BEFORE CLASS:

A charged stick exerts a force on an uncharged object (soap bubble).

What determines whether the force is attractive or repulsive? Why is there a force at all??

RECITATIONS START TOMORROW! DO THE PRERECITATION PROBLEMS!

FIRST HOMEWORK ASSIGNMENT IS DUE 11:59PM Tuesday Sept 8

Yes, Webassign will be used in 228H

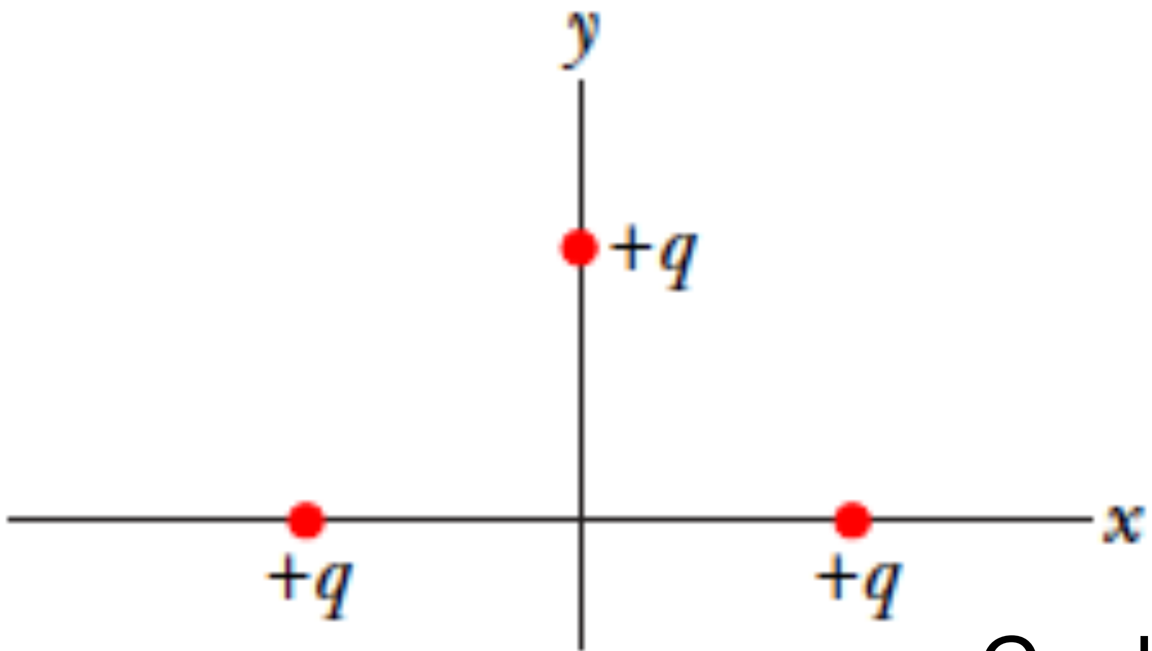
comment **on making formula sheet**

class web site

http://www.physics.rutgers.edu/ugrad/227H

Example:

What is the direction of the net force on the middle particle, if the particles on the x axis are equidistant from the origin?



(1)

Coulomb's law
Superposition
SYMMETRY

Electrical charge

Property of an object, electric force

units: C (coulombs)

Q or q

Matter is made up of charged particles:
electrons and nuclei (protons and neutrons)

Electron is elementary particle with charge $-e = -1.604 \times 10^{-19}$ C
Charge of composite object is sum of charges
Charge of nucleus is $+Ze$ (Z=number of protons, charge $+e$)

Charge of atom is exactly zero

Charge conservation

Simple charge conservation
Cut an object into two pieces
Put two objects together
(count up the electrons and nuclear charges)

In high energy physics
particles are created and destroyed
but **total charge does not change**

Can there be an electric force between a charged object and a neutral object?

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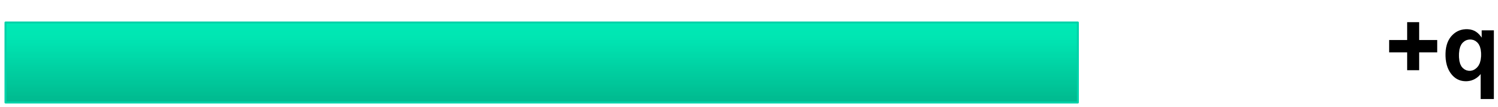
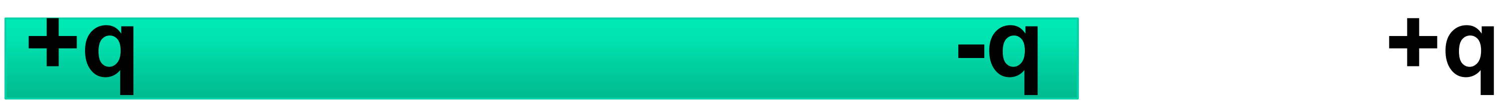


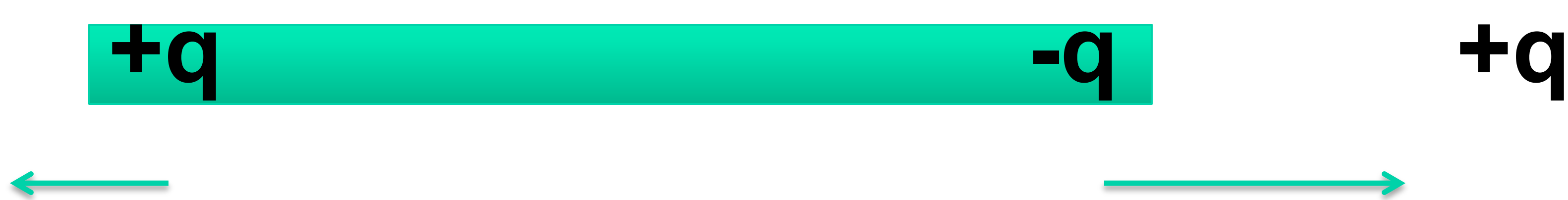
Can there be an electric force between a charged object and a neutral object?

Object can have charged regions and still have net charge = 0



Can there be an electric force between a charged object and a neutral object?

Object can have charged regions and still have net charge = 0
Simple example where net force is not zero



All materials are made of nuclei and electrons

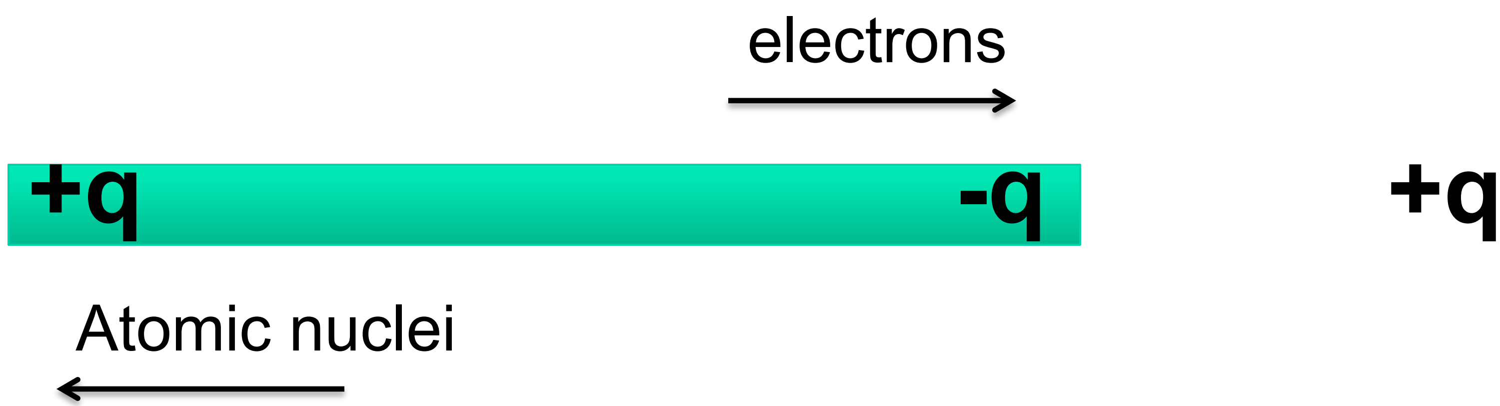
Insulators (wood, plastic, glass)

electrons have to stay close to their home nuclei – charges move only about an interatomic spacing

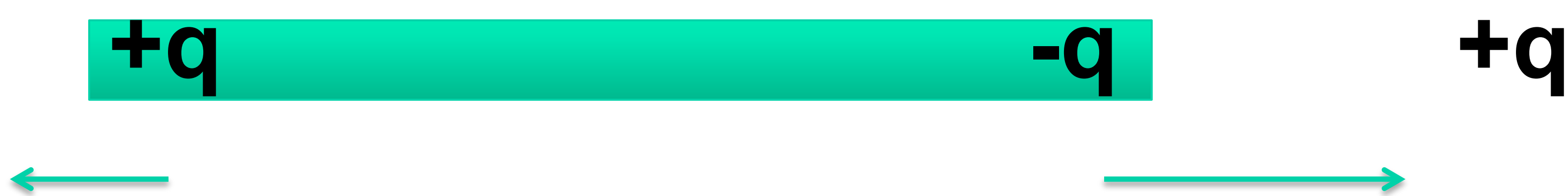
Conductors: (metal, tap water, the human body)

Some fraction of the electrons are free to move anywhere in the material

External charge induces rearrangement of charges in an object



Can there be an electric force between a charged object and a neutral object?



Induced charge rearrangement leads to a net force

What is the direction of the force for a negative external charge?

(A) towards the external charge
(B) away from the external charge
(C) the force is zero
(D) cannot determine without more information

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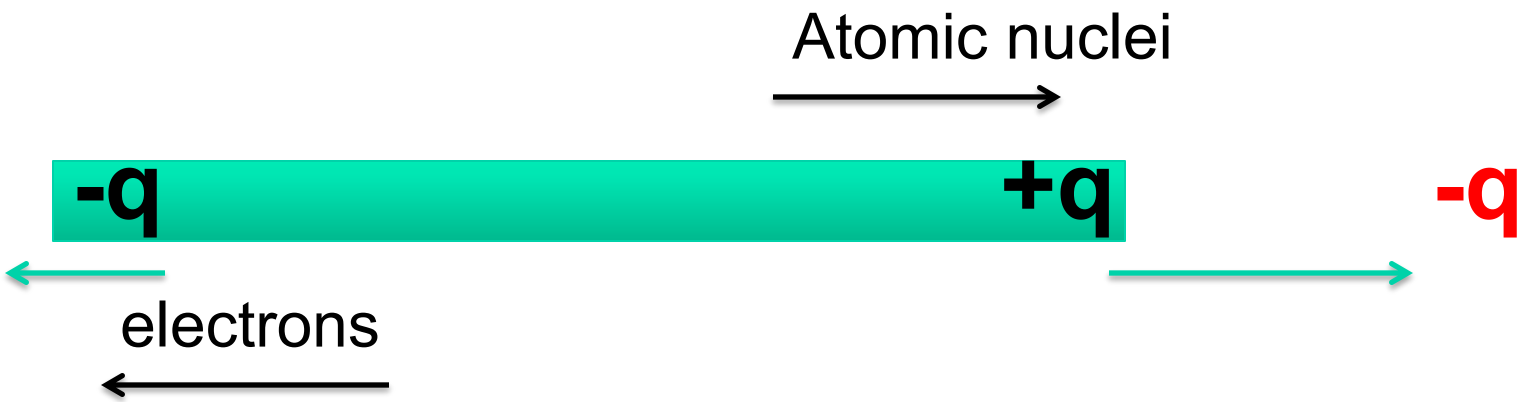

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Adding charge to conducting objects: a few operational rules

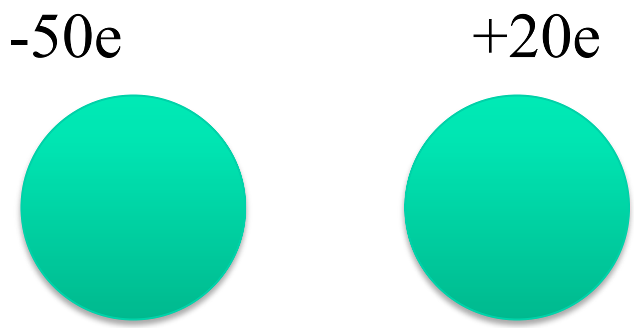
- The added charge spreads over the surface of the object

- If two conducting objects touch (or are momentarily connected by a conducting wire), their combined charge spreads over their combined surface

- Far away (at a distance much larger than size of object), the conducting object “looks like” a point charge

CHECKPOINT 4

Initially, sphere *A* has a charge of $-50e$ and sphere *B* has a charge of $+20e$. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere *A*?

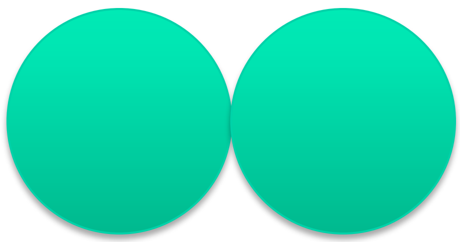


CHECKPOINT 4

Initially, sphere A has a charge of $-50e$ and sphere B has a charge of $+20e$. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?

Total q = -50e+20e=-30e

Shared equally -> -15e



“Grounding” a conducting object – connect to a gigantic conductor (the Earth)

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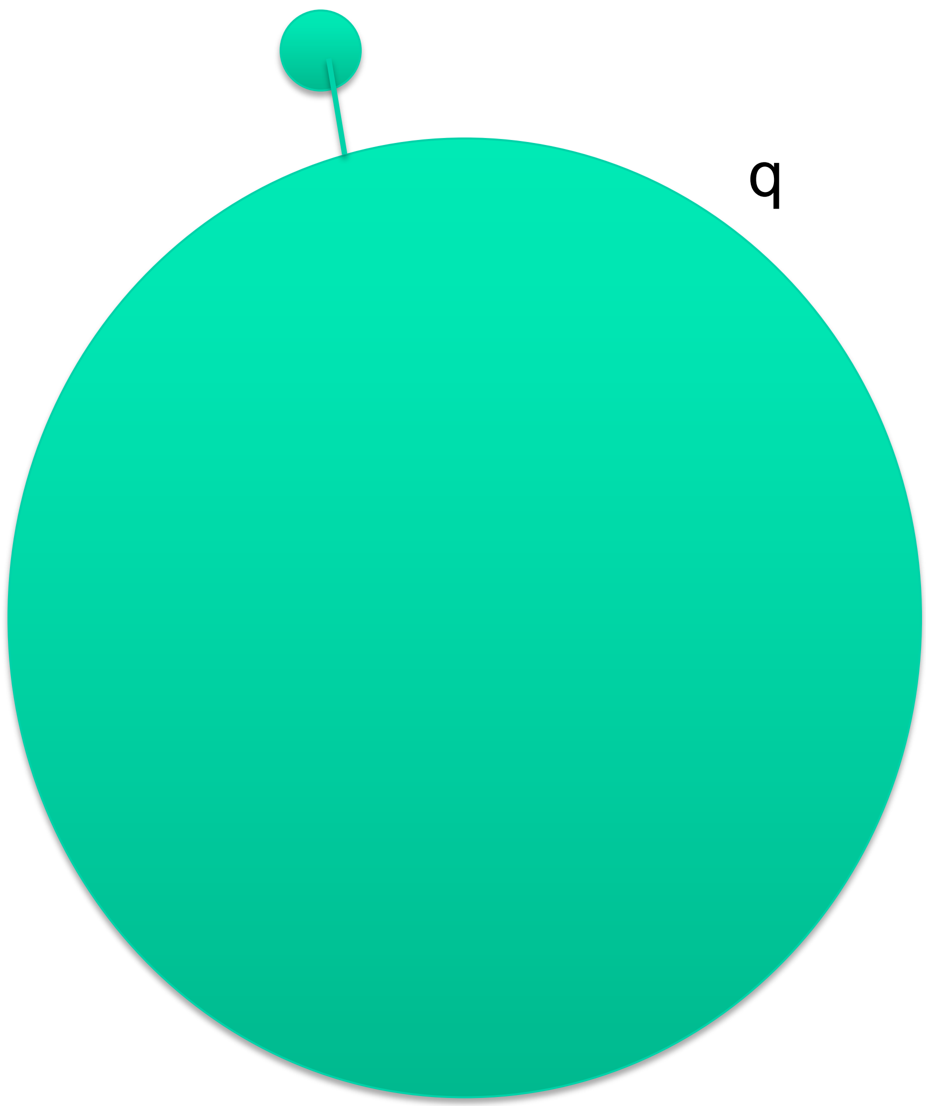
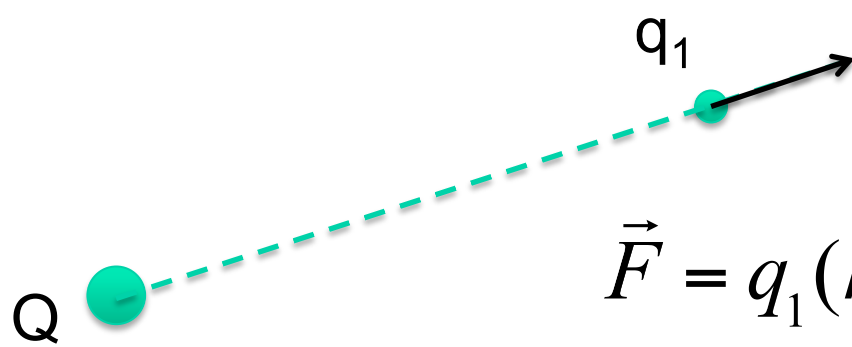


Charged particle Q

Q 

Charged particle Q

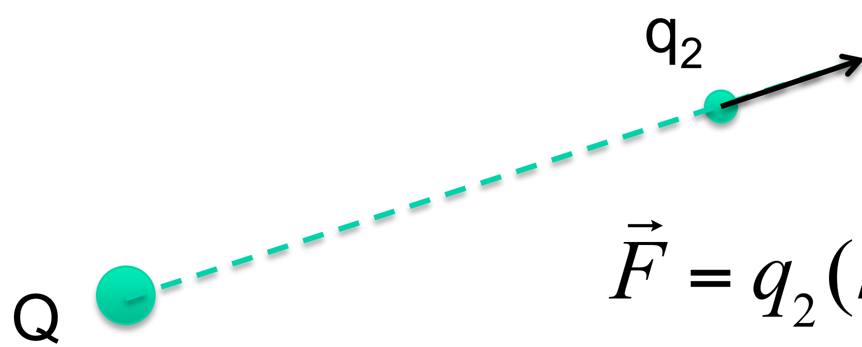


$$\vec{F} = q_1(kQ / r^2)\hat{r}$$

$\vec{r}$ = vector from Q to q_1

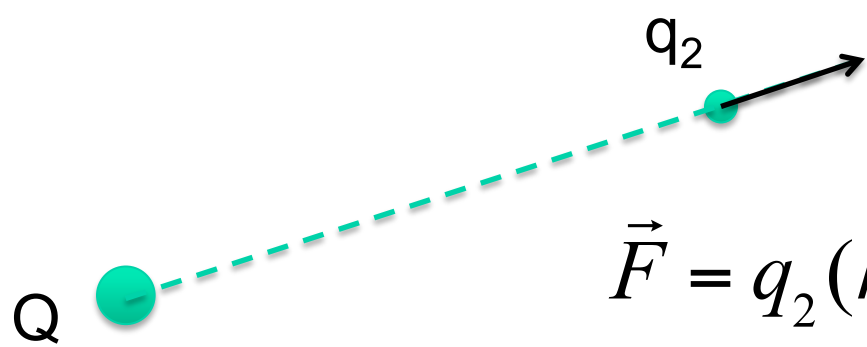
$\hat{r} = \vec{r} / |\vec{r}|$

Charged particle Q



$$\vec{F} = q_2(kQ / r^2)\hat{r}$$

Charged particle Q



$$\vec{F} = q_2(kQ / r^2)\hat{r}$$

Repeat for any value q of the charge of the 2nd particle
Repeat for any position **r**

$$\vec{F} = q(kQ / r^2)\hat{r}$$

Electric field $\vec{E}(\vec{r}) = (kQ / r^2)\hat{r}$ (vector field, units are N/C)

$$\vec{F} = q\vec{E}(\vec{r})$$

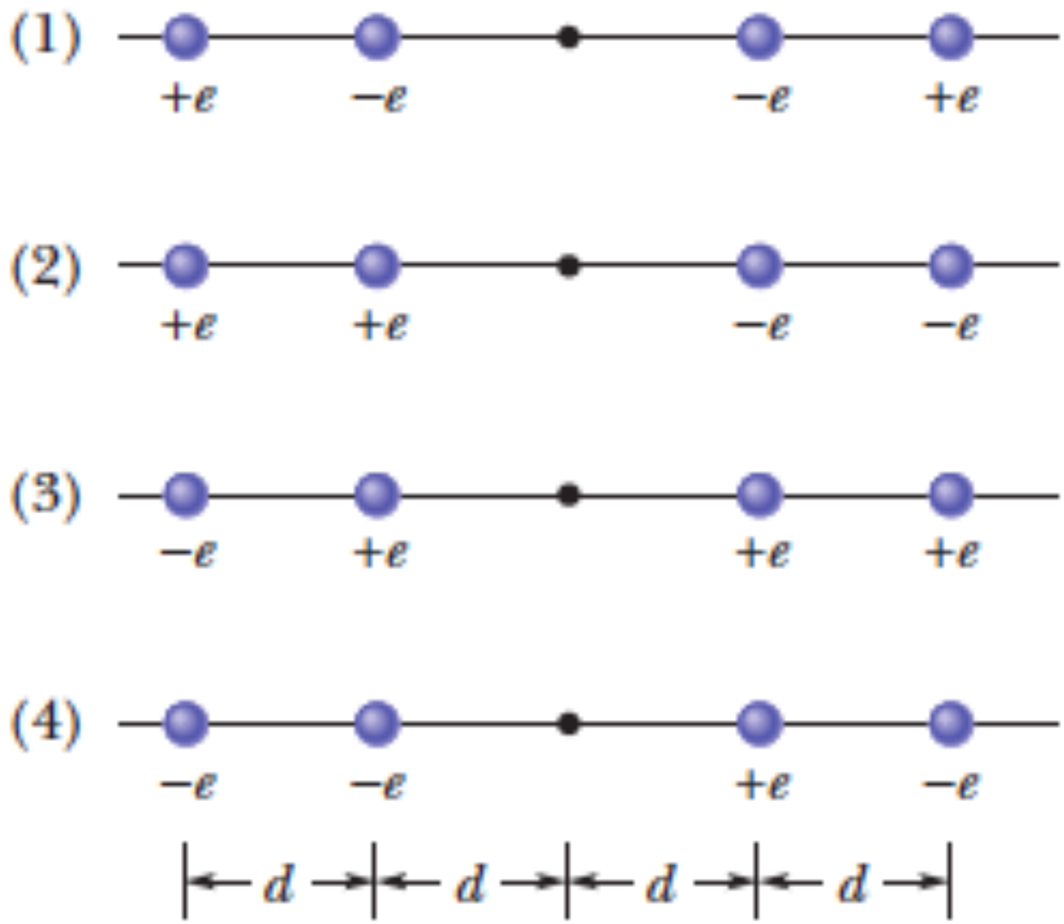
Electric field

More than just a computational convenience

A charged particle produces a electric field, modifying the space around it

The electric field produced by a system of two or more charges is the vector sum of the electric field produced by each particle

The figure shows four systems in which charges are arranged on a line. In which system is the magnitude of the electric field at the central point GREATEST?



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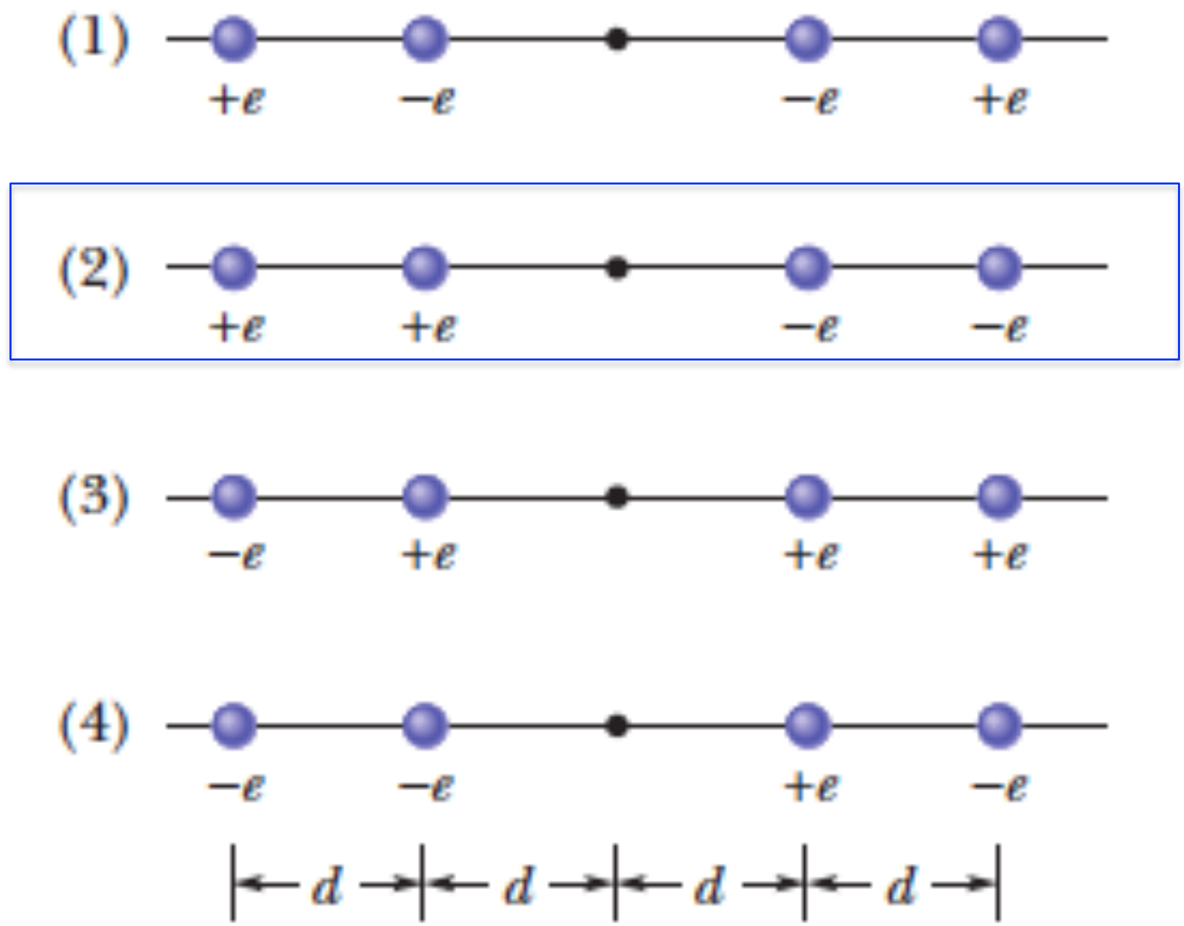
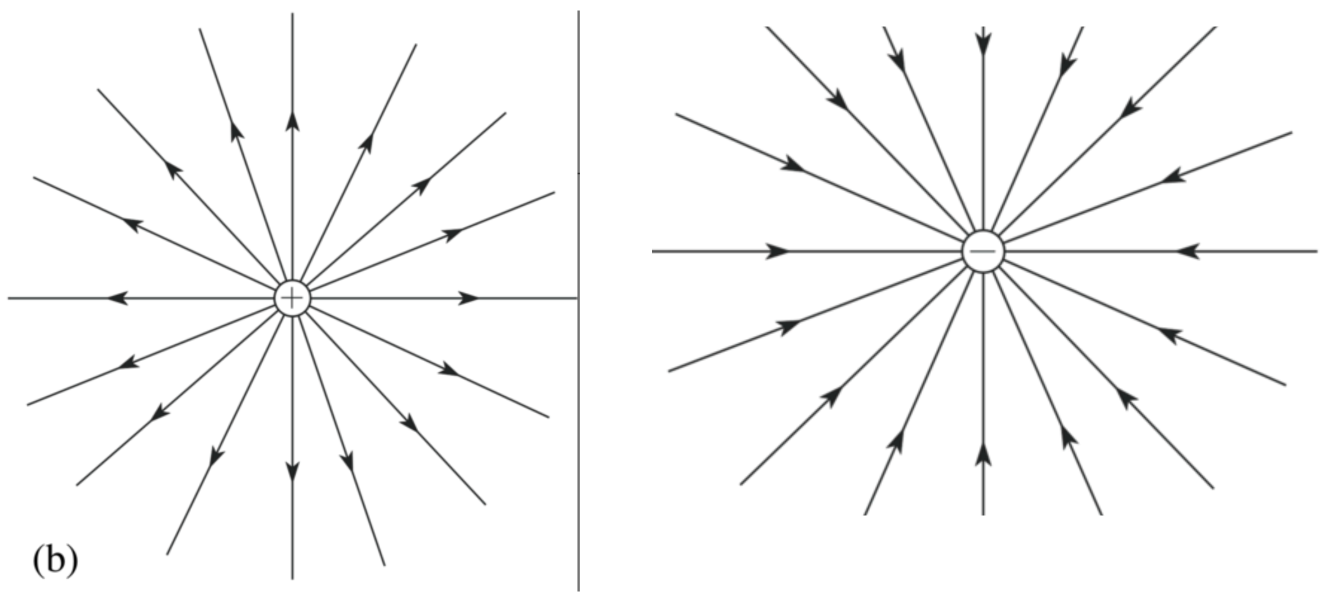


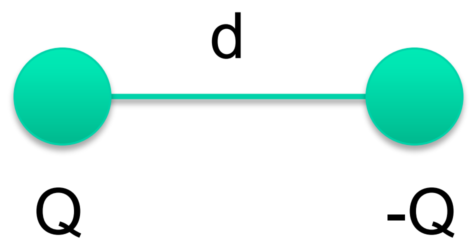
Electric field lines point in the direction of $\vec{E}$ at any point

Spacing of lines decreases as magnitude of $\vec{E}$ increases



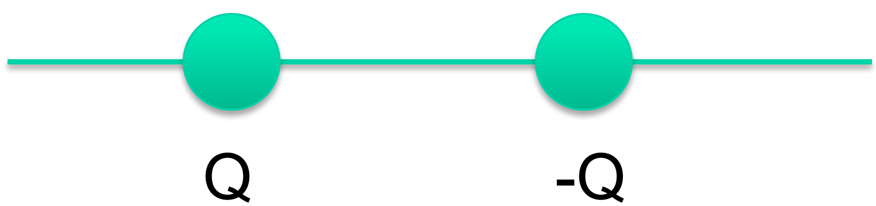
$q>0$ $q<0$

Definition of **dipole**

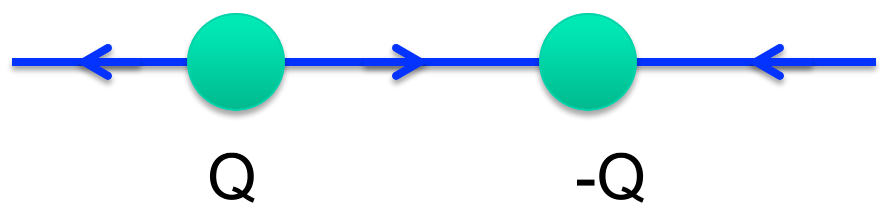


Electric field of the dipole?

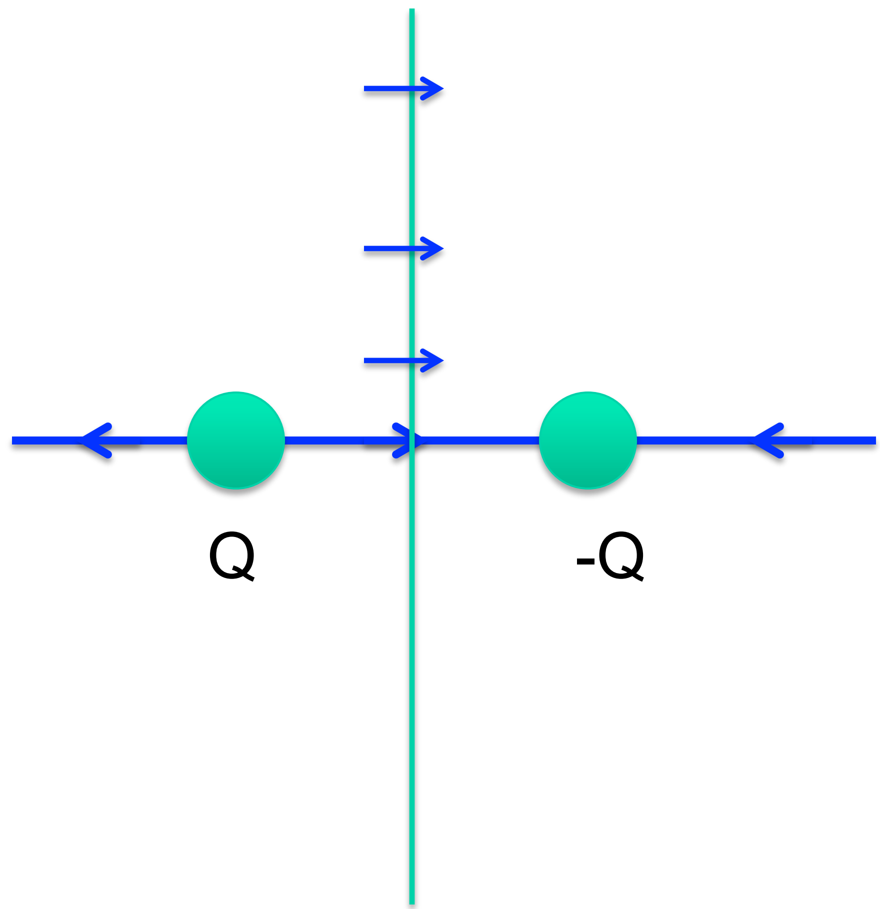
Electric field at points on the x-axis

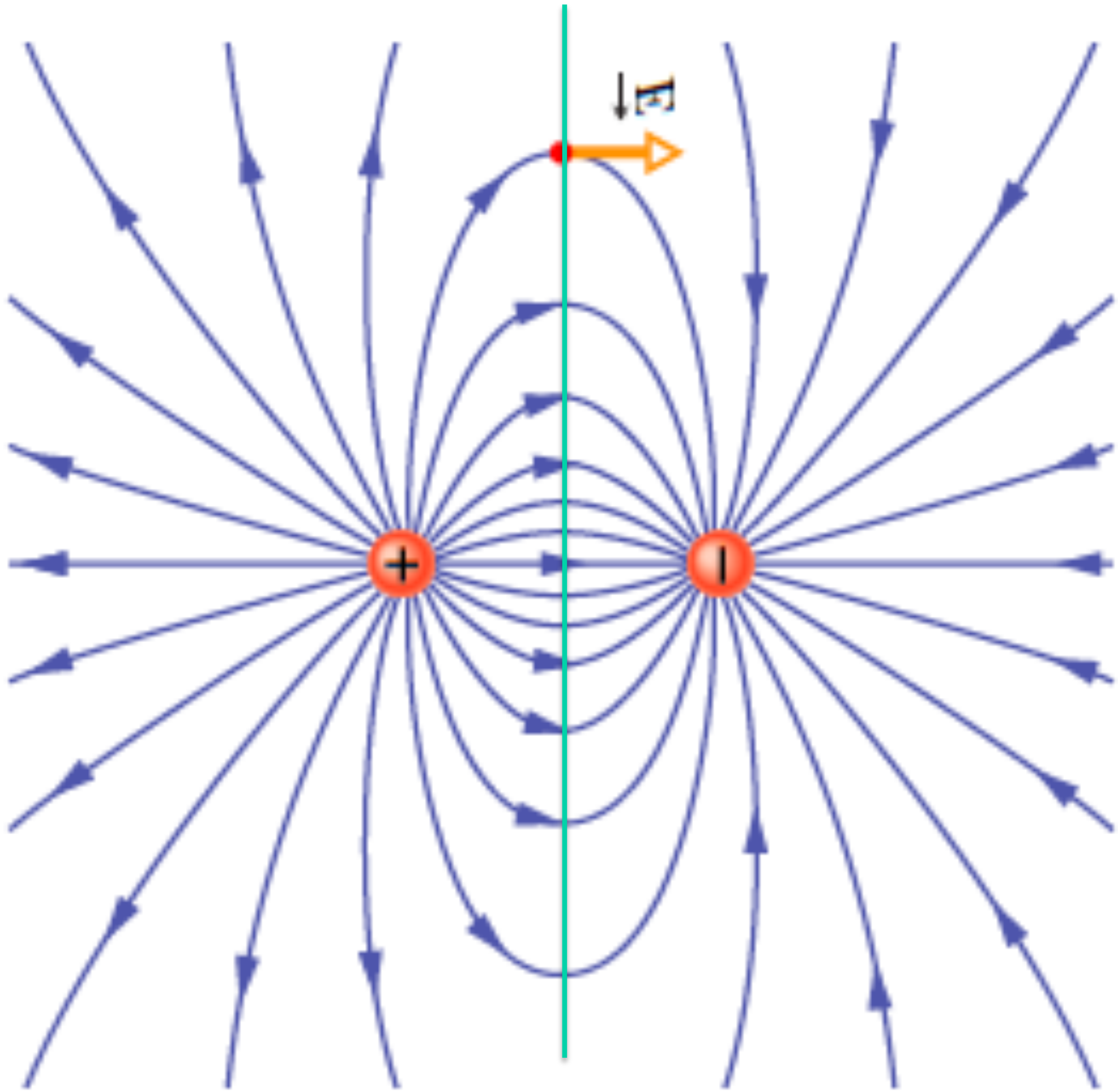


Electric field at points on the x-axis



Electric field at points on the y-axis




E

Continuous charge distributions

Surface charge density σ: charge/area (C/m^2)
EXAMPLE: uniform spherical shell Q, R
$\sigma = Q/(4\pi R^2)$

Line charge density λ: charge/length (C/m)
Volume density ρ: charge/volume (C/m^3)

Force exerted by a uniform shell

on a particle outside the shell

A uniform spherical shell of matter attracts a particle that is outside the shell as if all the shell's mass were concentrated at its center.

A shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated at its center.

on a particle inside the shell

A uniform shell of matter exerts no net gravitational force on a particle located inside it.

If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.