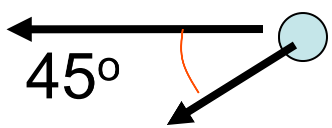
$$r_{23}^2 = r_{13}^2 + r_{12}^2$$

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

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

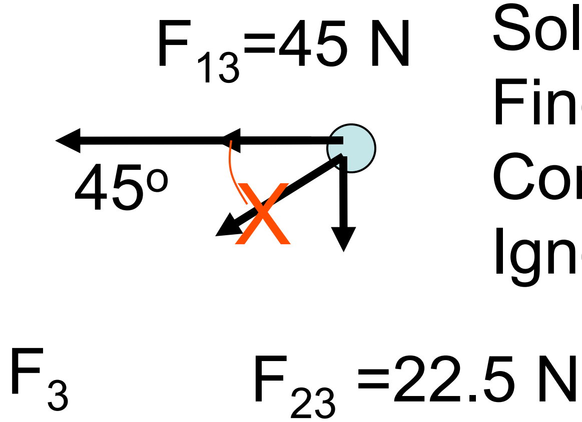
$$F_{13} = \frac{k_e q_1 q_3}{r_{13}^2} = \frac{9x10^9(10^{-6})(2x10^{-6})}{(2x10^{-2})^2} = 45N$$

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



Solve
Find x and y components.
Consider only the relative magnitudes
Ignore the minus sign

F_3 F_{23} =22.5 N



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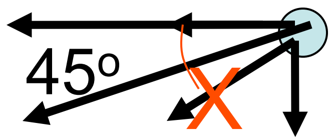

Solve

Find x and y components.

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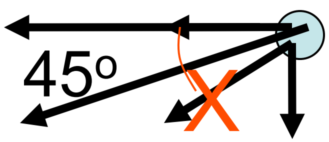
$$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2}$$



Solve

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

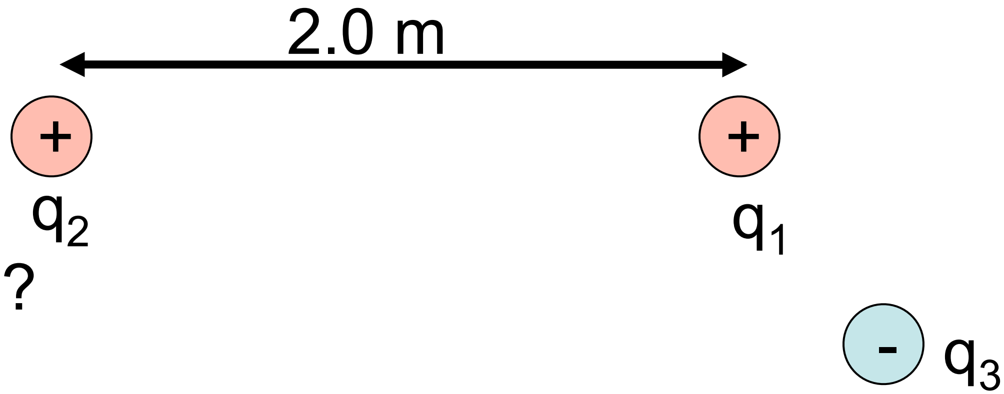
$$F_{3x} = 45 + 22.5(\cos 45) = 61N$$

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

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

Example 15.3 Where is the resultant force zero?

Two charges are in a line
q_1=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 ?

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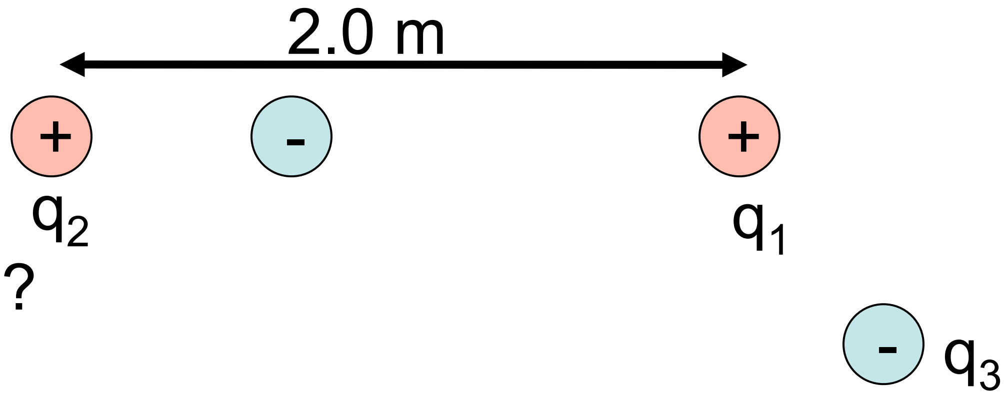

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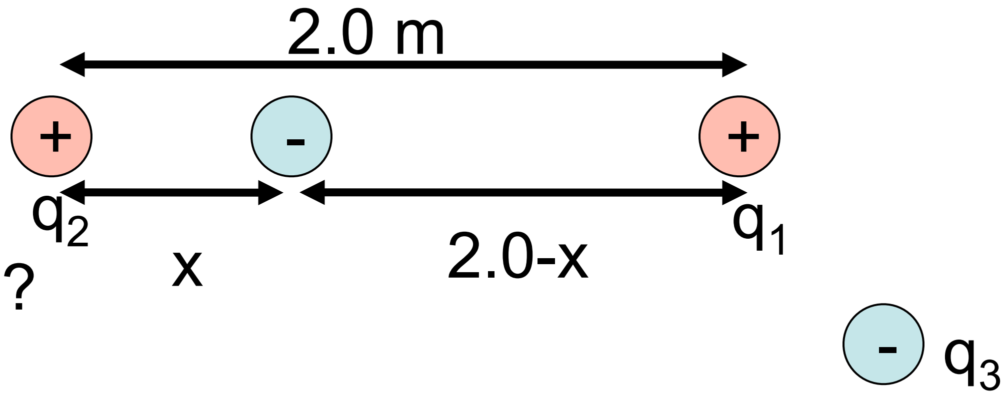

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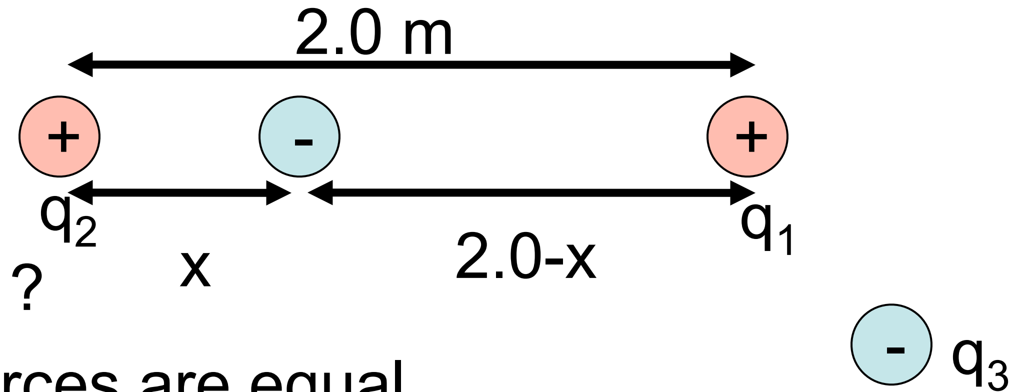

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Magnitudes of forces are equal

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

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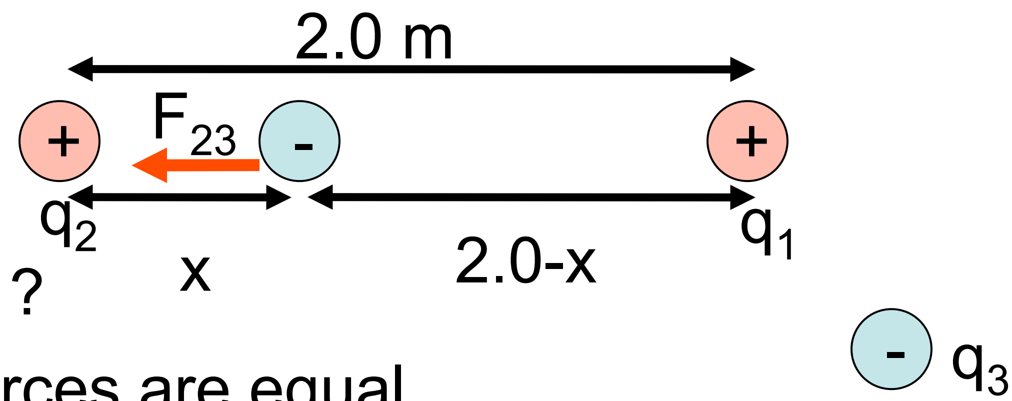

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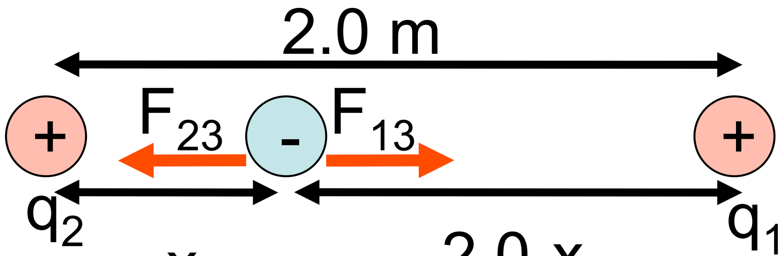

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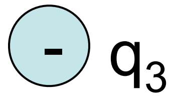

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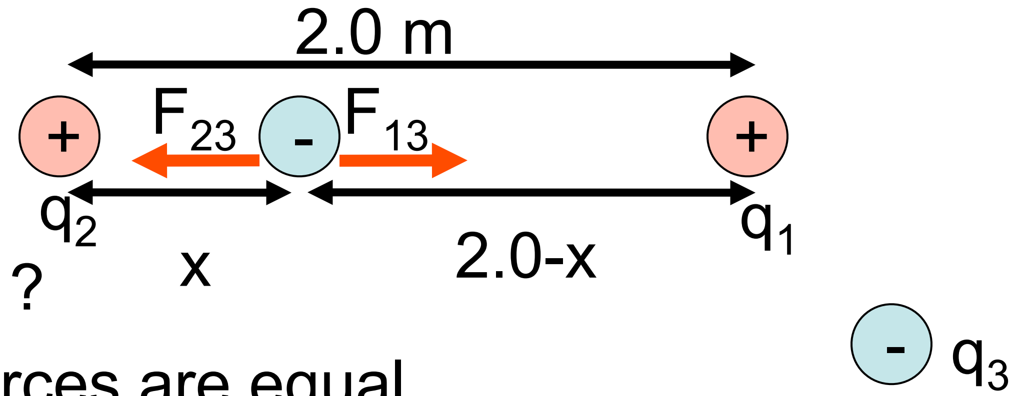

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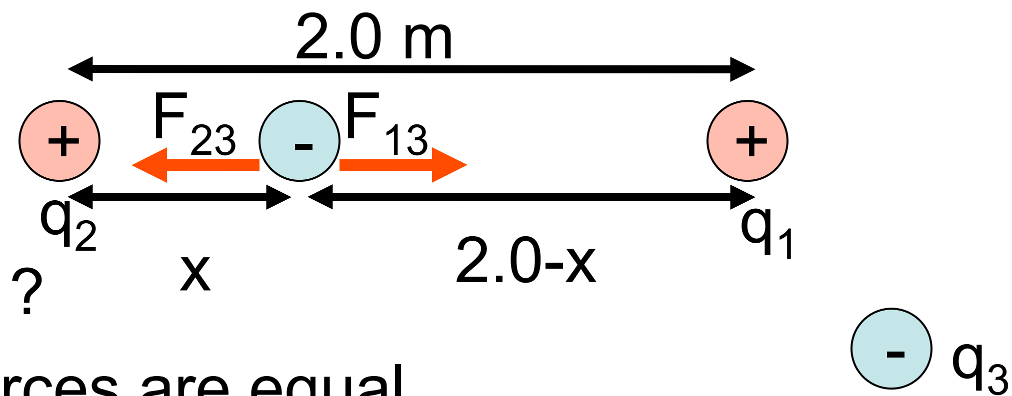

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Magnitudes of forces are equal

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

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

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

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

$$\frac{x}{2-x} = \sqrt{\frac{q_2}{q_1}} = \sqrt{\frac{6}{15}} = 0.63 = \alpha$$

$$x = \frac{2\alpha}{1+\alpha} = \frac{2(0.63)}{1+0.63} = 0.77 \text{ m}$$

2-x=2-0.77=1.23m

Chapter 15.4 & 15.5
Electric Fields / Electric Field Lines

Chapter 15.4 & 15.5
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.

PHYSICS 1B – Fall 2009

Electricity & Magnetism

October 2, 2009

Course Week 1

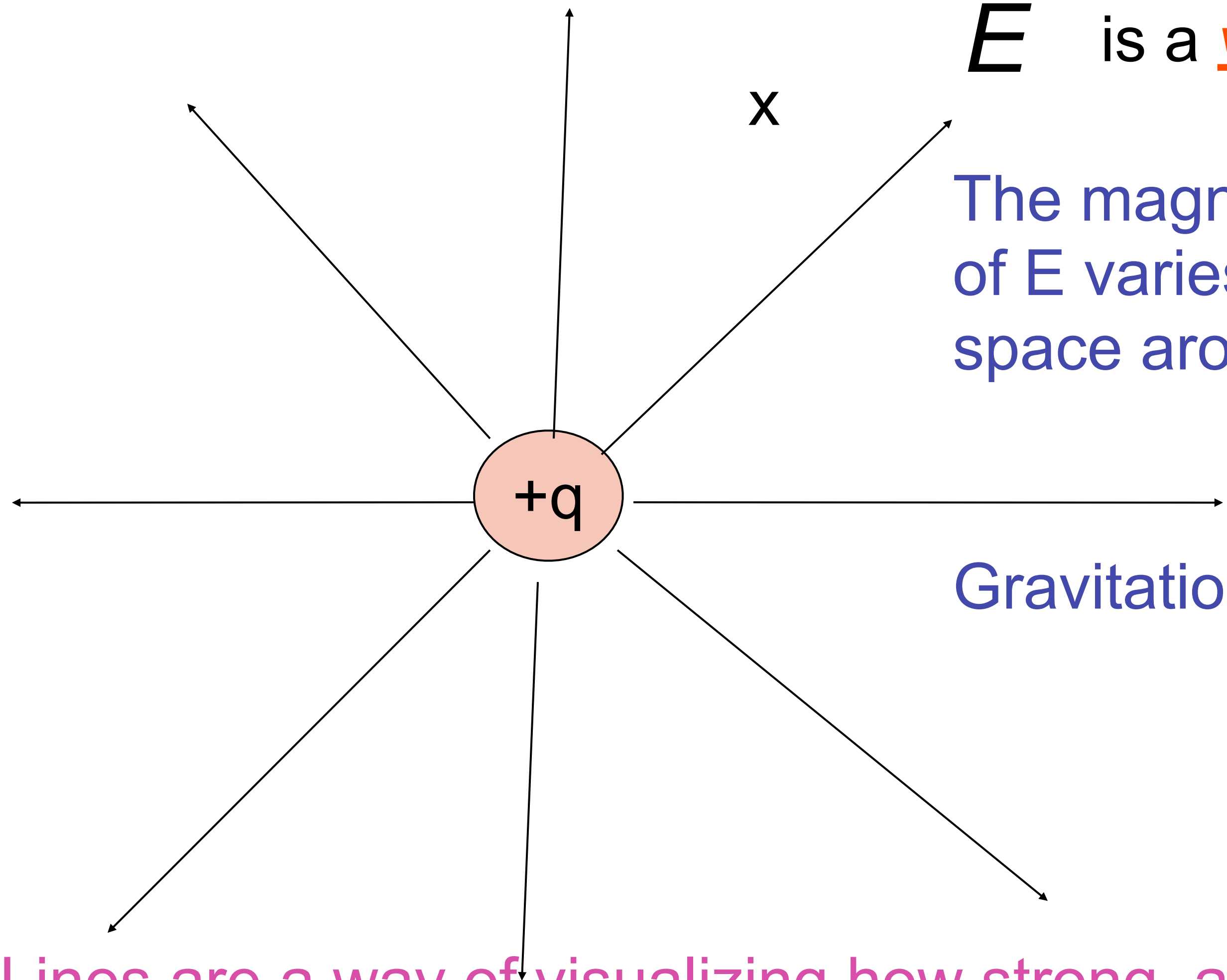
Professor Brian Keating

SERF Building. Room 333

UCSD

UCSD

The Electric Field exists in space surrounding a charge



E is a ***vector quantity***

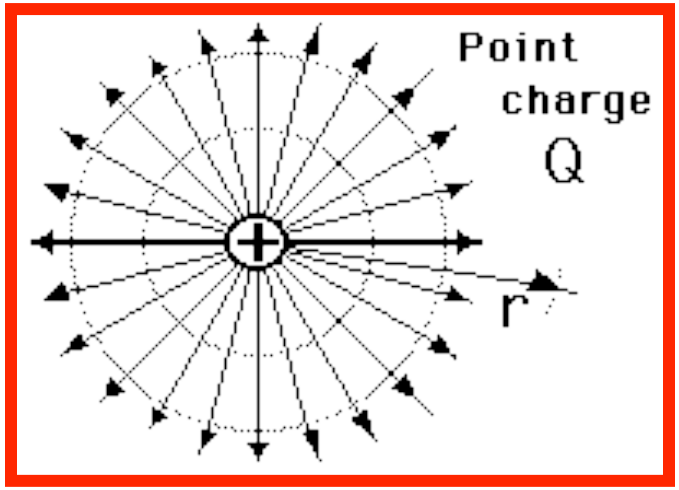
The magnitude and direction of E varies with position in space around a charge.

Gravitational field analogy

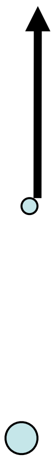
Lines are a way of visualizing how strong, and in what direction, an Electric Force will act on a test charge.

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

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



E



+q

E

-q

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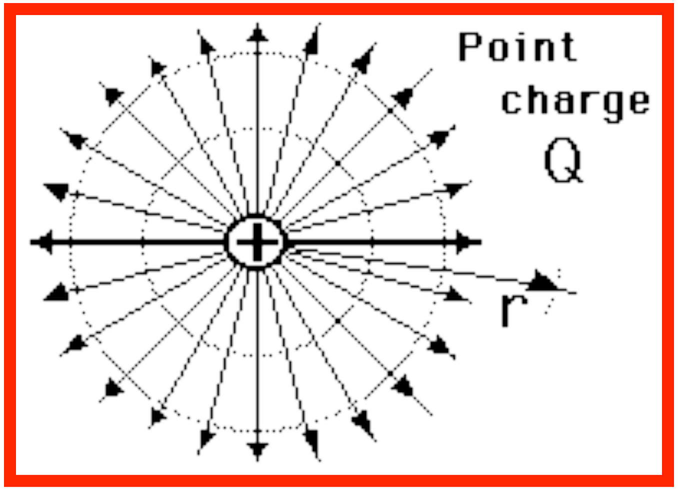

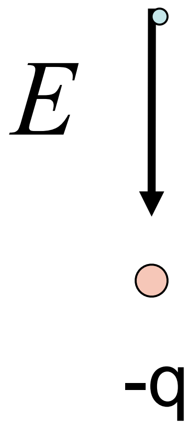

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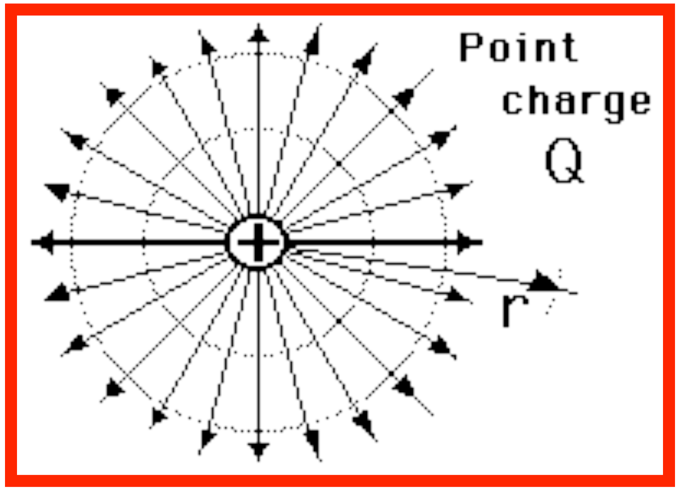


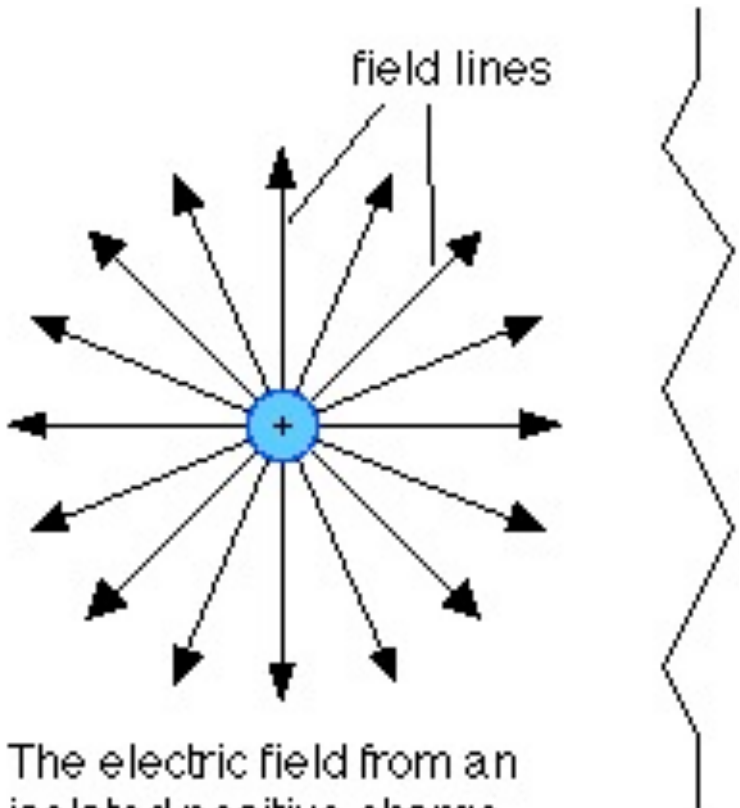
E

+q

E

-q

15.5 Electric field lines

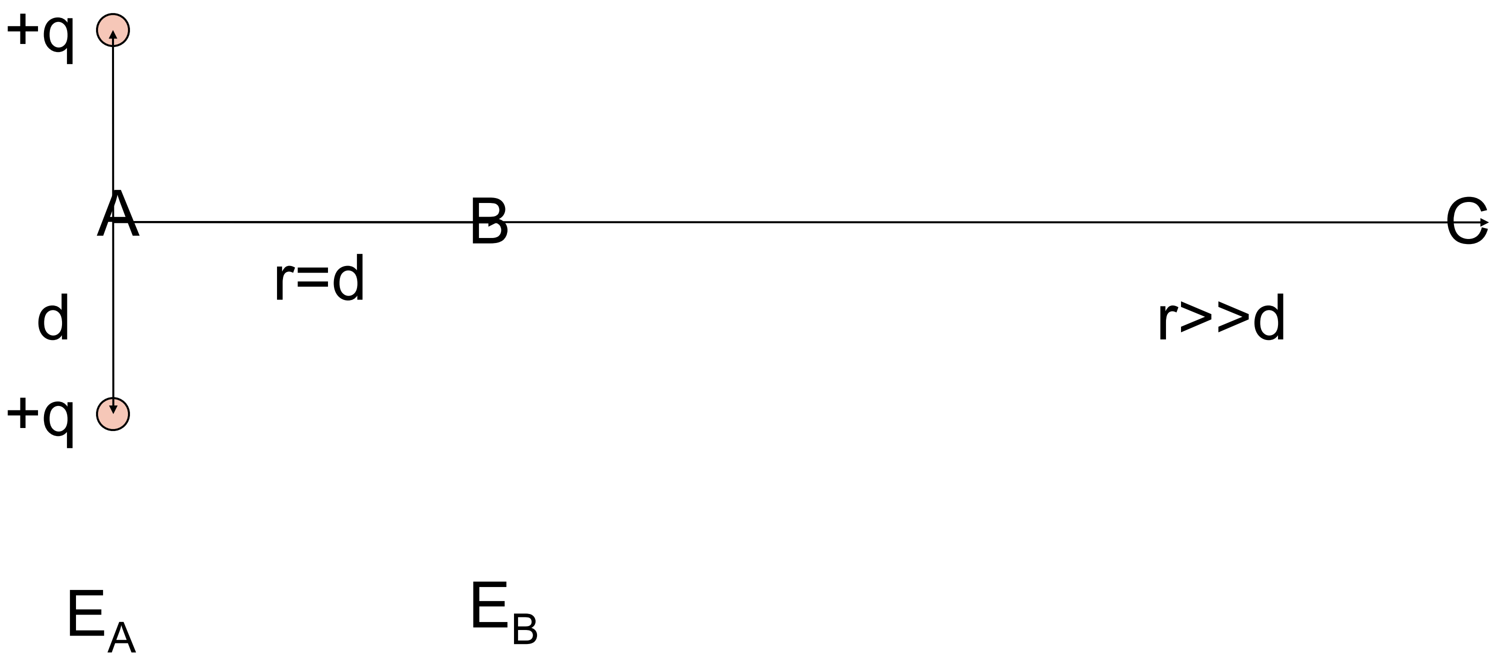


The electric field from an isolated positive charge

The electric field vector **E** is along 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.

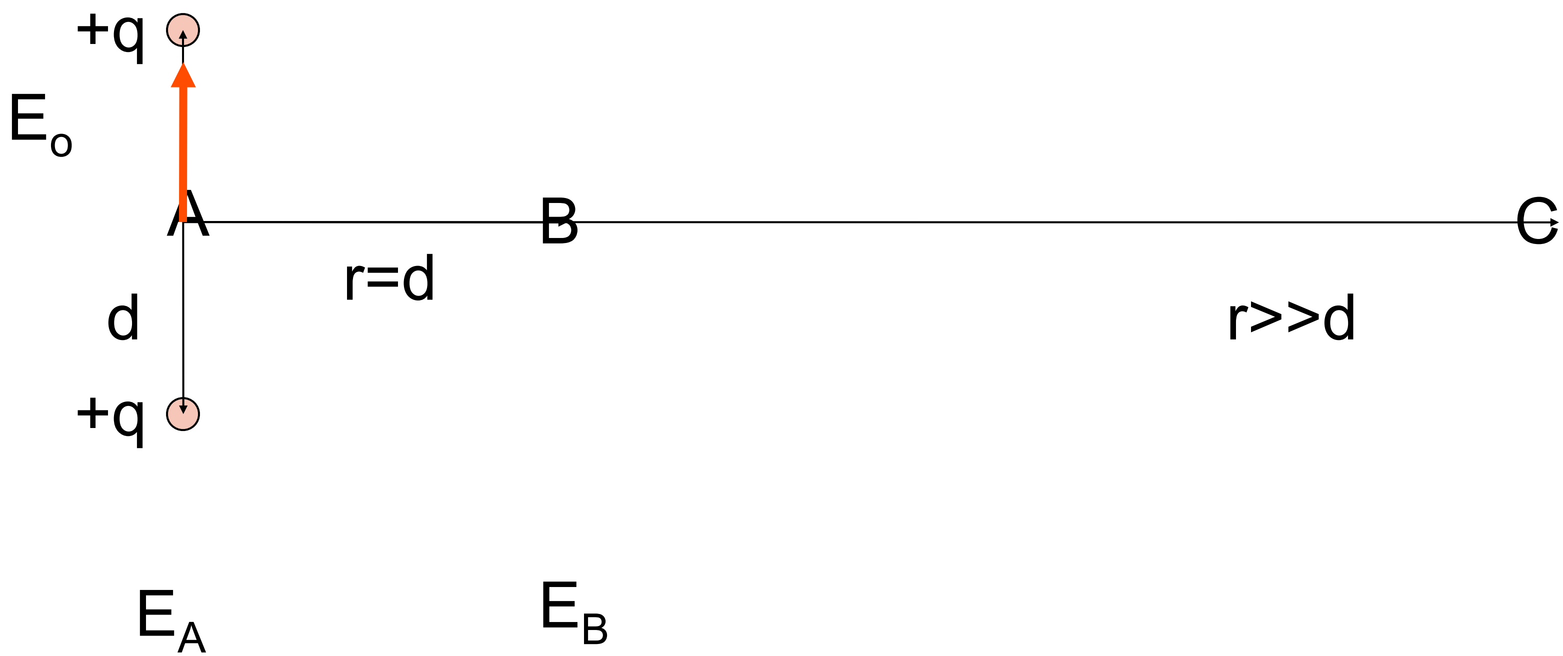
Electric field due to 2 + charges



This charge distribution is not neutral.

Total charge=+2q

Electric field due to 2 + charges



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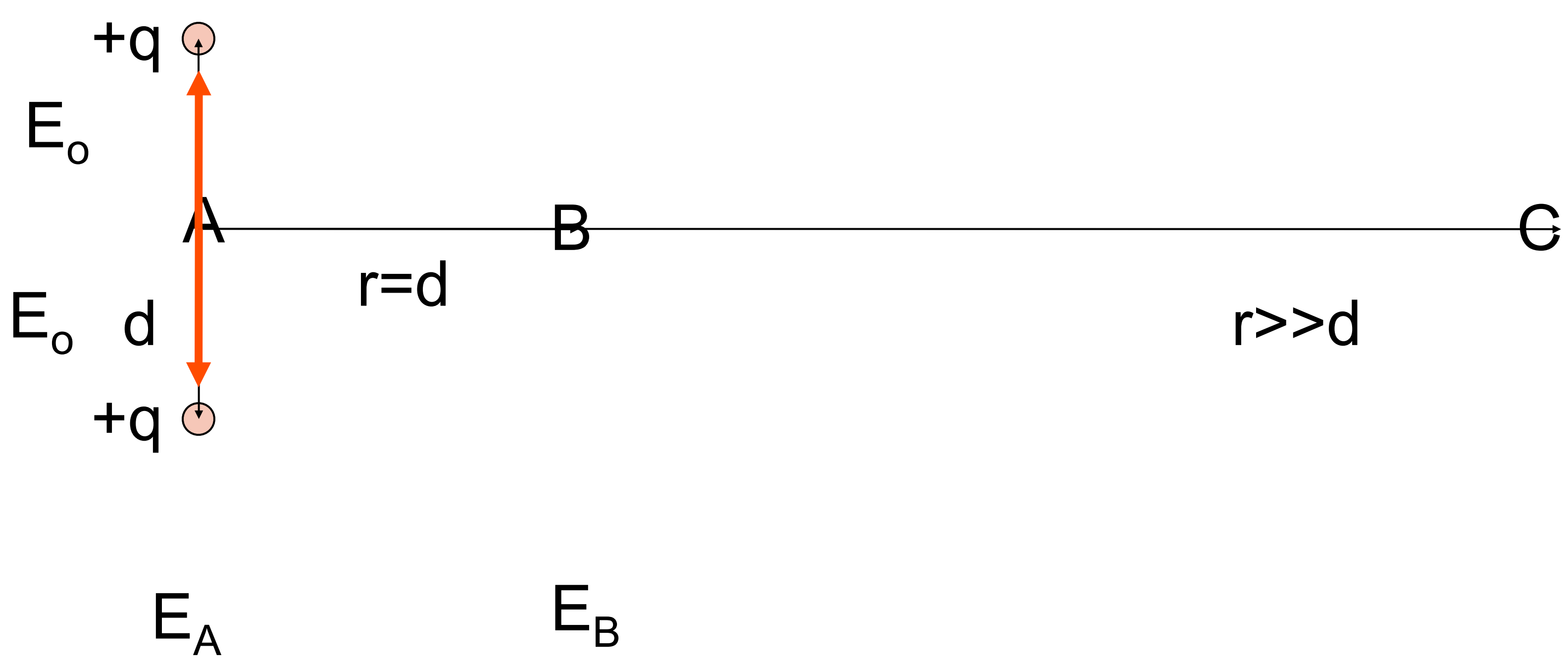

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Electric field due to 2 + charges

E_A E_B

$E_A=0$

This charge distribution is not neutral.

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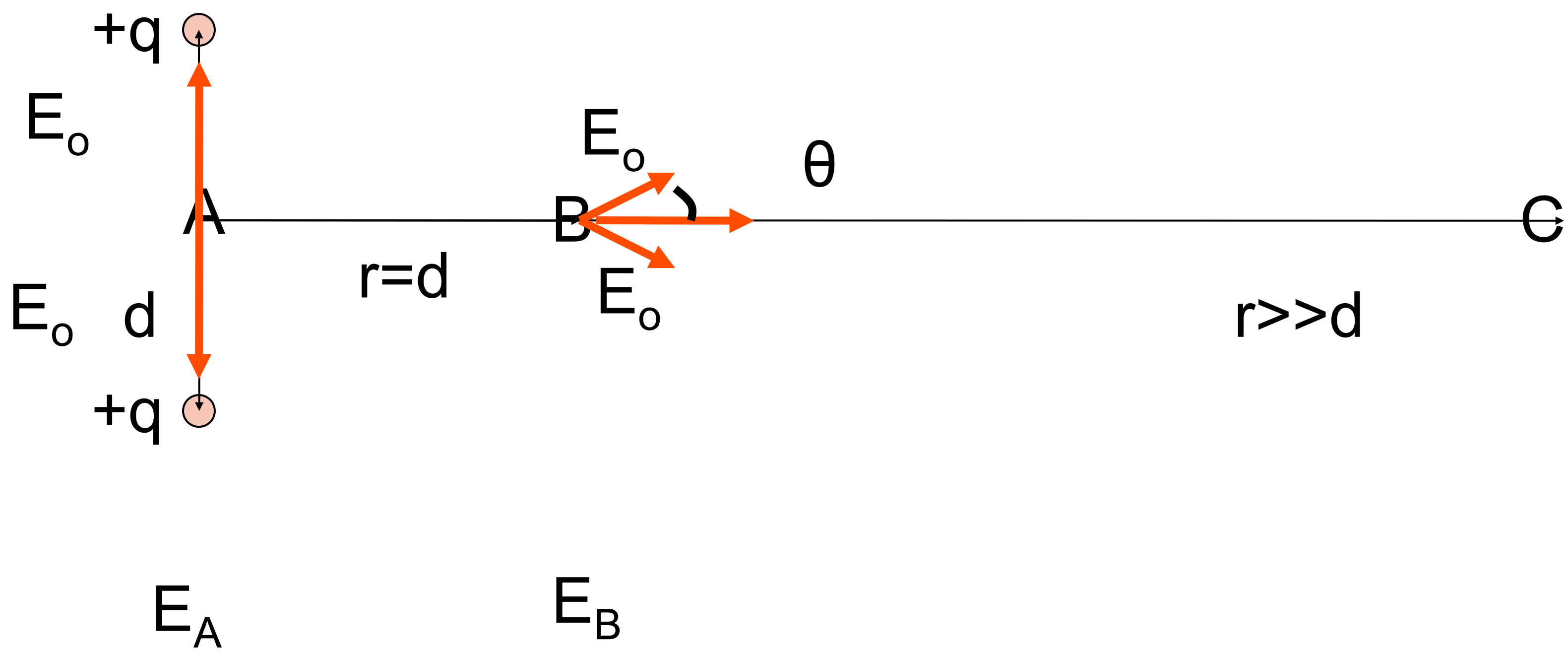
Electric field due to 2 + charges



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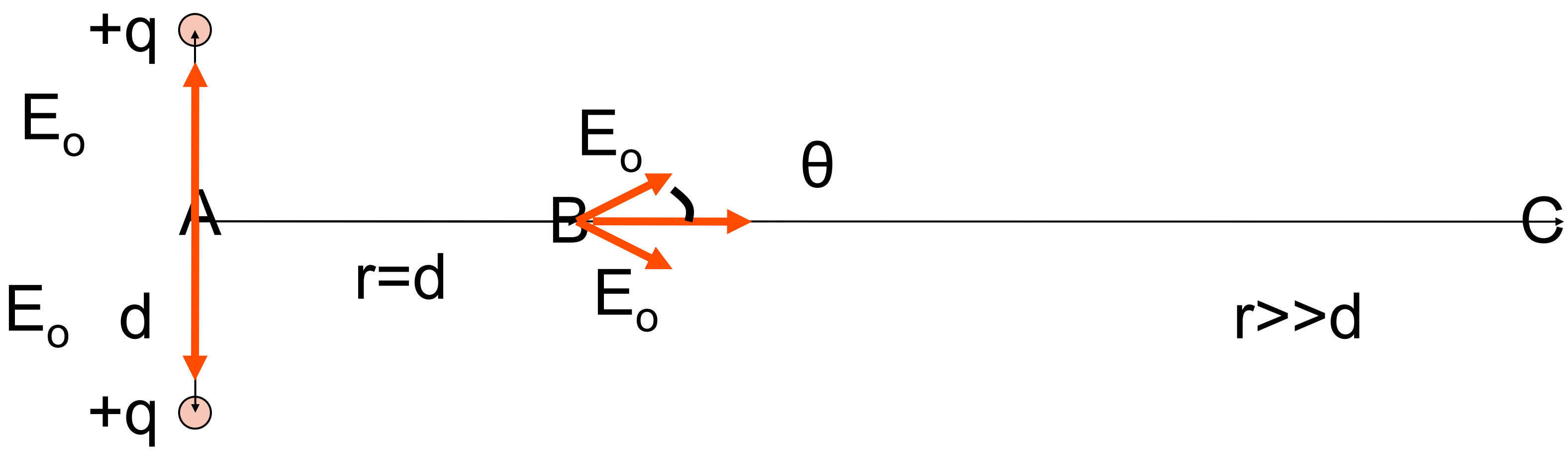

E_A

E_B

$E_A=0$

$$E_B = 2E_o \cos\theta$$

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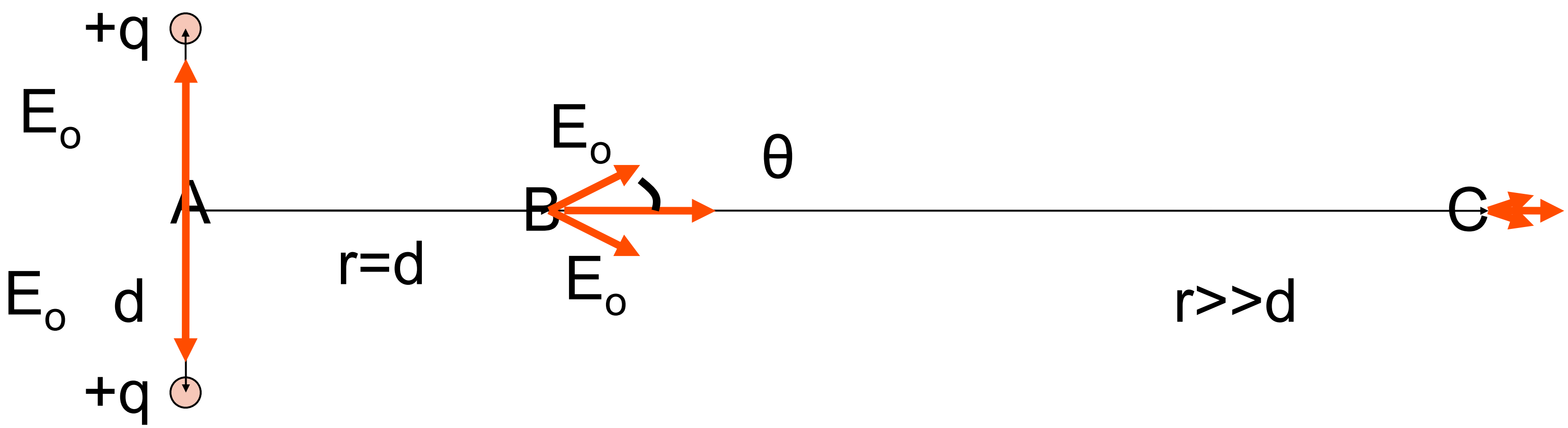
Electric field due to 2 + charges



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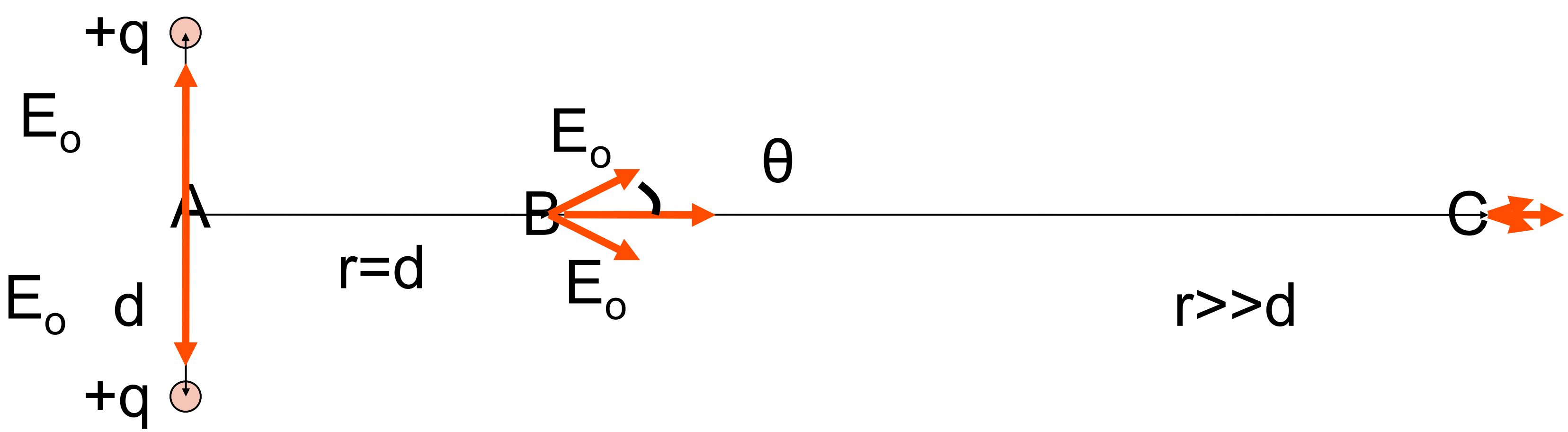

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E_B

$E_A=0$

$E_B = 2E_o \cos\theta$

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

as θ->0

This charge distribution is not neutral.

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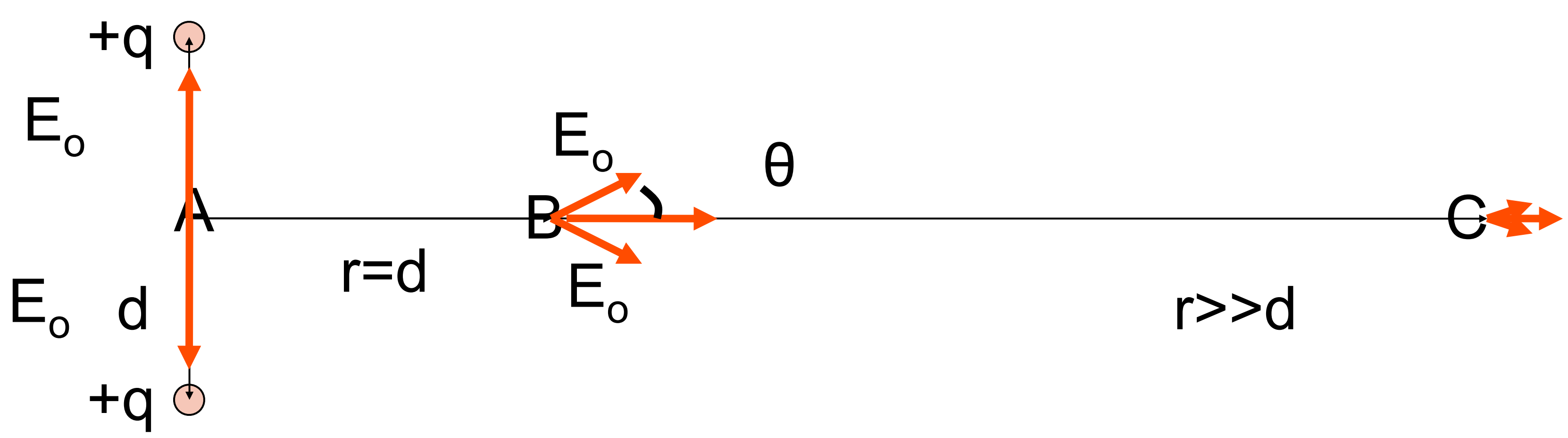
Electric field due to 2 + charges



E_A

$E_A=0$

E_B

$E_B = 2E_o \cos\theta$

This charge distribution is not neutral.

Total charge=+2q

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

as θ->0

looks like a point charge of 2q

Electric field due to a dipole dipole moment $qd=\mu$

What is the total charge of this dipole distribution?

A. +2q

B. 0

C. -2q

Electric field due to a dipole dipole moment $qd=\mu$

Far field

E_A E_B as θ goes to 0

This charge distribution is neutral, but field is not equal to zero!

Electric field due to a dipole dipole moment $qd = \mu$

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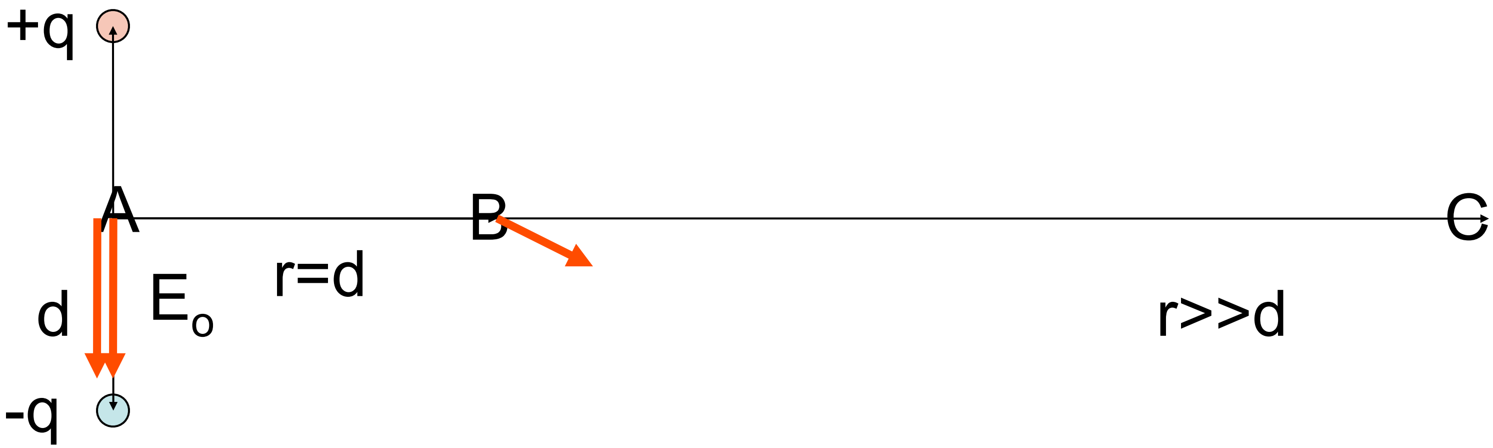

Far field

E_A E_B

as θ goes to 0

$E_A=2E_o$

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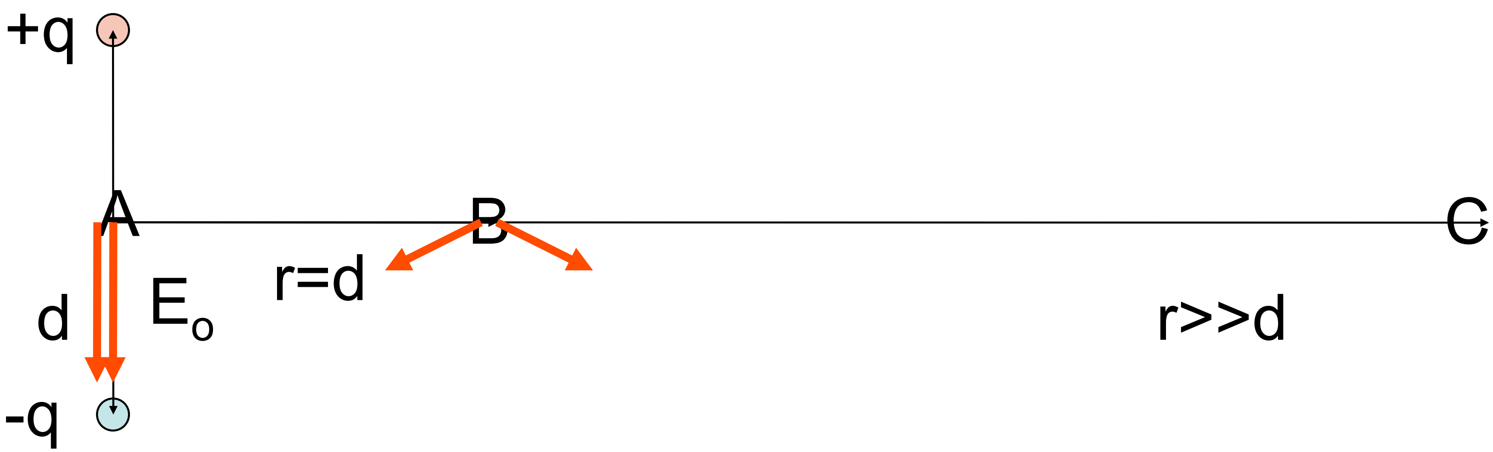
Electric field due to a dipole   dipole moment $qd=\mu$



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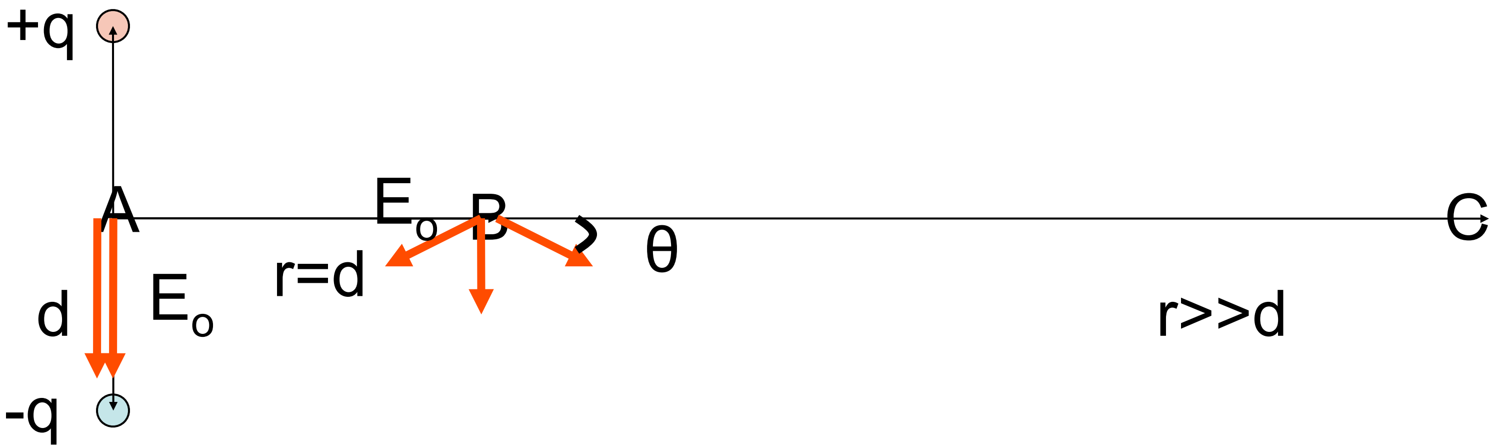

Far field

E_A E_B as θ goes to 0

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

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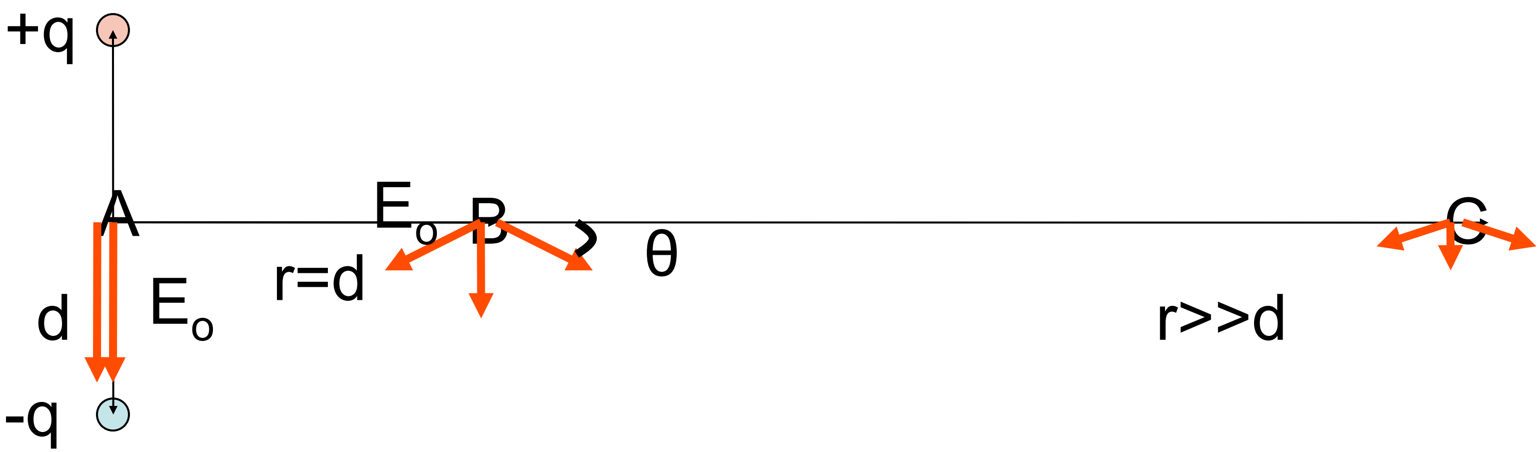

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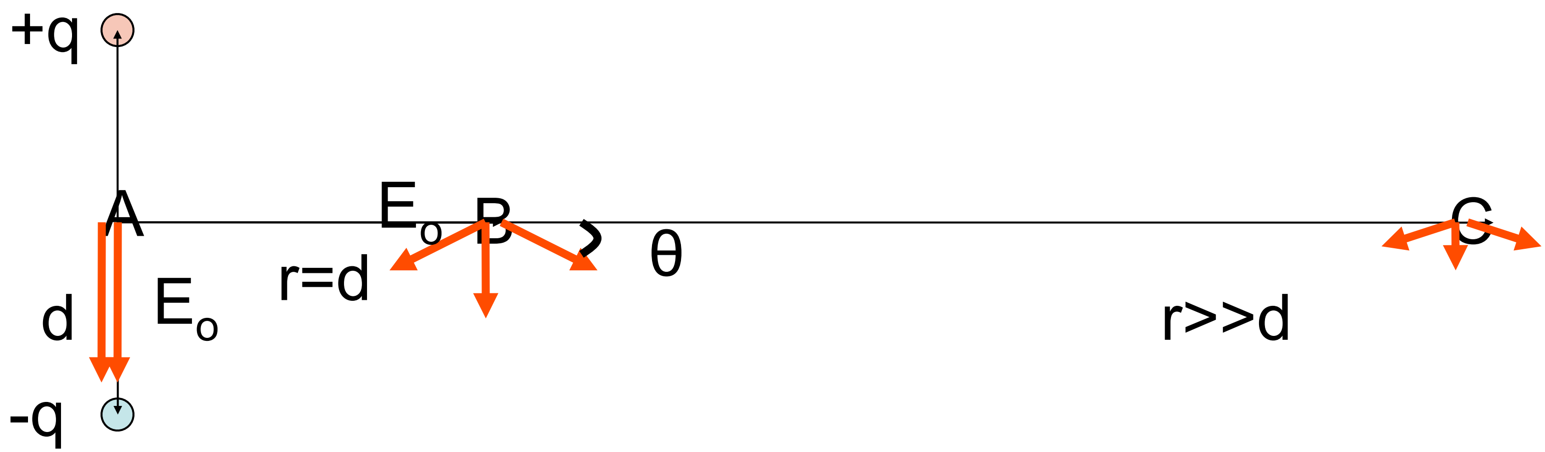


Far field

E_A

E_B

as θ goes to 0

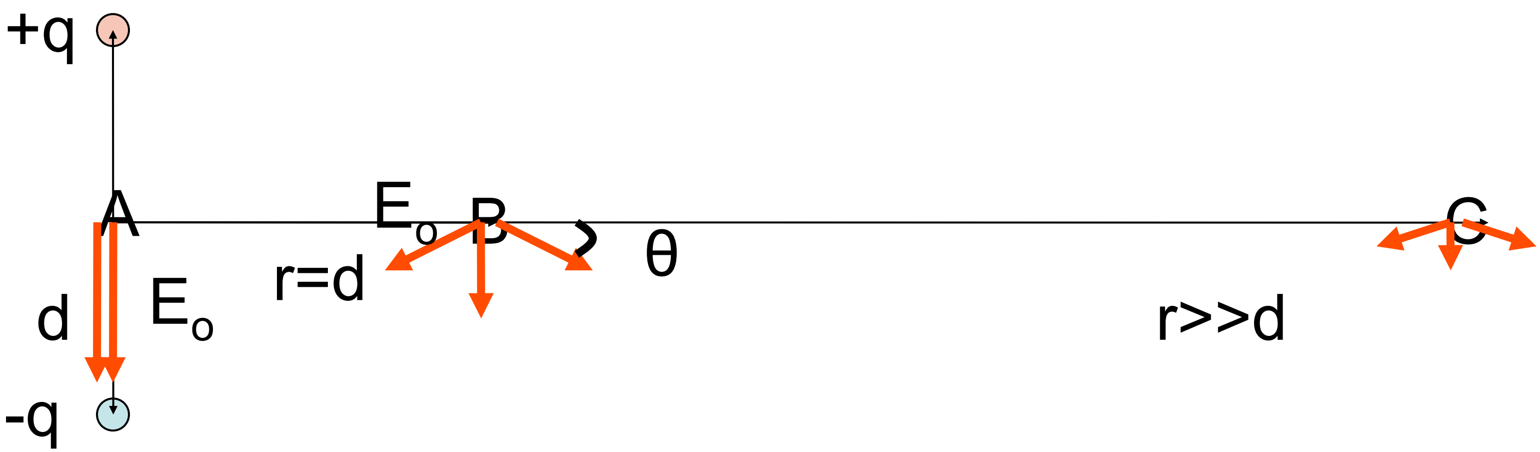
$E_A = 2E_o$

$E_B = 2E_o \sin\theta$

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

This charge distribution is neutral, but field is not equal to zero!

Electric field due to a dipole   dipole moment $qd=\mu$



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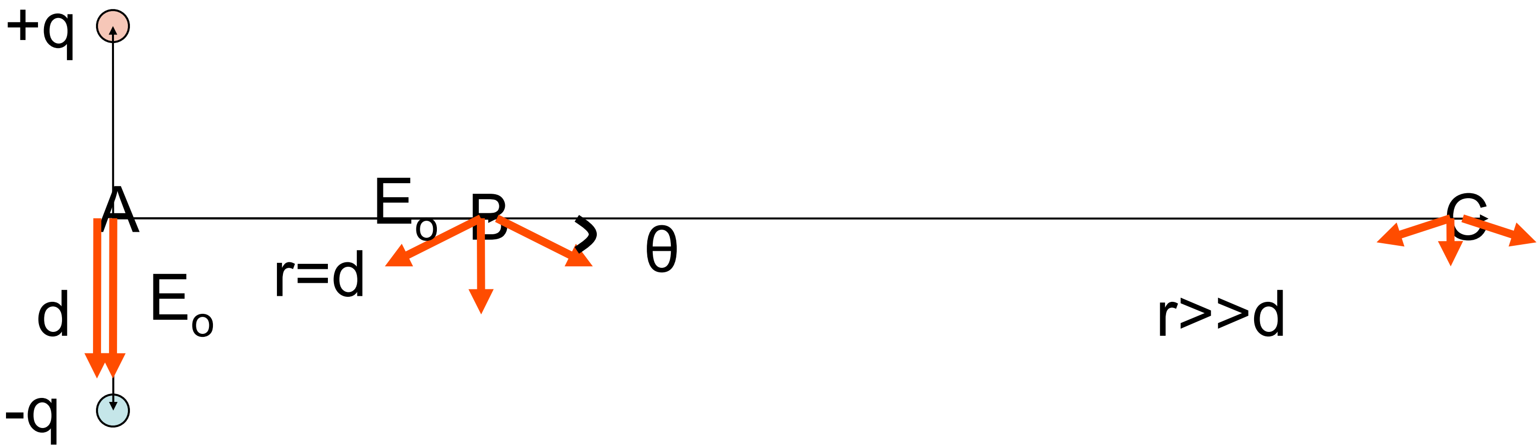

Far field

E_A E_B as θ goes to 0

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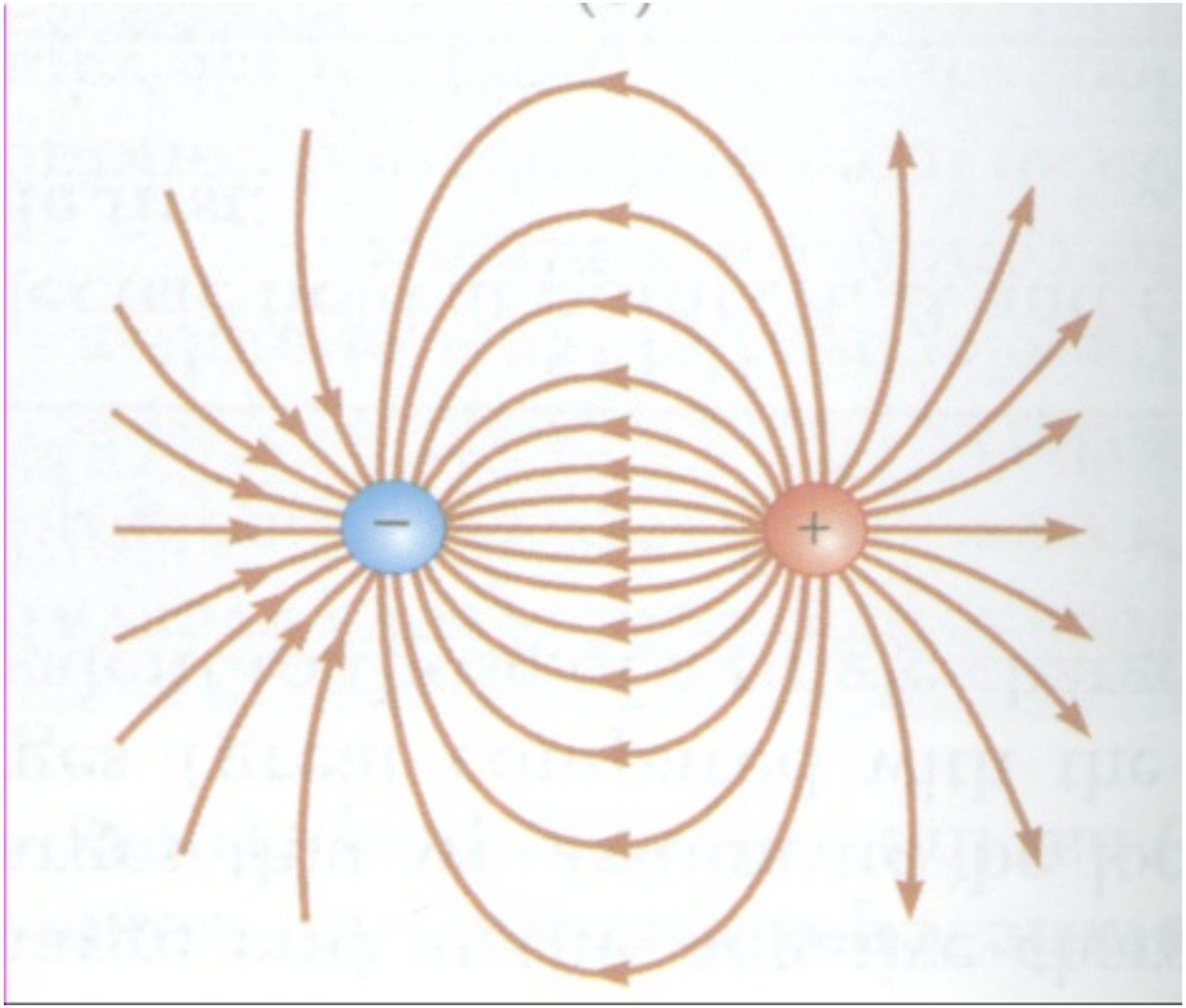
$E_o = \dfrac{k_e q}{r^2}$

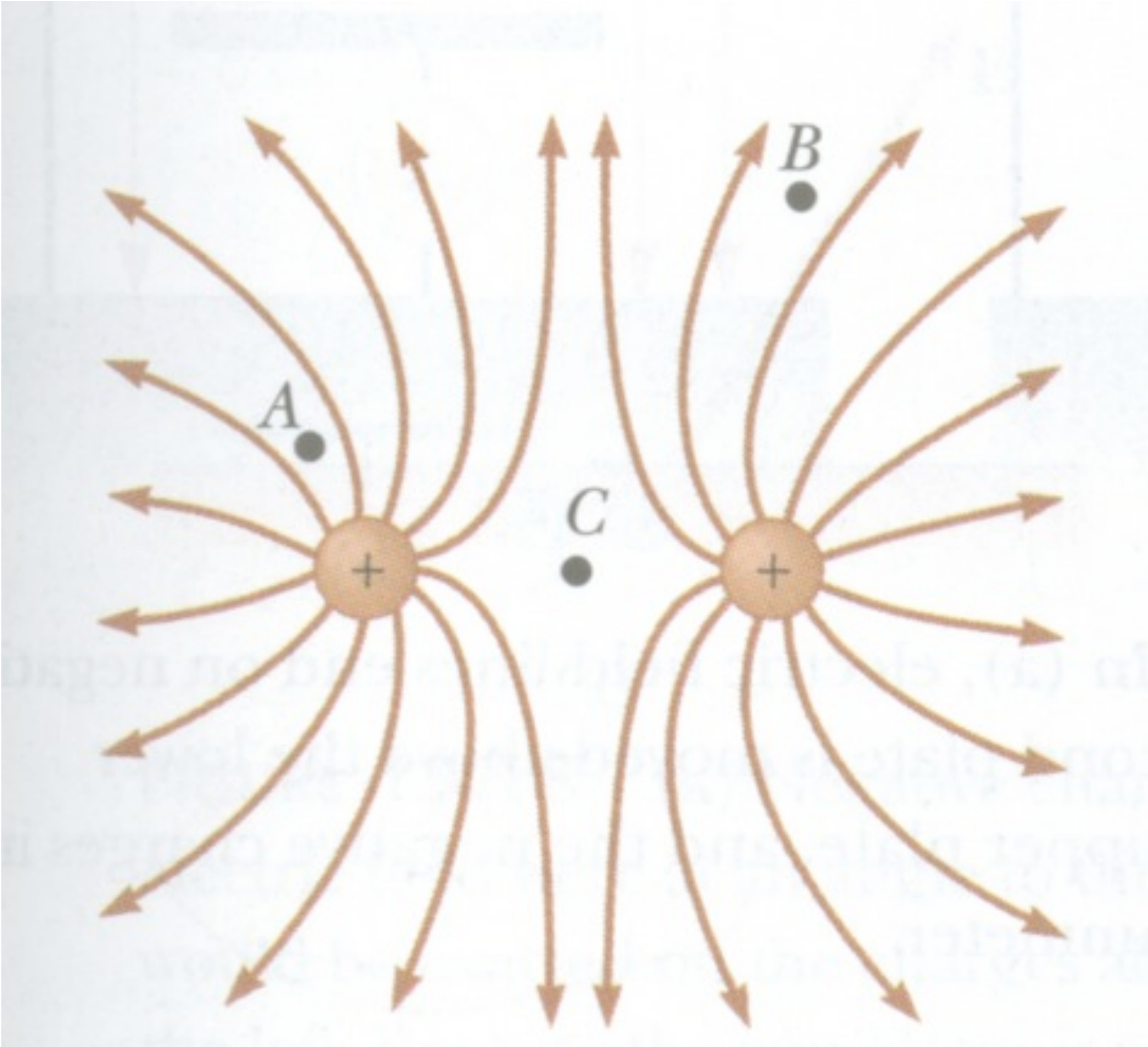
This charge distribution is neutral, but field is not equal to zero!

E falls off as $1/r^3$ $E_c = \dfrac{k_e qd}{r^3} = \dfrac{k_e \mu}{r^3}$

Electric field lines from a dipole +q, -q

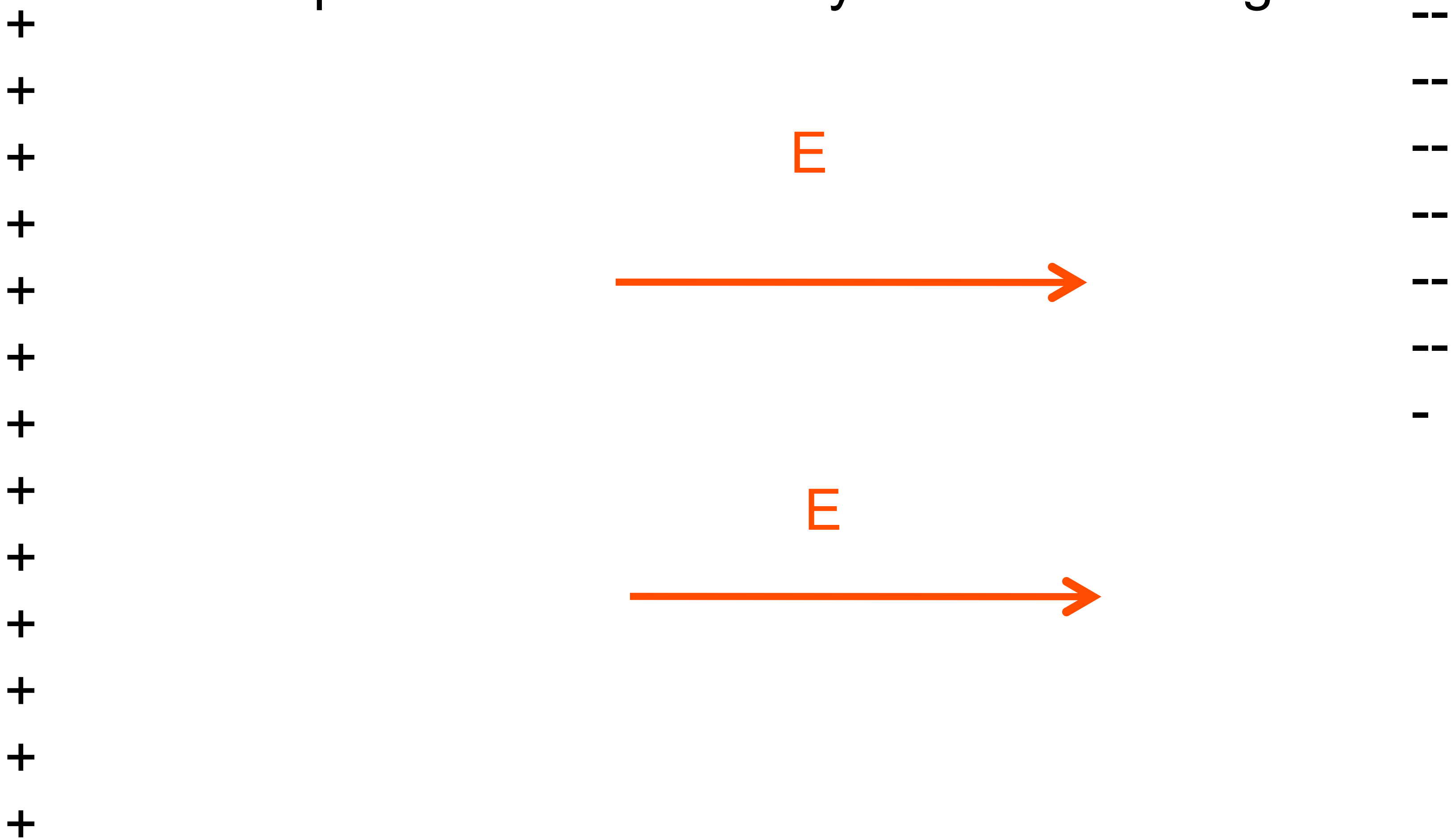


Electric field lines from 2 + q charges



The Electric Field exerts a Force on a Charge

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



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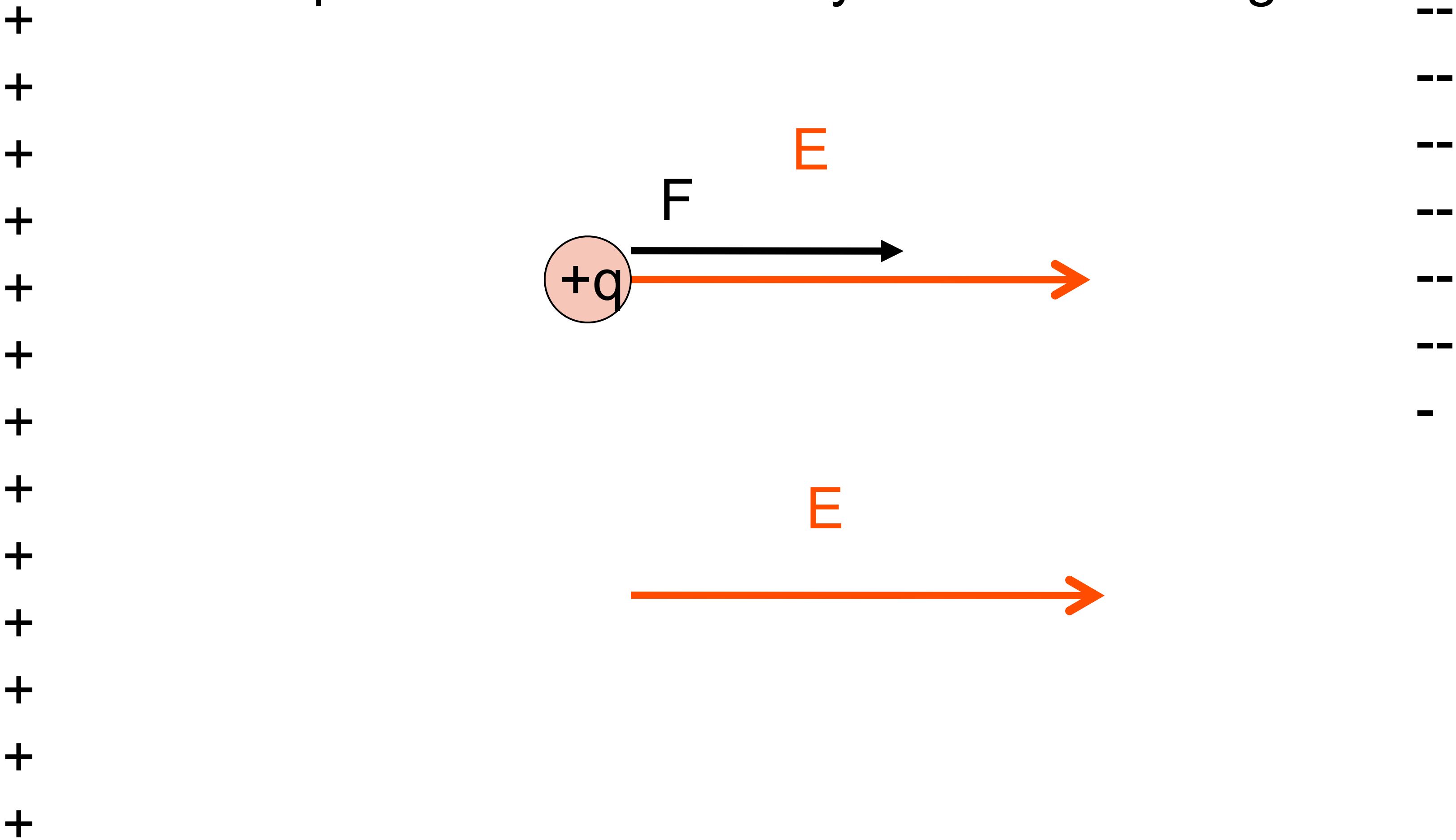
E field in space- due to an array of + and - charge



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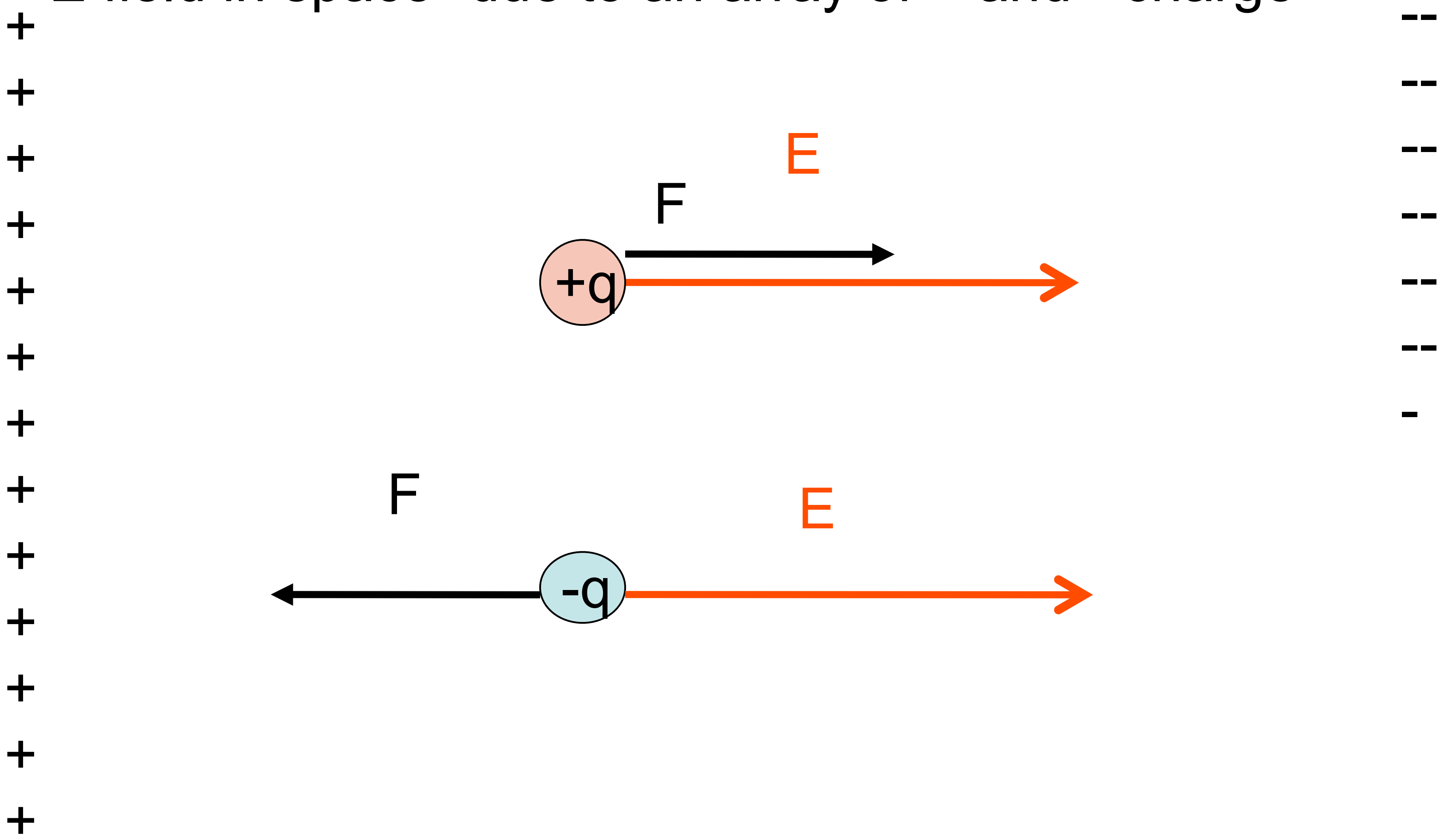

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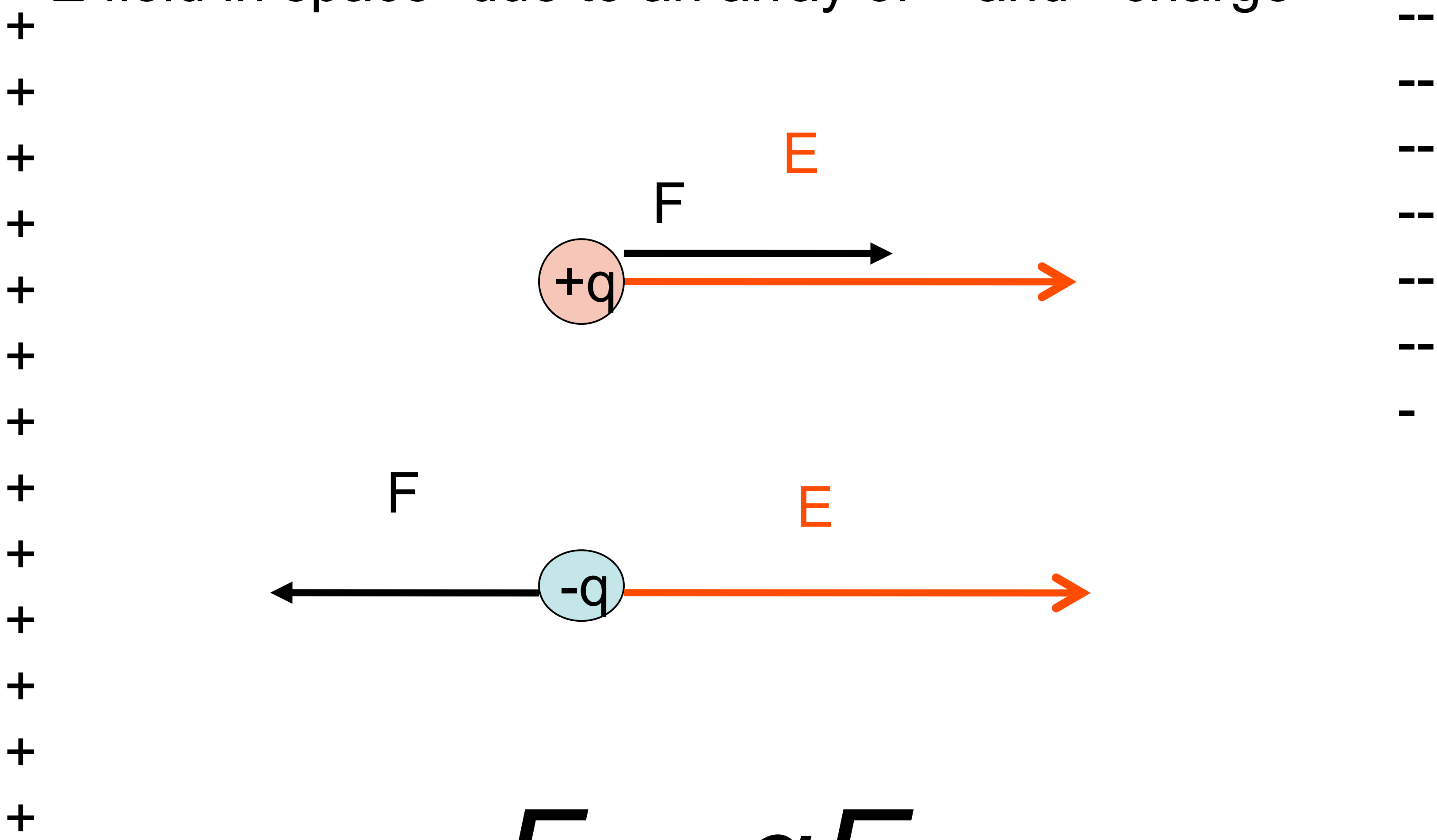
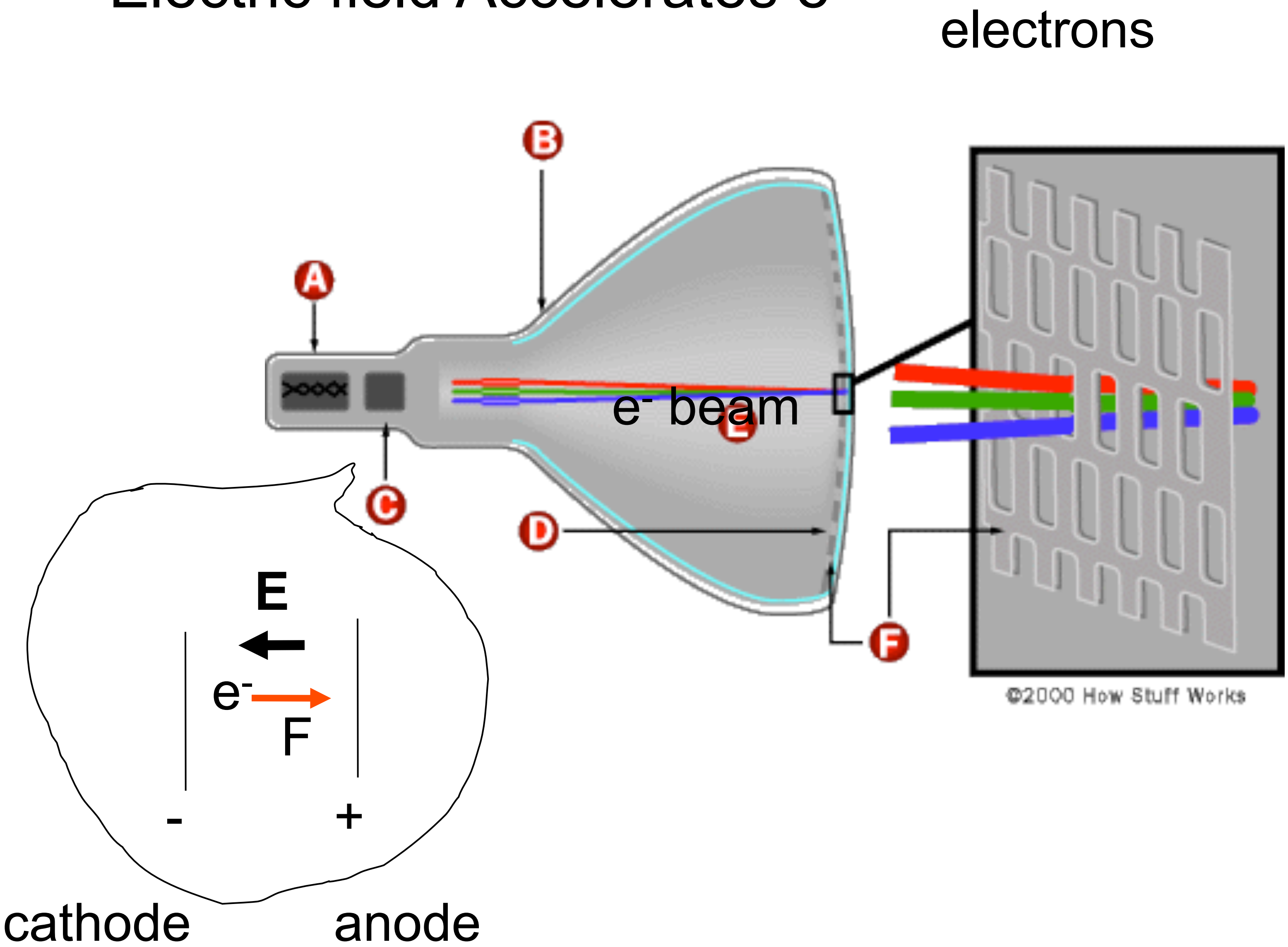
E field in space- due to an array of + and - charge



$$F = qE$$

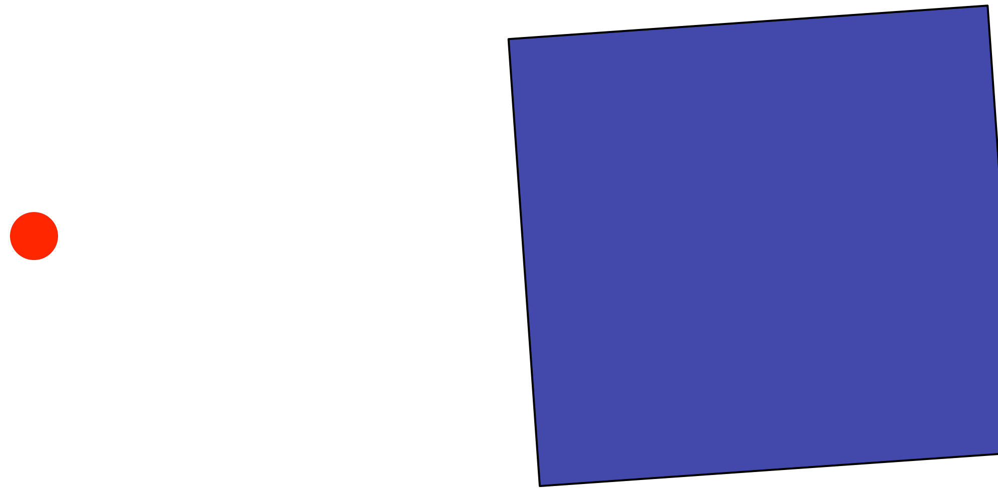
Cathode ray tube

Electric field Accelerates e-



Oscilloscope (ok, or a non Flat Panel TV)

J.J.Thomson
N.P. physics 1906



1. Shoot in an electron with battery, E field off

Oscilloscope (ok, or a non Flat Panel TV)

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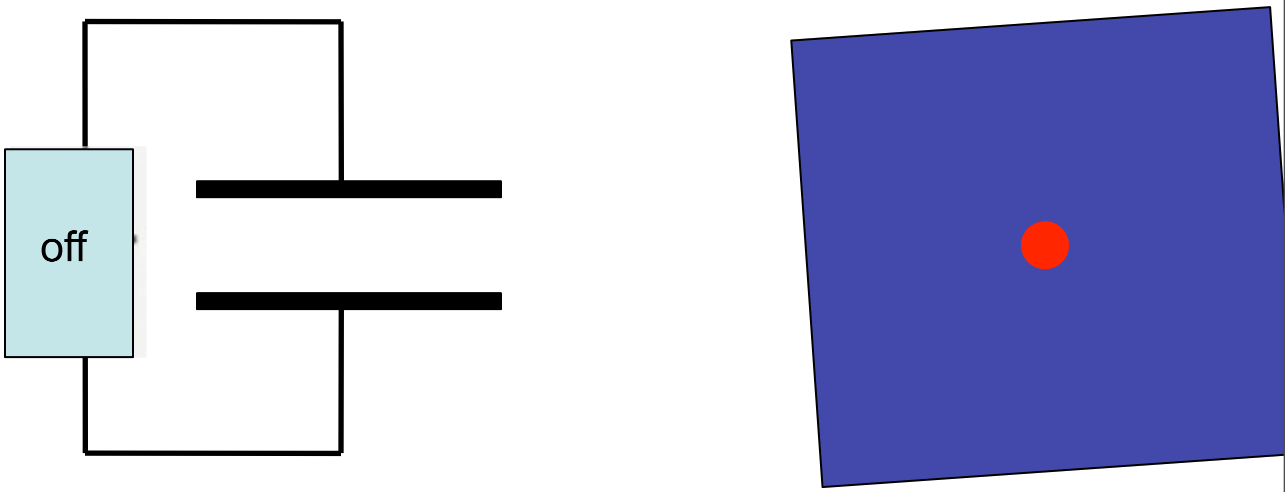

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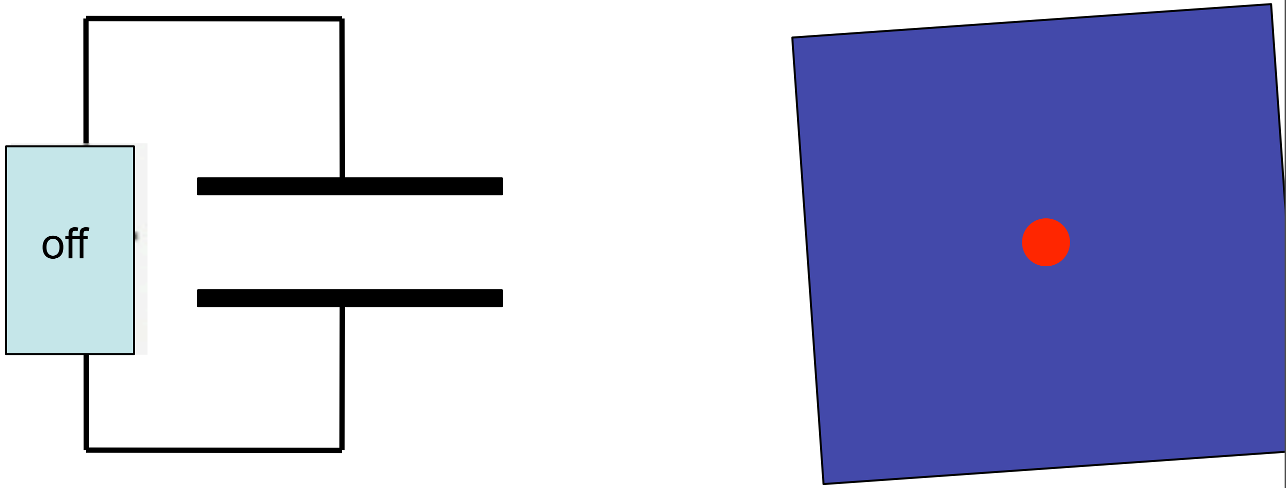

1. Shoot in an electron with battery, E field off
2. Then turn on field and shoot another electron

Oscilloscope (ok, or a non Flat Panel TV)

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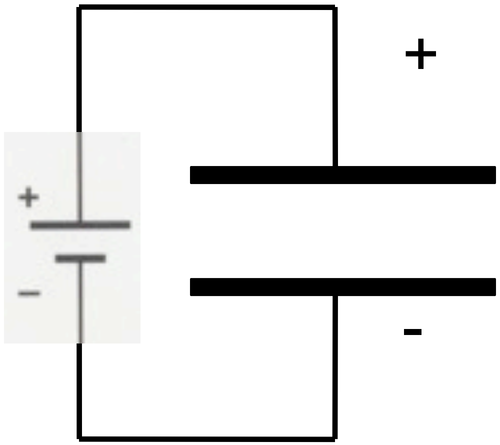

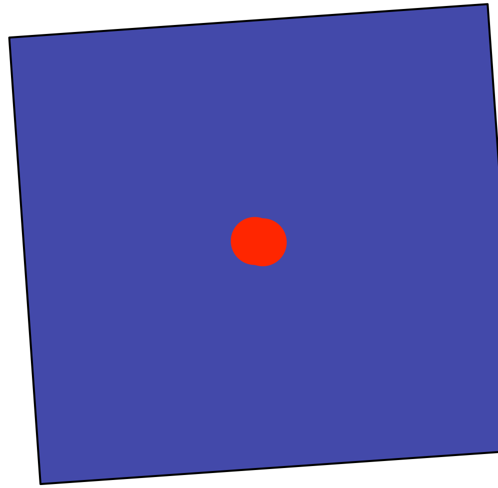

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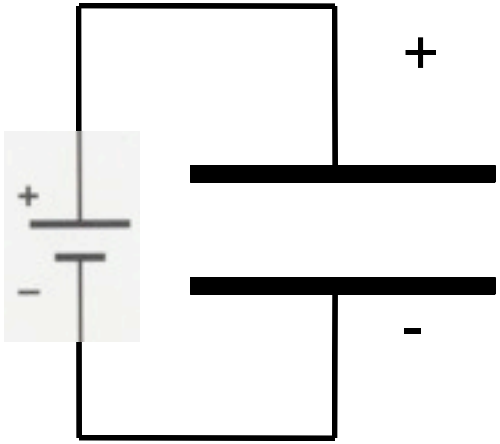

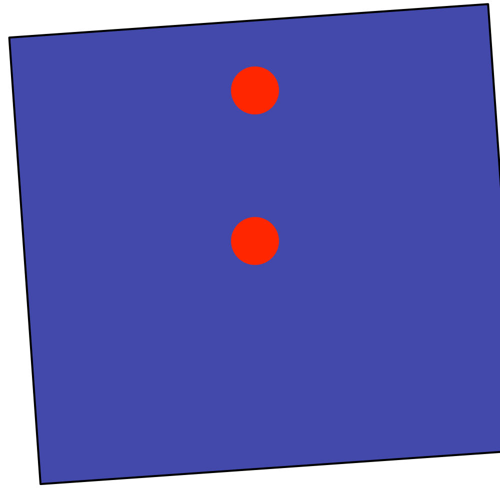

1. Shoot in an electron with battery, E field off
2. Then turn on field and shoot another electron

An electron moving horizontally at *constant velocity* flies into a *constant vertical electric field* of 1000 N/C for a distance of 3 cm. What happens to the electron in the field region?

- A. It continues to move with constant velocity
- B. It moves in quantum steps
- C. it moves with constant acceleration
- D. it stops moving

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.

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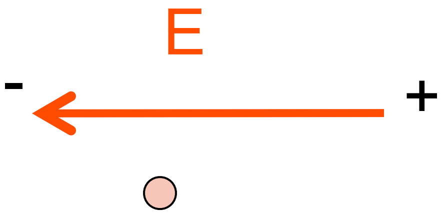

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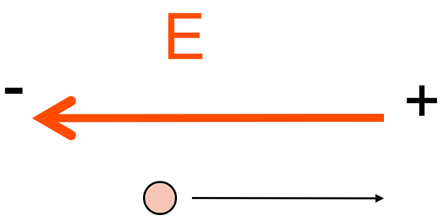

F=ma

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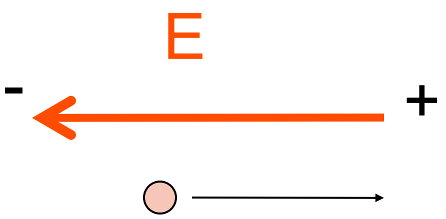

$$F = qE = 1.6x10^{-19}(1000) = 1.6x10^{-16}N$$

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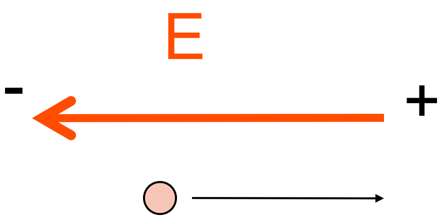

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F=ma

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

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

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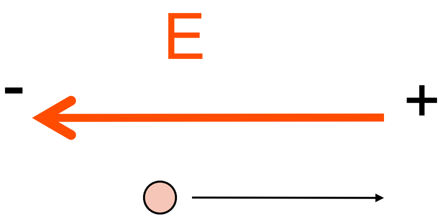


$$F = qE = 1.6x10^{-19}(1000) = 1.6x10^{-16}N$$

F=ma

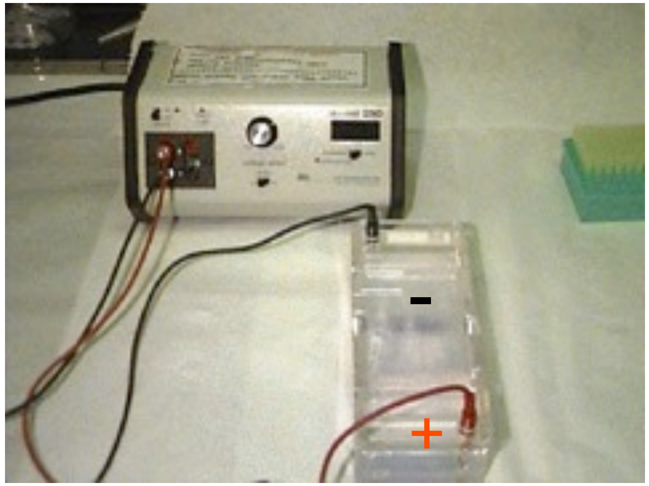
$$a = \frac{F}{m}$$

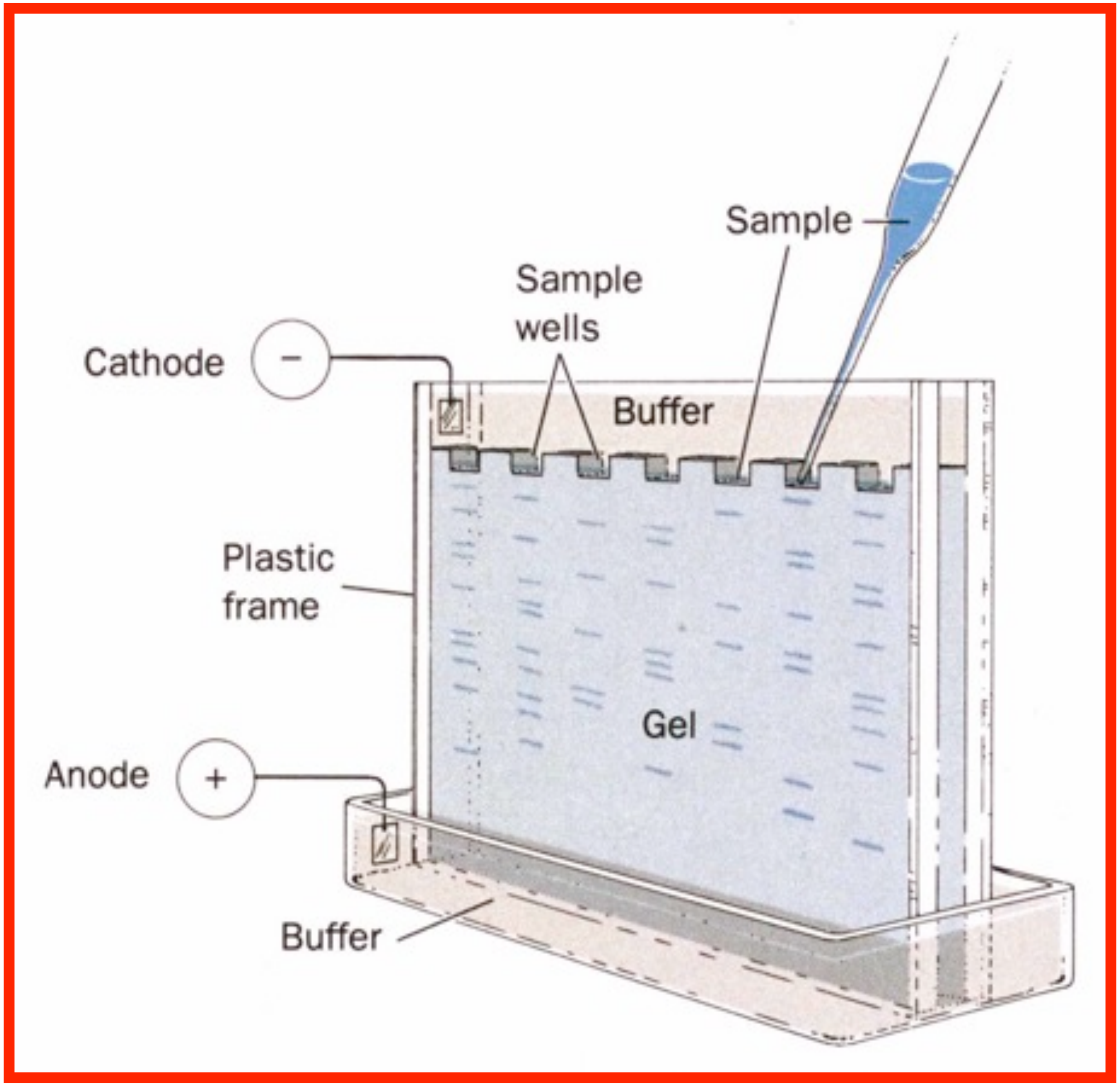
$$v^2 = v_o^2 + 2ax$$

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

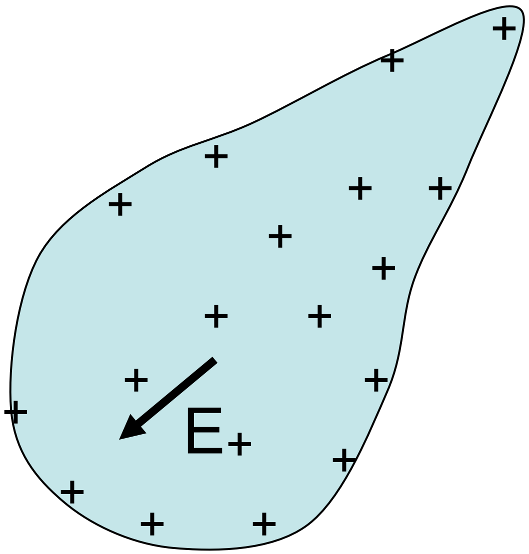
$$v = 3.3x10^6 m/s$$

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

15.6 Conductors in electrostatic equilibrium



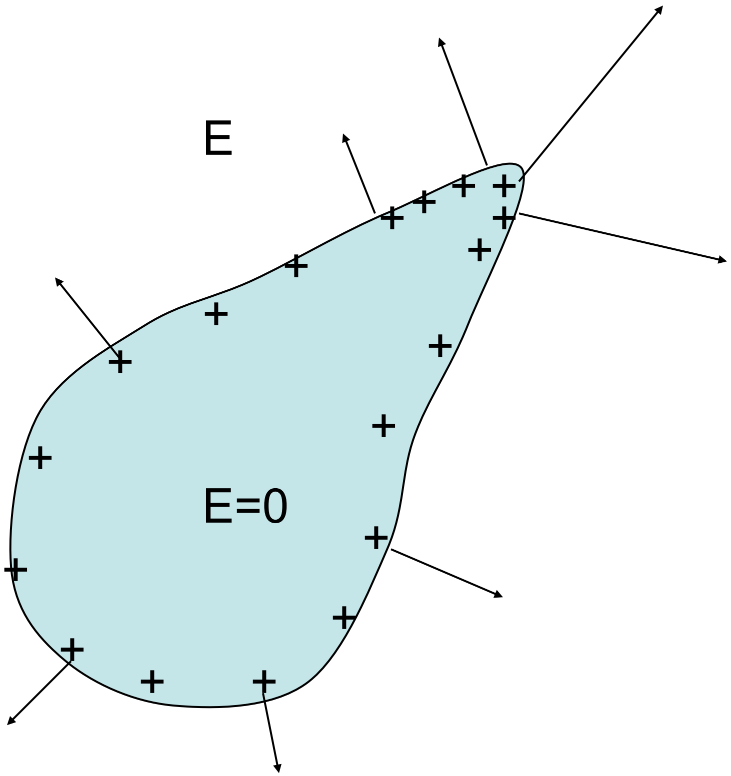
initial state
non-equilibrium

Like Charges Repel

Charges can move freely in a Conductor

At Equilibrium – the charges are not moving

15.6 Conductors in electrostatic equilibrium



At Equilibrium

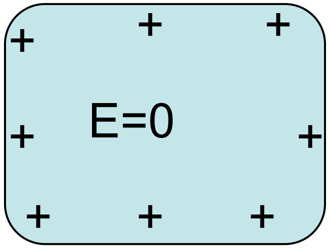
Charge is on surface (no charge inside the conductor)

Electric field is zero inside the conductor

Electric field is perpendicular to surface

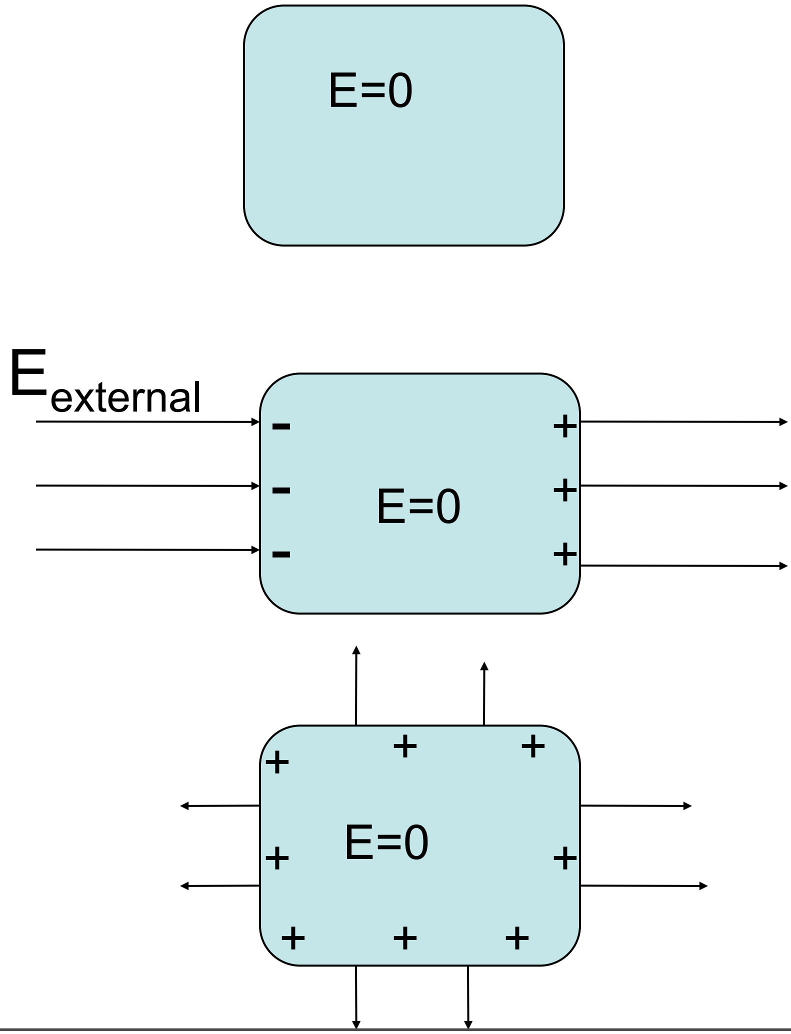
Charge accumulates at sharp points (small radius of curvature)

Excess charge is on the surface



Excess charge moves to the surface due to repulsion. They move as far apart as is possible.

E field is zero in the conductor



If E≠0, then mobile charges would move and not be in equilibrium. When motion stops E=0.

This is true in an external E field or a net charge

PHYSICS 1B – Fall 2009

Electricity & Magnetism

October 7, 2009

Course Week 2

Professor Brian Keating

SERF Building. Room 333

UCSD UCSD

Info

- HW Solutions for CH 15 on Web after class on Wednesday

1 page, front and back Notes Allowed.

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…but not formulae…☹

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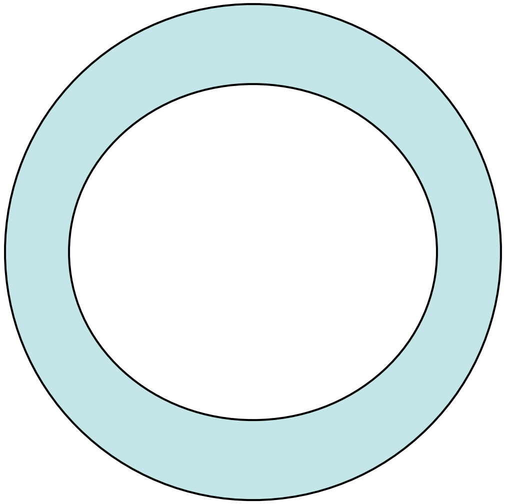
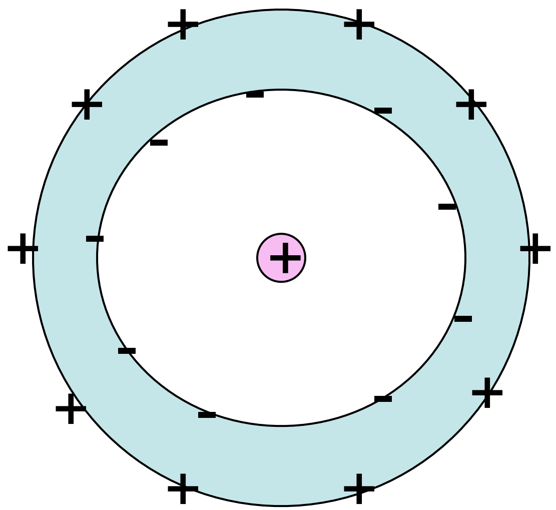
Example – spherical metal shell



Example – spherical metal shell

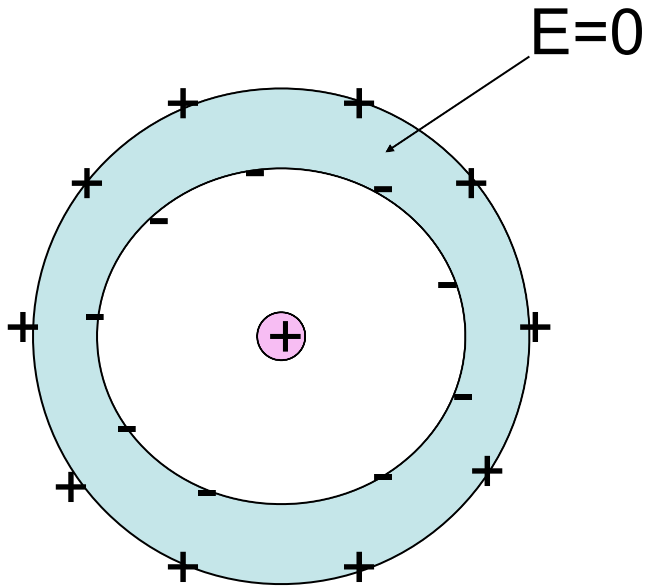


+q placed at center

- charges accumulate inside

+ charges accumulate outside

Example – spherical metal shell



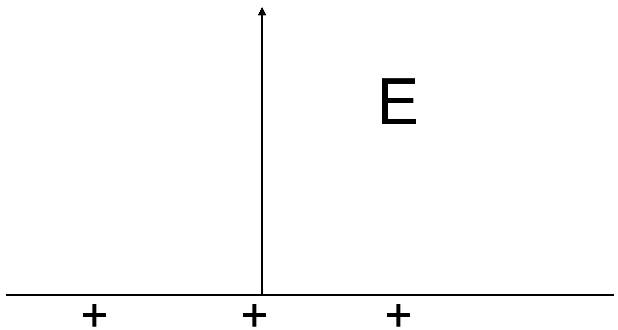
+q placed at center

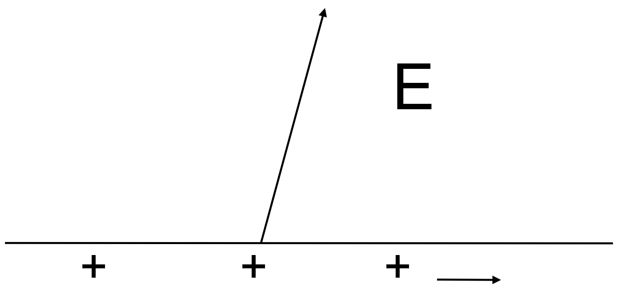
- charges accumulate inside

+ charges accumulate outside

E =0 in the metal

Electric field outside is perpendicular to the surface

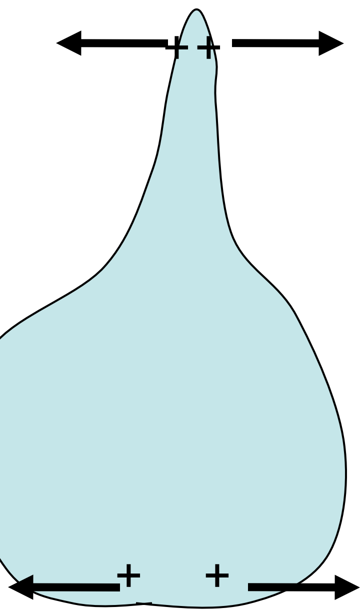




Component of E $\perp$ to the surface =0

If not, charges would move

Charge accumulates at smaller radius of curvature

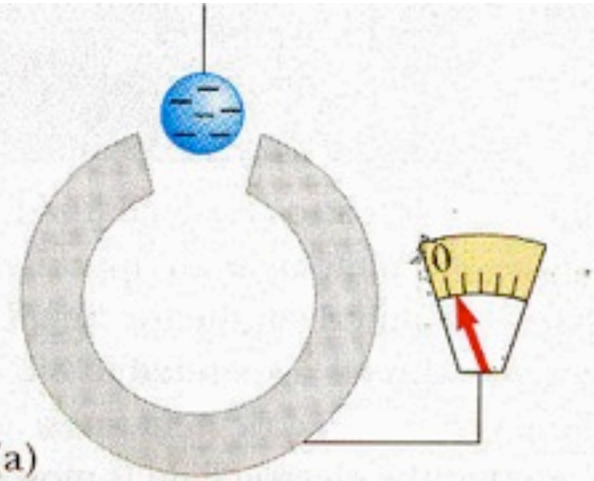


$F_{\perp}$ to surface is less.

Therefore the charges can be closer together

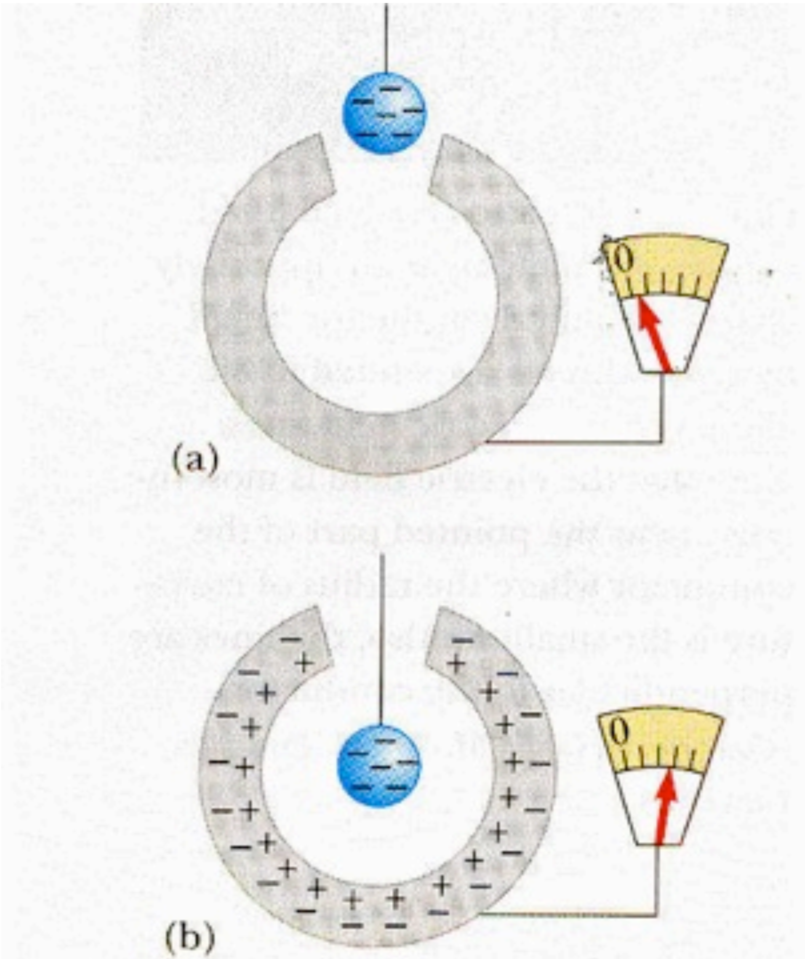
Charge moves to the outer surface of the conductor

(b)

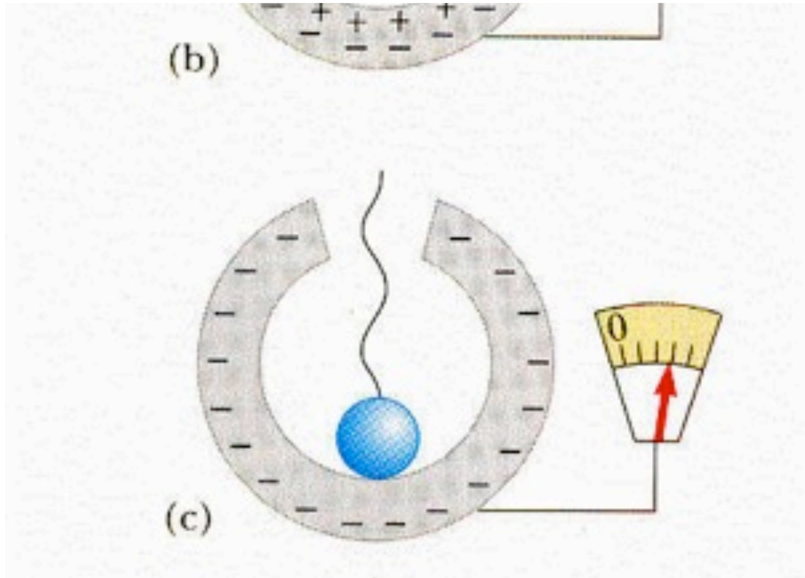


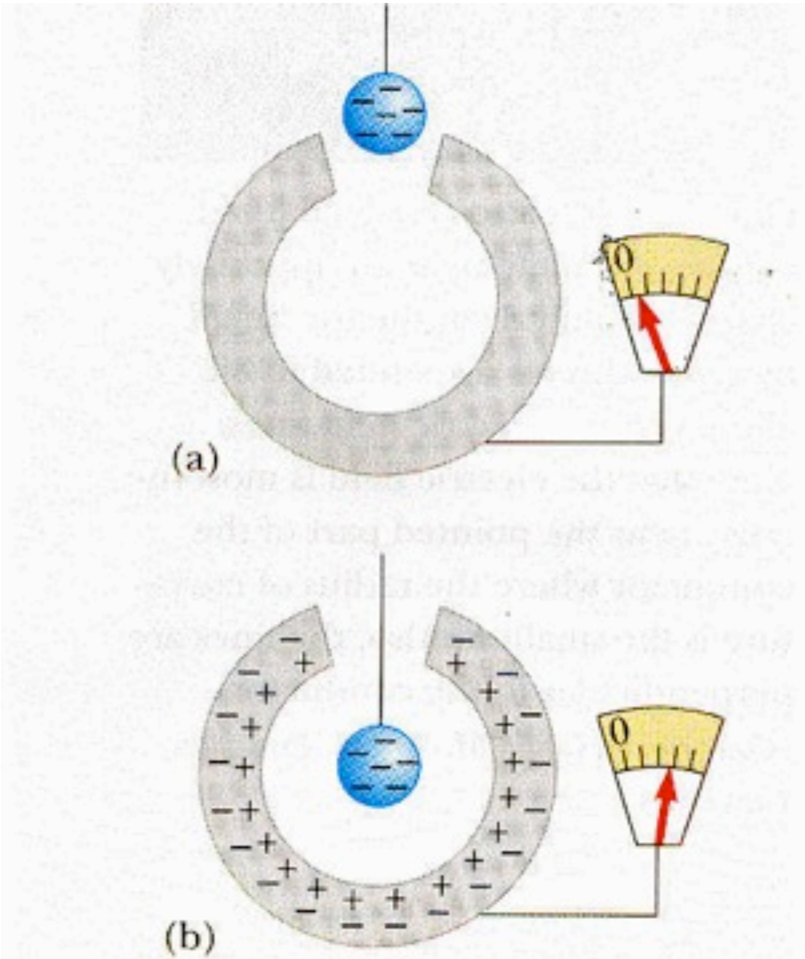
(a)

Charge moves to the outer surface of the conductor

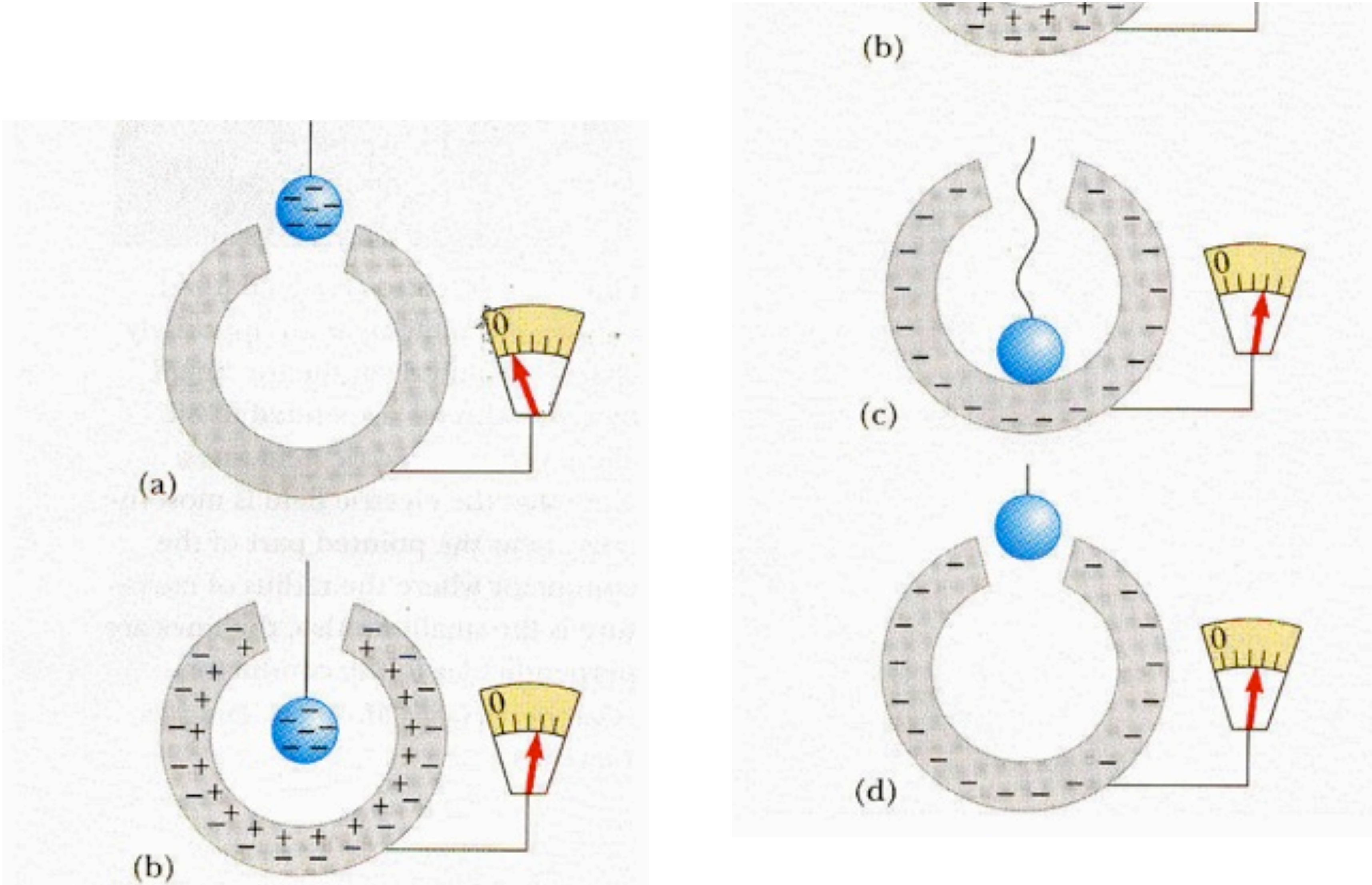


Charge moves to the outer surface of the conductor





Charge moves to the outer surface of the conductor



Charging – Van de Graaf

Spark- charge conduction due to ionization of atoms.

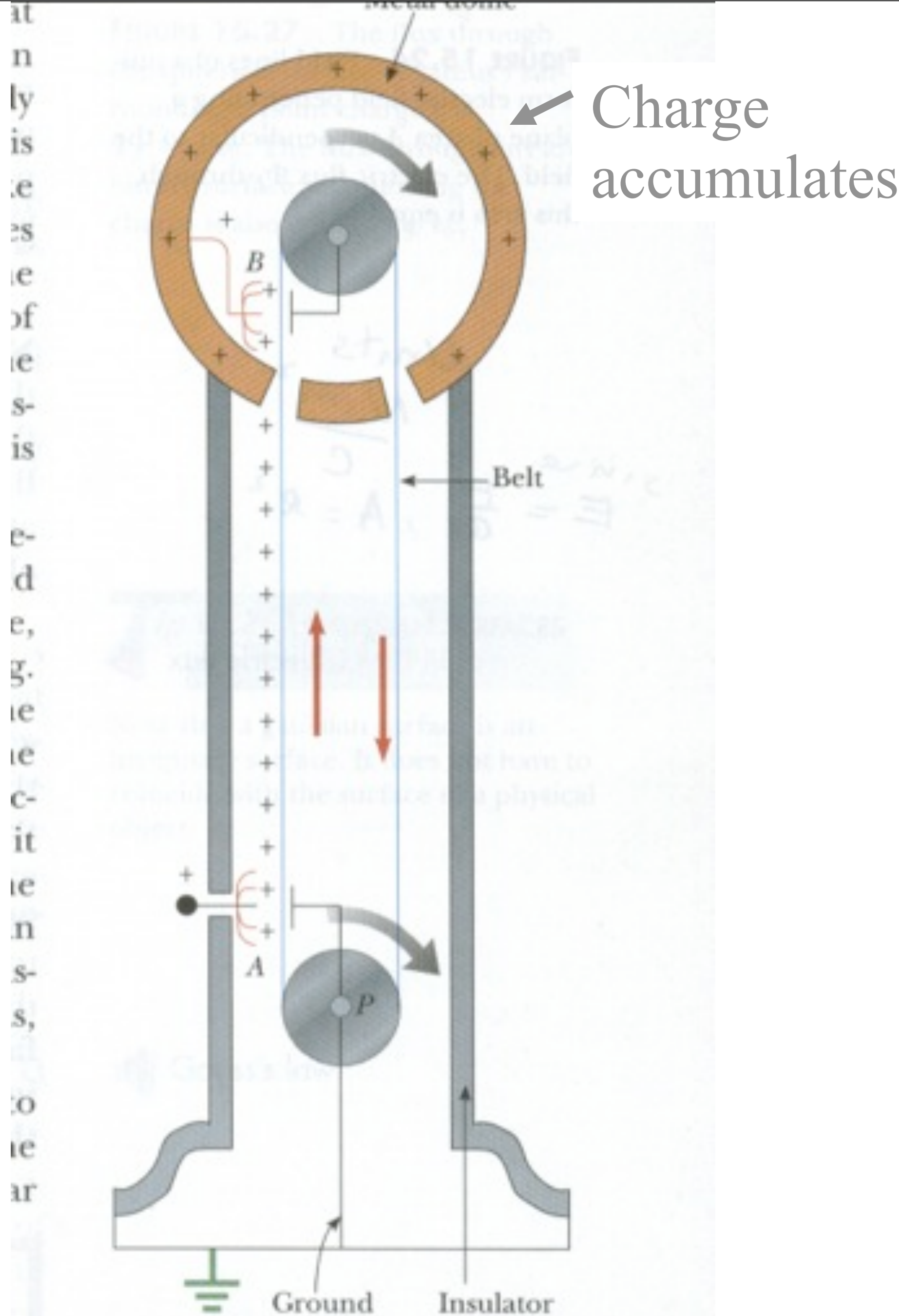
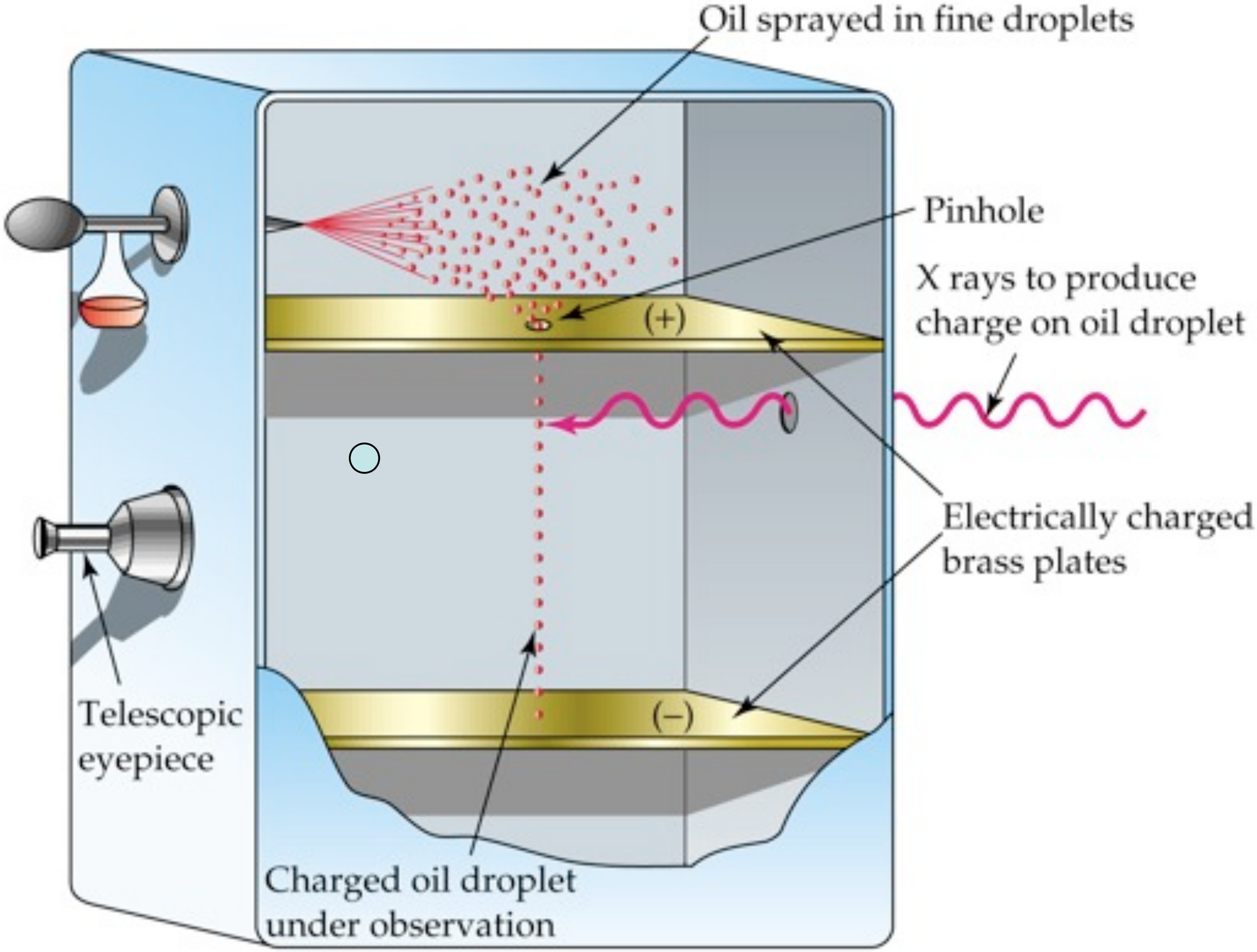


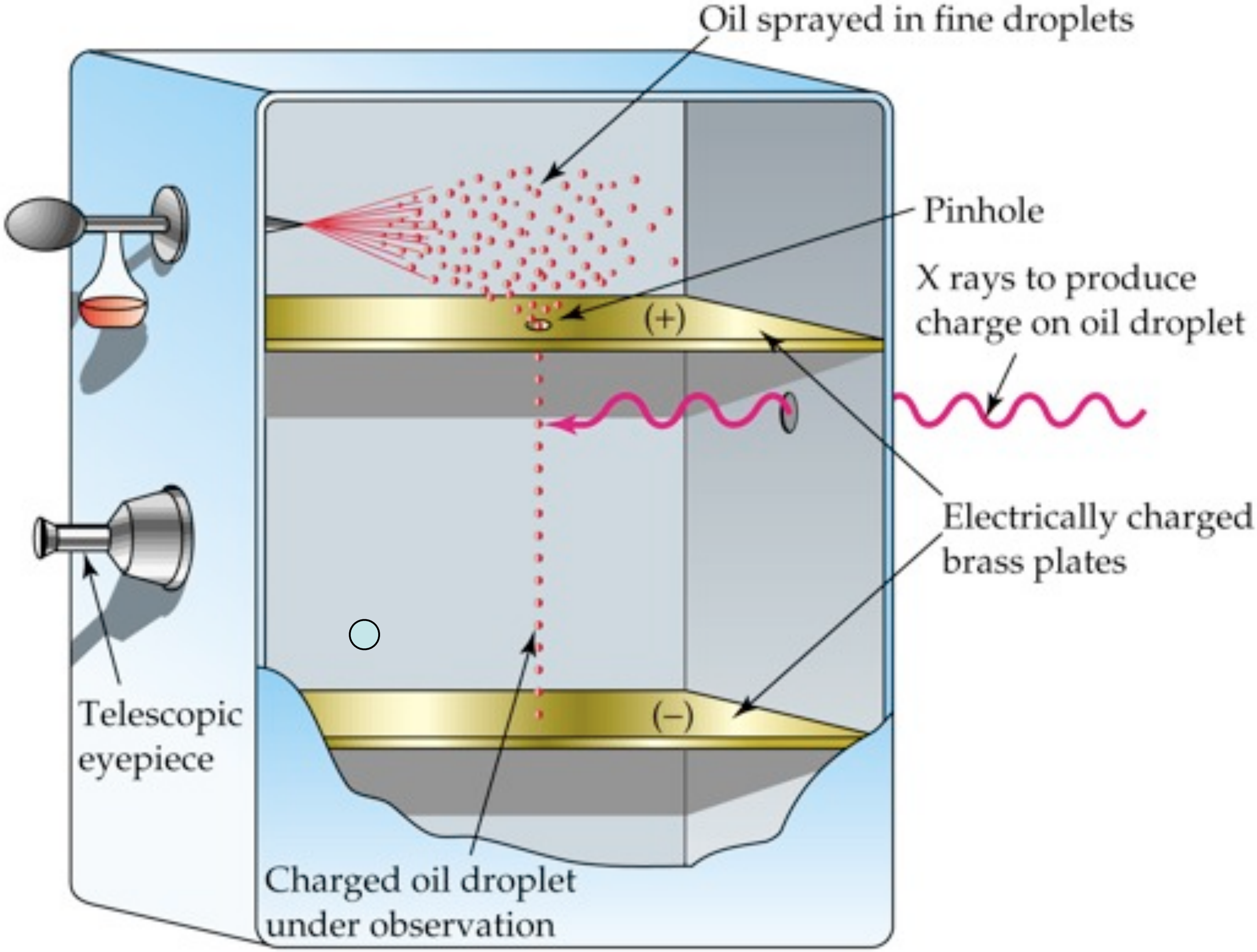
FIGURE 15.23 A diagram of a Van de Graaff generator. Charge is trans-

Milliken Oil drop experiment



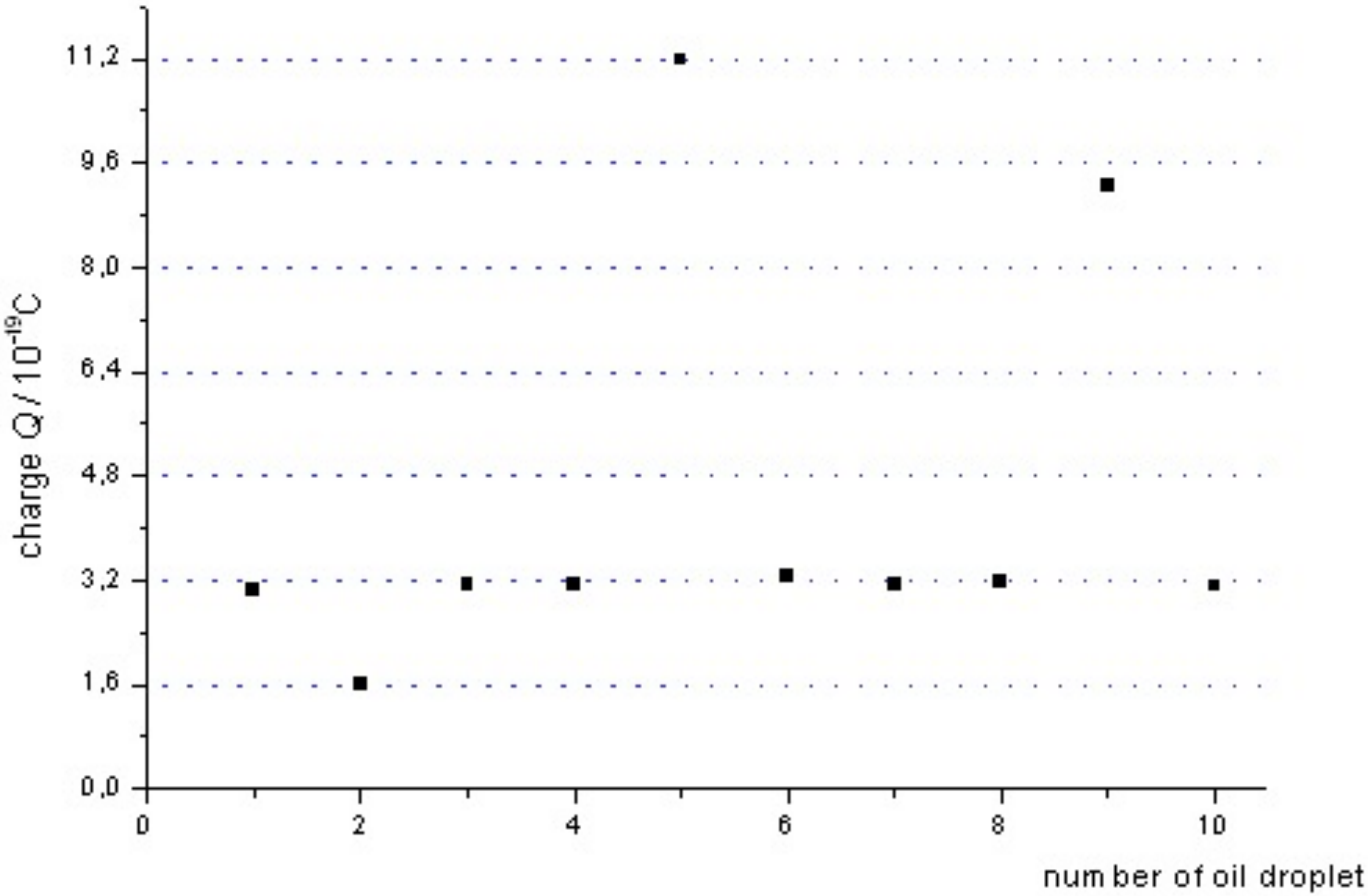
Robert Milliken
(1868-1953)

Milliken Oil drop experiment



Robert Milliken
(1868-1953)

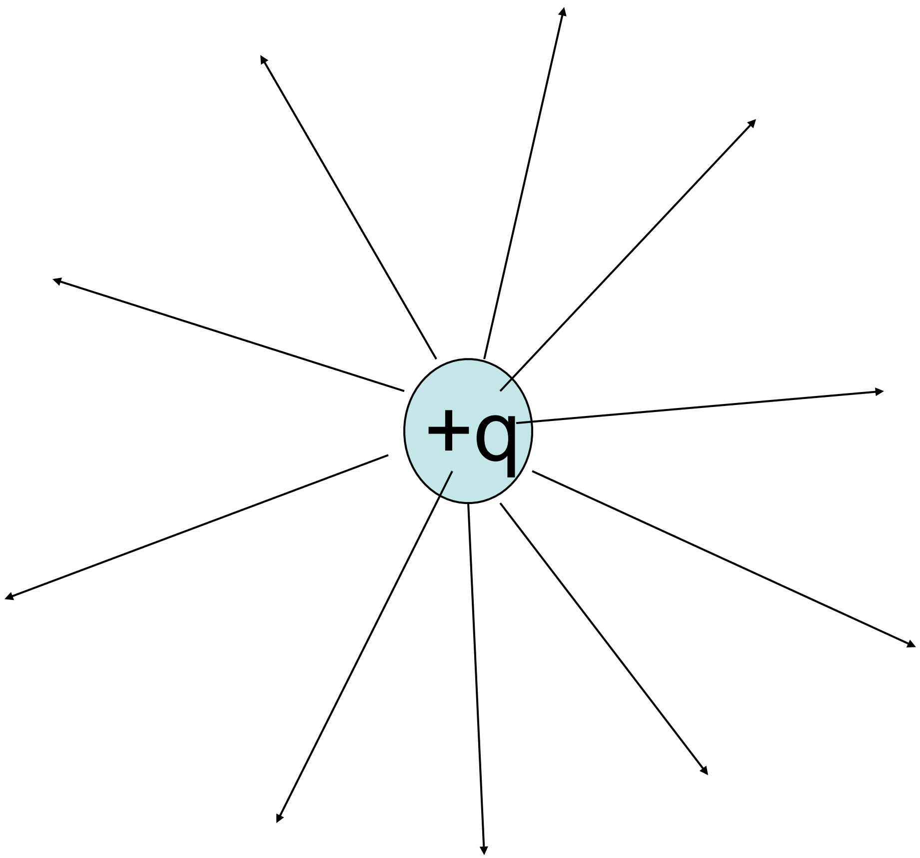
Results of Oil Drop Measurements



Chapter 15.9
Electric Flux Gauss’ Law

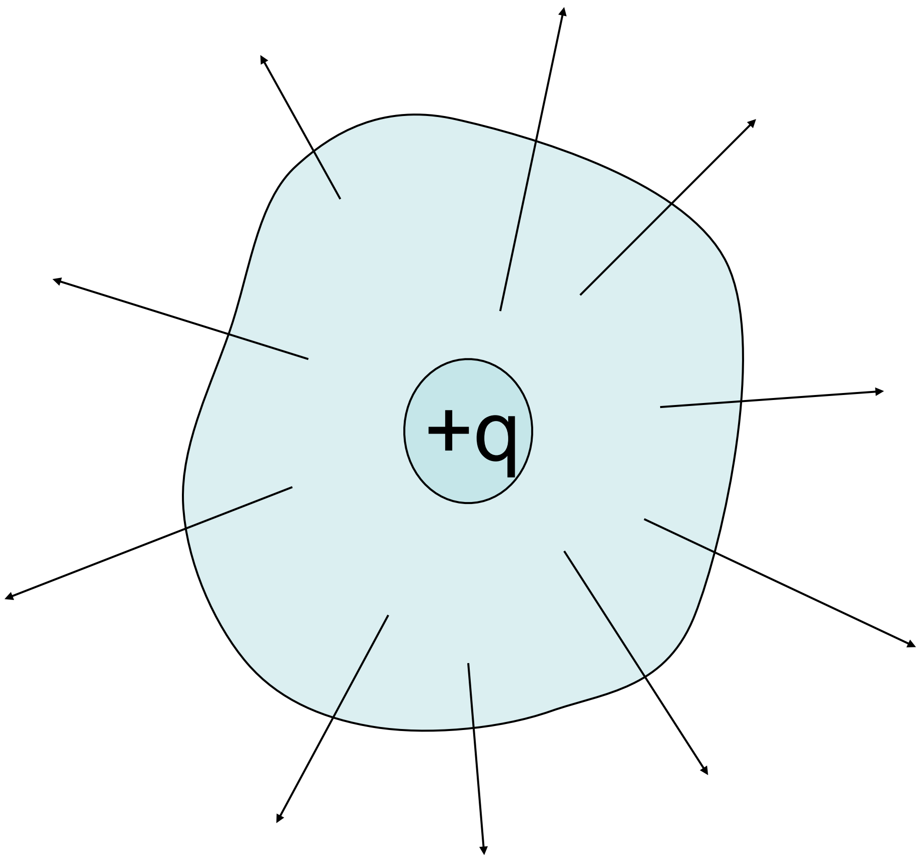
- Gauss’s Law gives relation between electric fields and charges.
- Equivalent to Coulomb’s Law
- Useful for determining E for simple distributions of charge.

Basic Idea of Gauss' Law



Total number of E field lines is proportional to charge

Density of E field lines is proportional to the magnitude of E

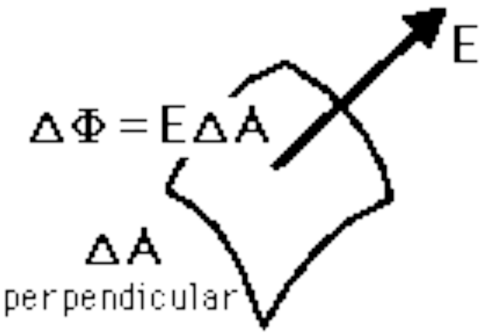


surround the charge by
a closed surface

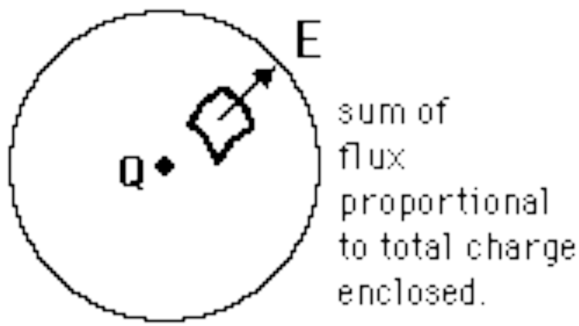
The density of E-field
lines (i.e. the E field) at
the surface can be related
to the charge q

Gauss's Law

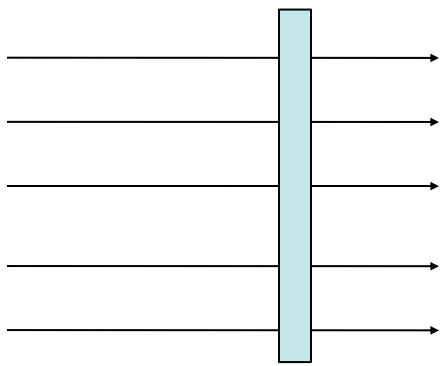
The total of the electric flux out of a closed surface
is equal to the charge enclosed divided by the permittivity.



$$\Phi_{electric} = \frac{Q}{\varepsilon_0}$$



Electric Flux, Φ_E, through an area A

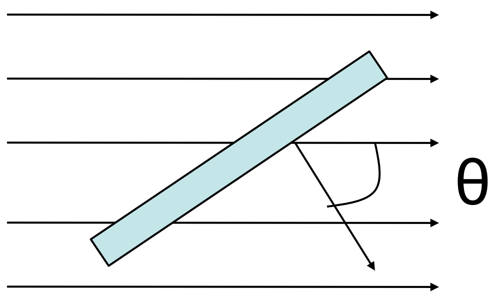


E

area A (perpendicular to electric field lines)

$$\Phi_E = EA \propto N$$

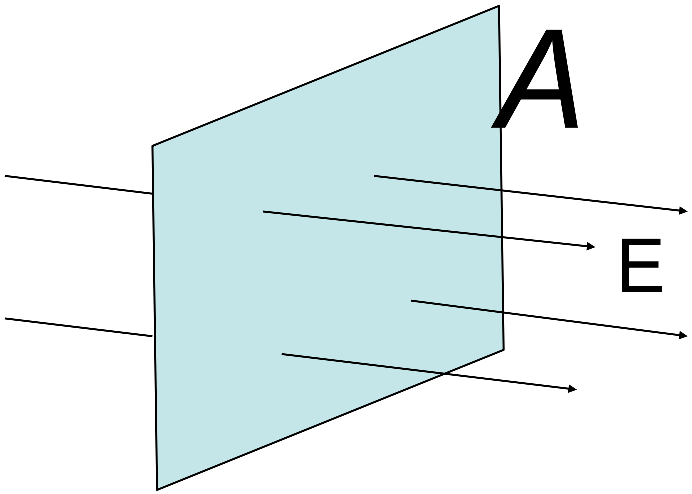
N = no. of electric field lines

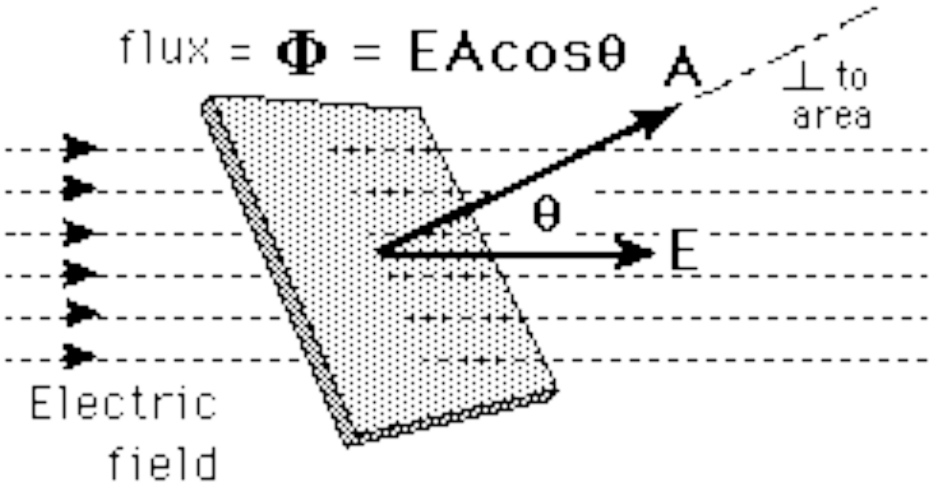


E at angle of Θ to surface normal (red).

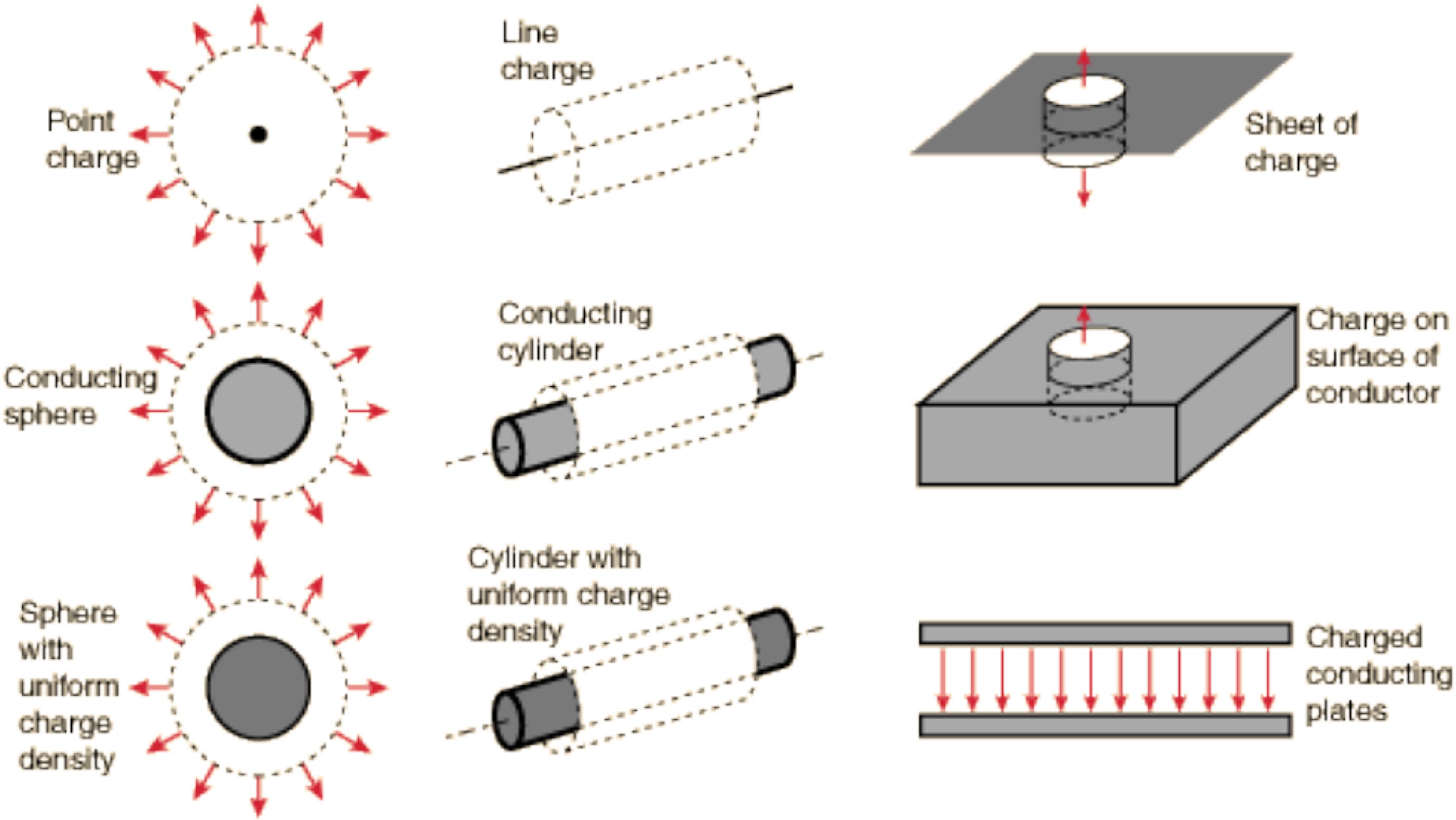
$$\Phi_E = EA\cos\theta$$

Finding E from the flux

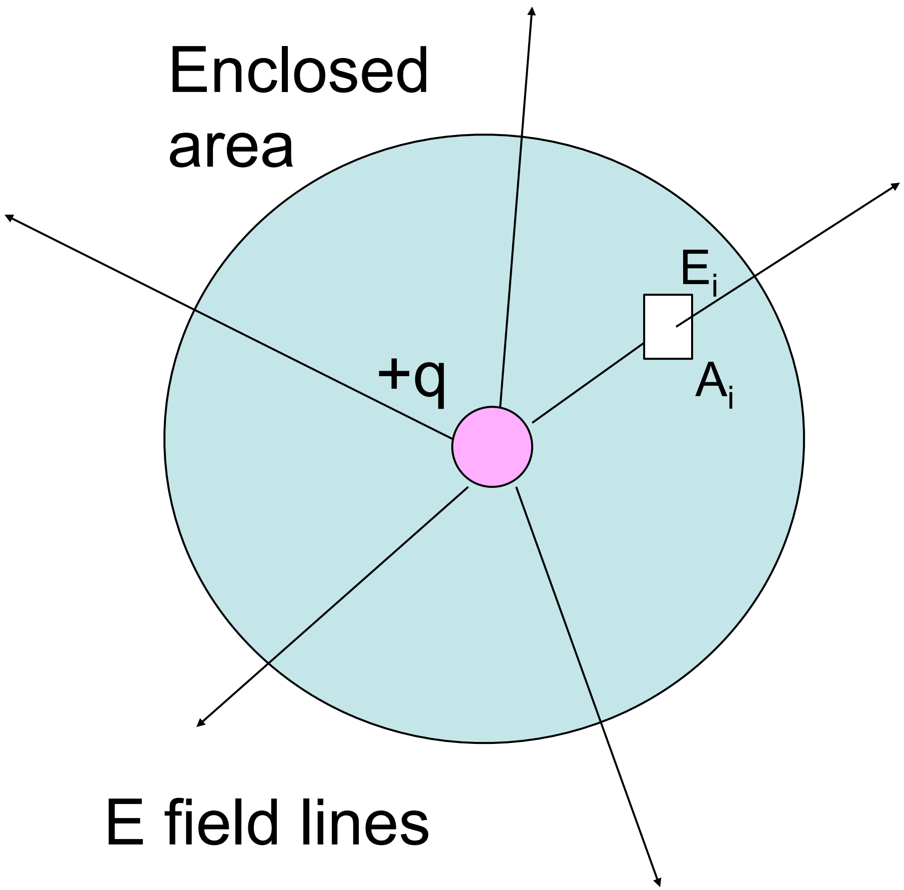




$$E = \frac{\Phi_E}{A_\perp}$$


Point
charge
Line
charge
Sheet of
charge
Conducting
sphere
Conducting
cylinder
Charge on
surface of
conductor
Sphere
with
uniform
charge
density
Cylinder with
uniform charge
density
Charged
conducting
plates

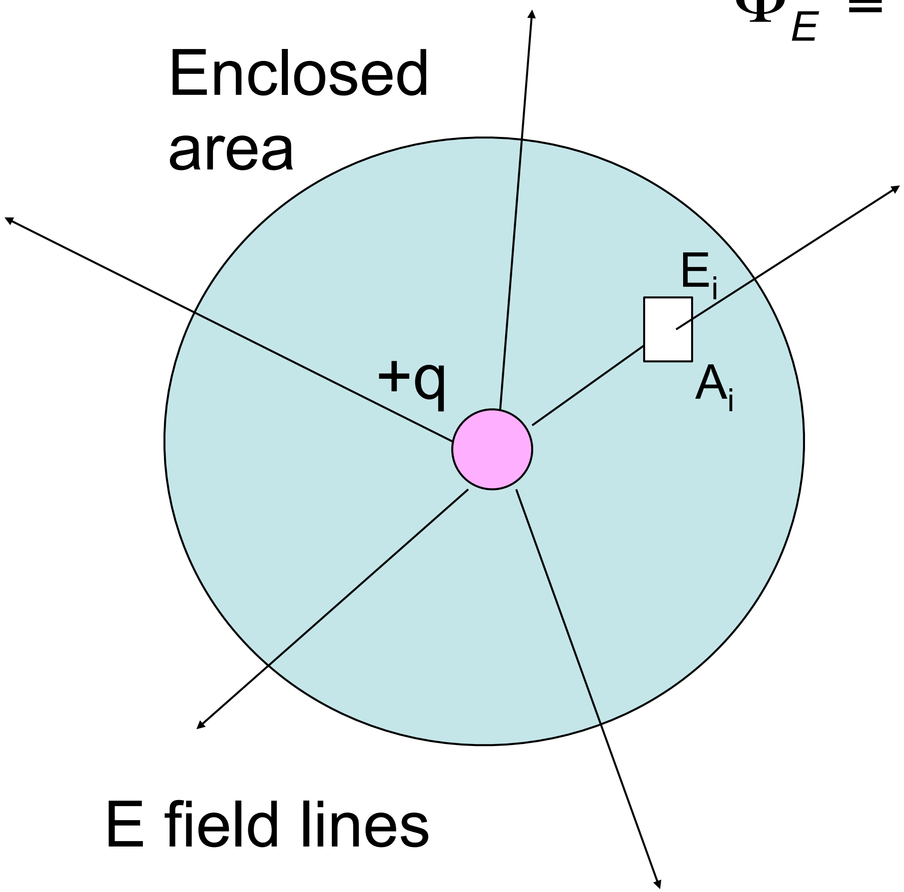
Flux through an enclosed area is proportional to amount of charge enclosed



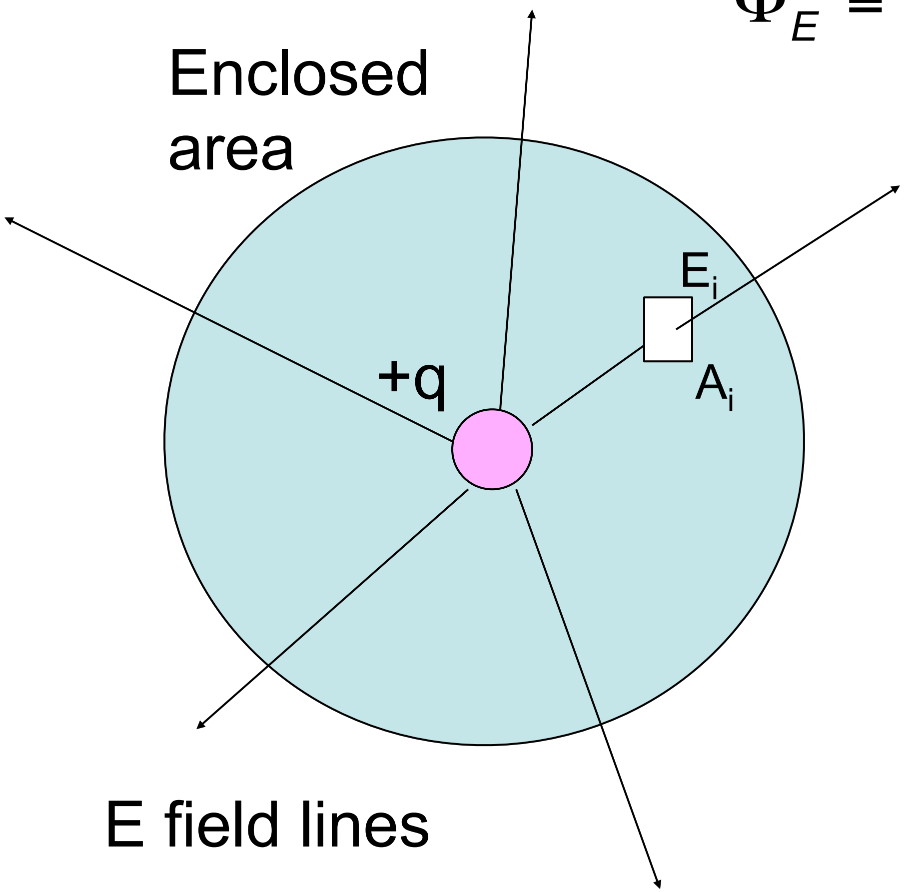
Flux through an enclosed area is proportional to amount of charge enclosed

$$\Phi_E = \sum E_i A_i \cos\theta \propto N \propto q$$

Sum over enclosed area



Flux through an enclosed area is proportional to amount of charge enclosed



$$\Phi_E = \sum E_i A_i \cos\theta \propto N \propto q$$

Sum over enclosed area

Gauss's Law

$$\Phi_E = \frac{q}{\varepsilon_o}$$

Proportionality Constant

$$\varepsilon_o = \frac{1}{4\pi k_e}$$

$$= 8.85x10^{-12} C^2 / Nm^2$$

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