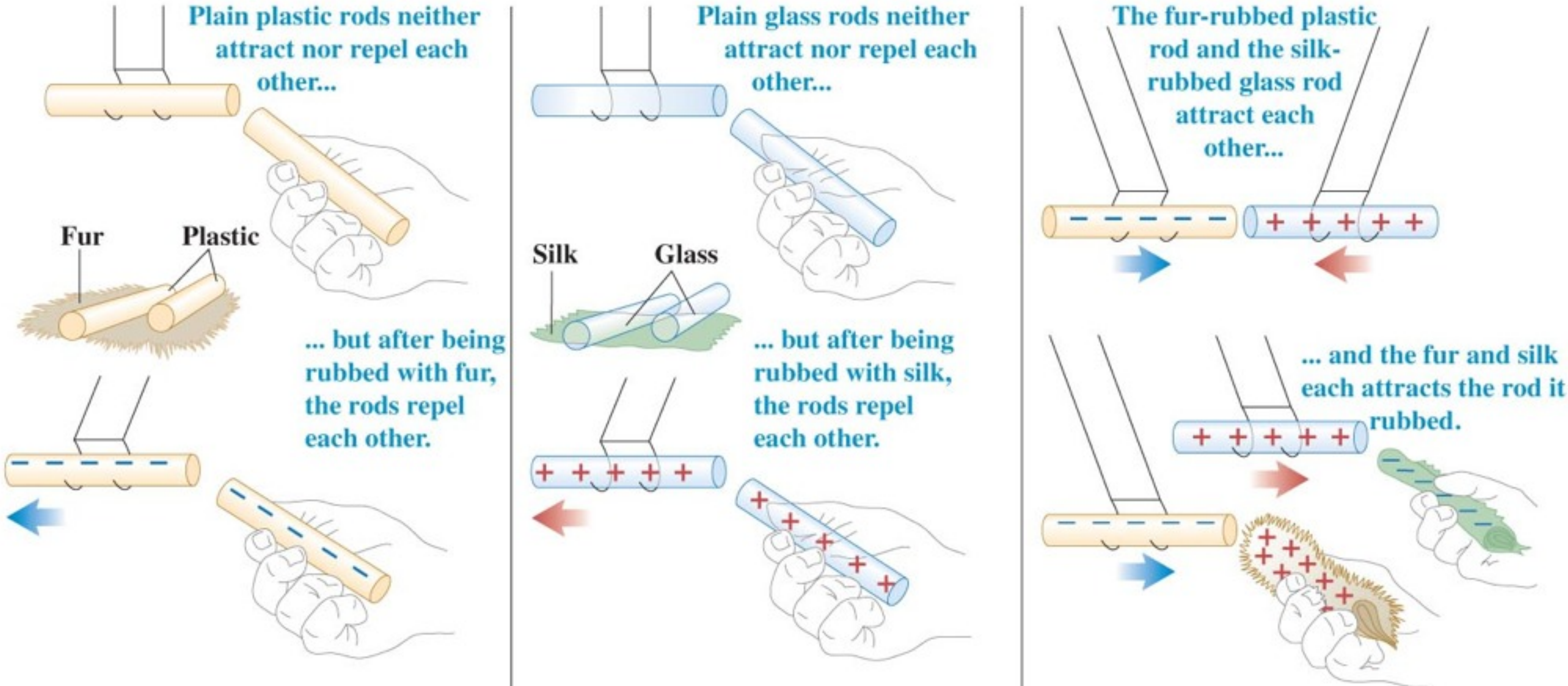
electric charges, forces and fields

static electricity



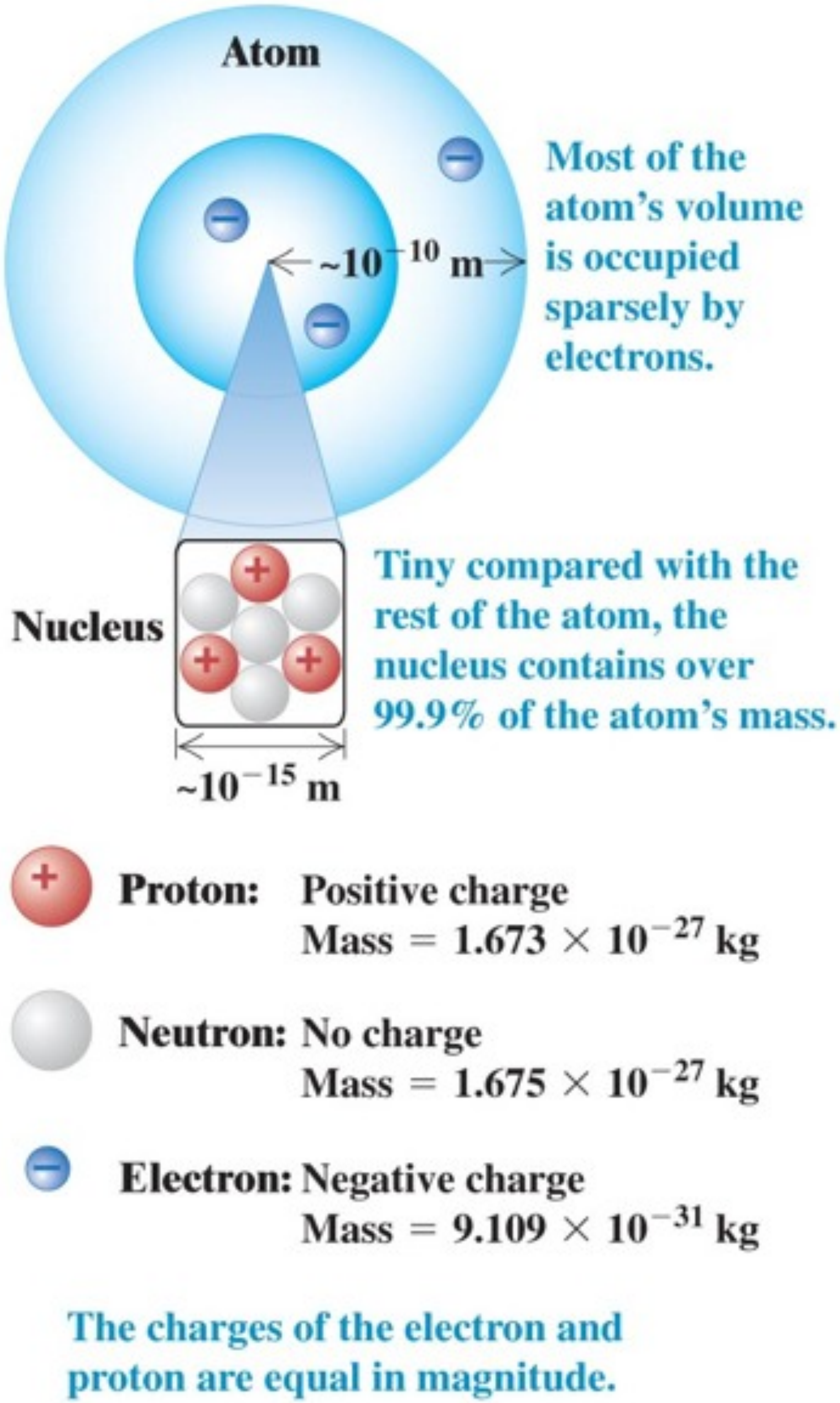
(a) Interaction between plastic rods rubbed on fur

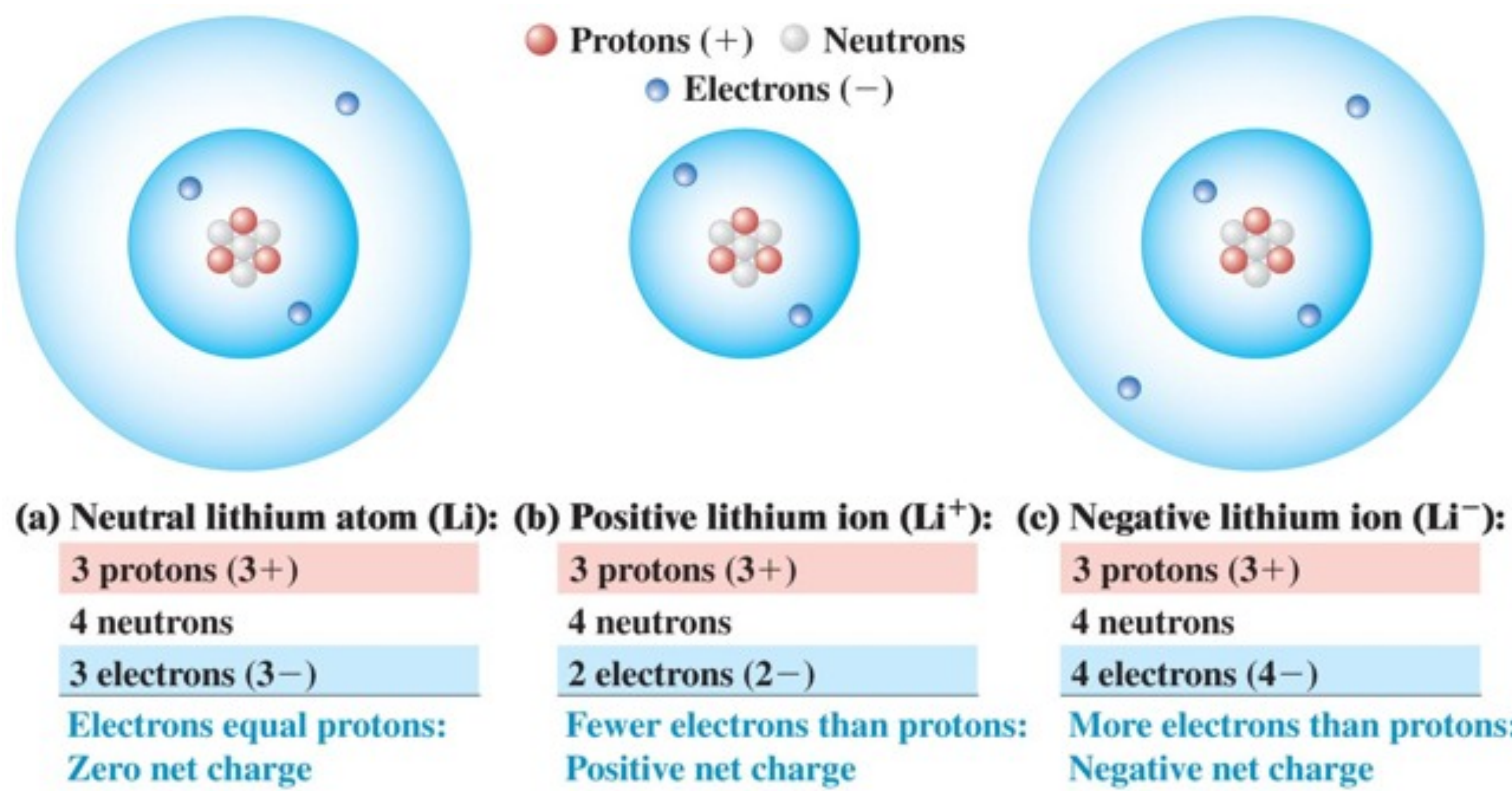
(b) Interaction between glass rods rubbed on silk

(c) Interaction between objects with opposite charges

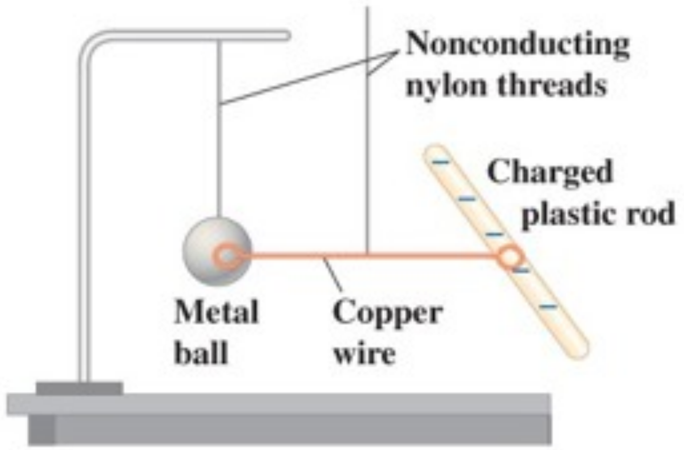
➜ like charges repel, unlike charges attract

atomic origin of charge



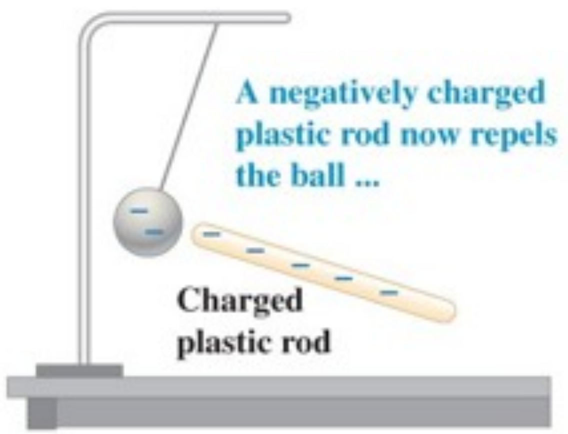


conductors and insulators

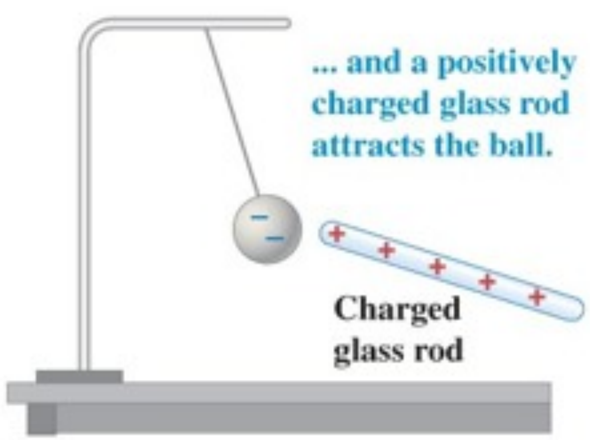


The wire conducts charge from the negatively charged plastic rod to the metal ball.

(a)



(b)



(c)

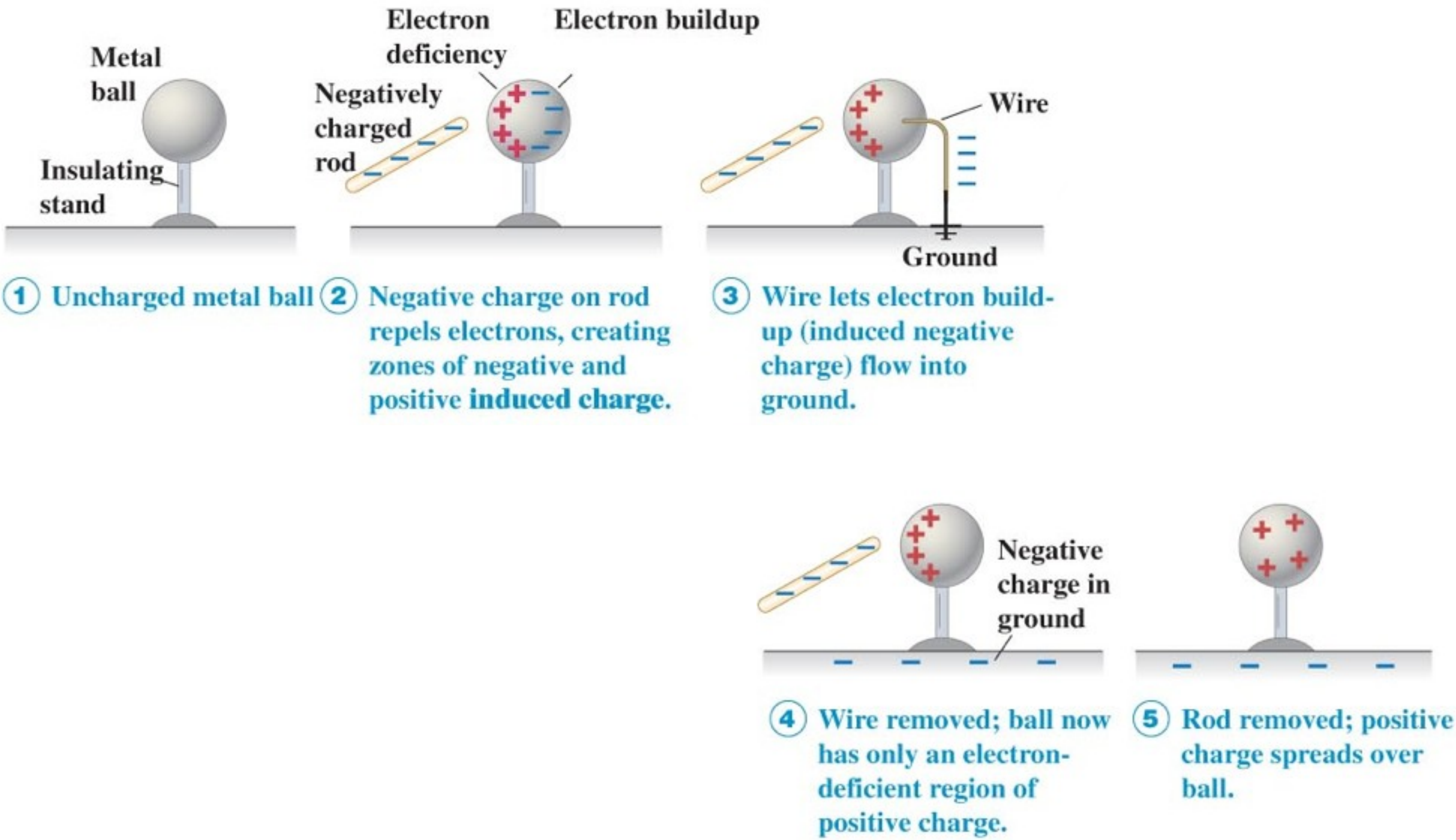
➜ materials which permit the movement of charge through them are called **conductors**

➜ e.g. most metals

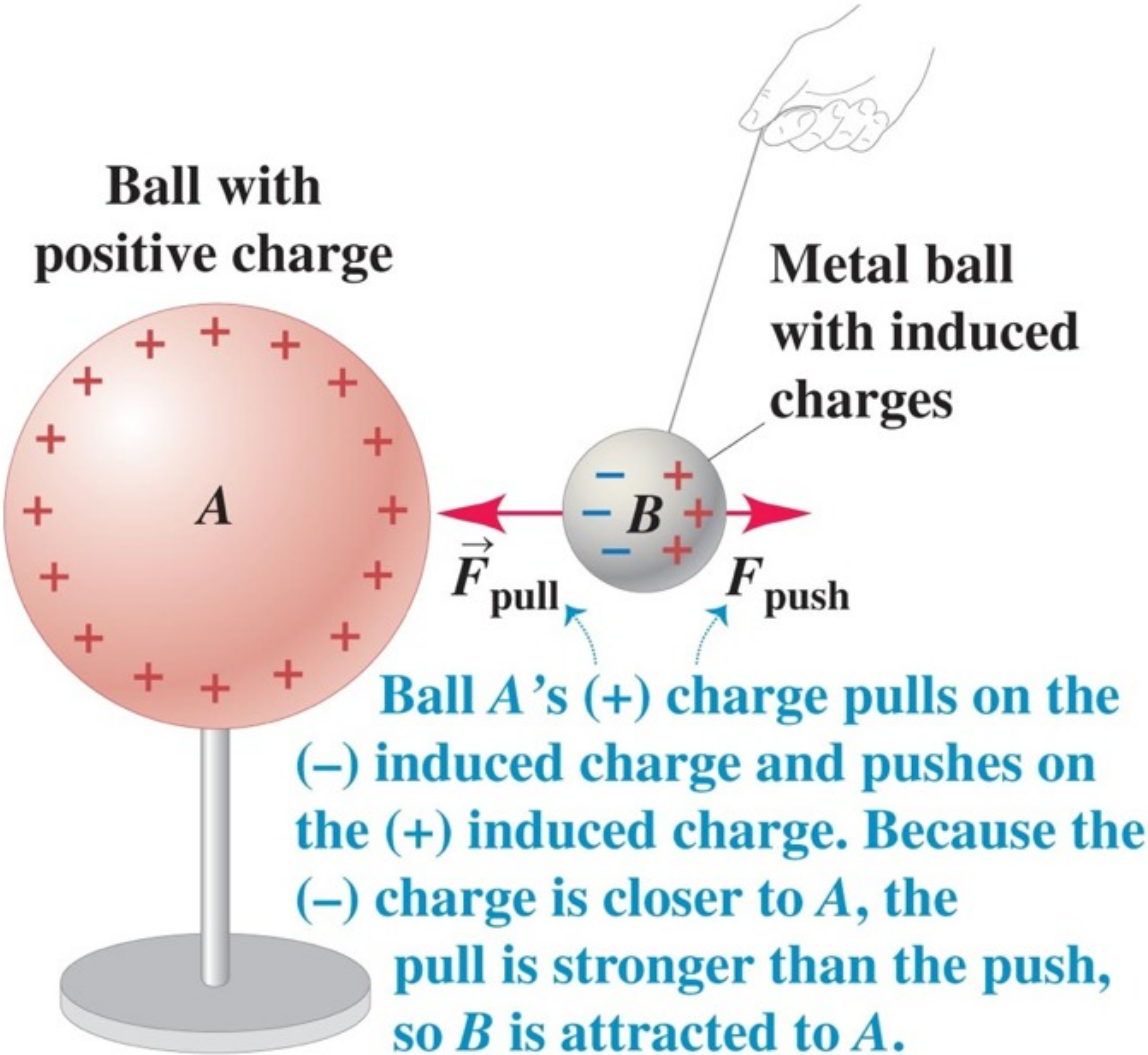
➜ materials which resist the movement of charge through them are called **insulators**

➜ e.g. plastic, wood ...

charge induction

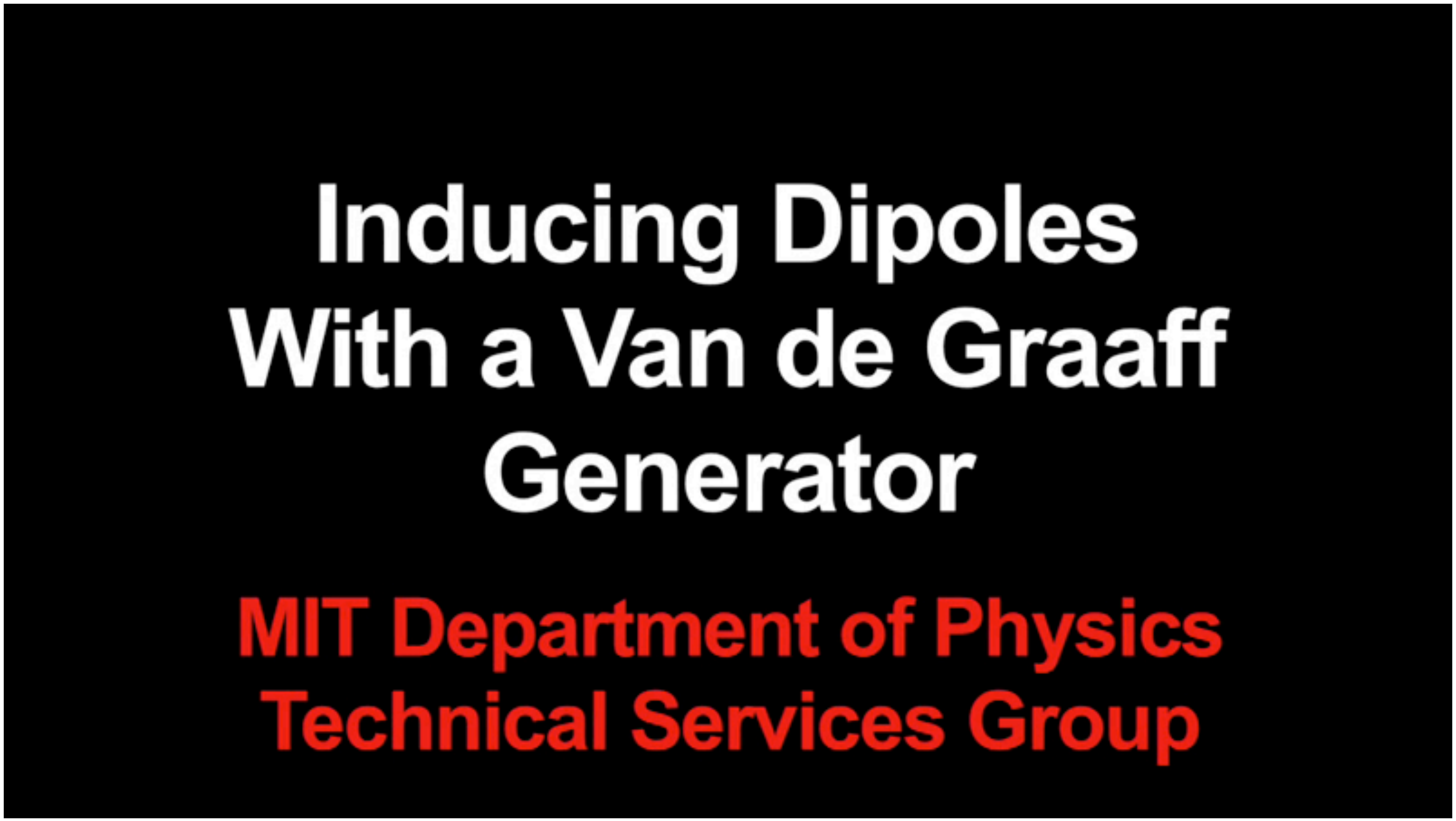


charge induction in conductors



induction

➜ inducing charge separation with a van der Graaf generator



induction

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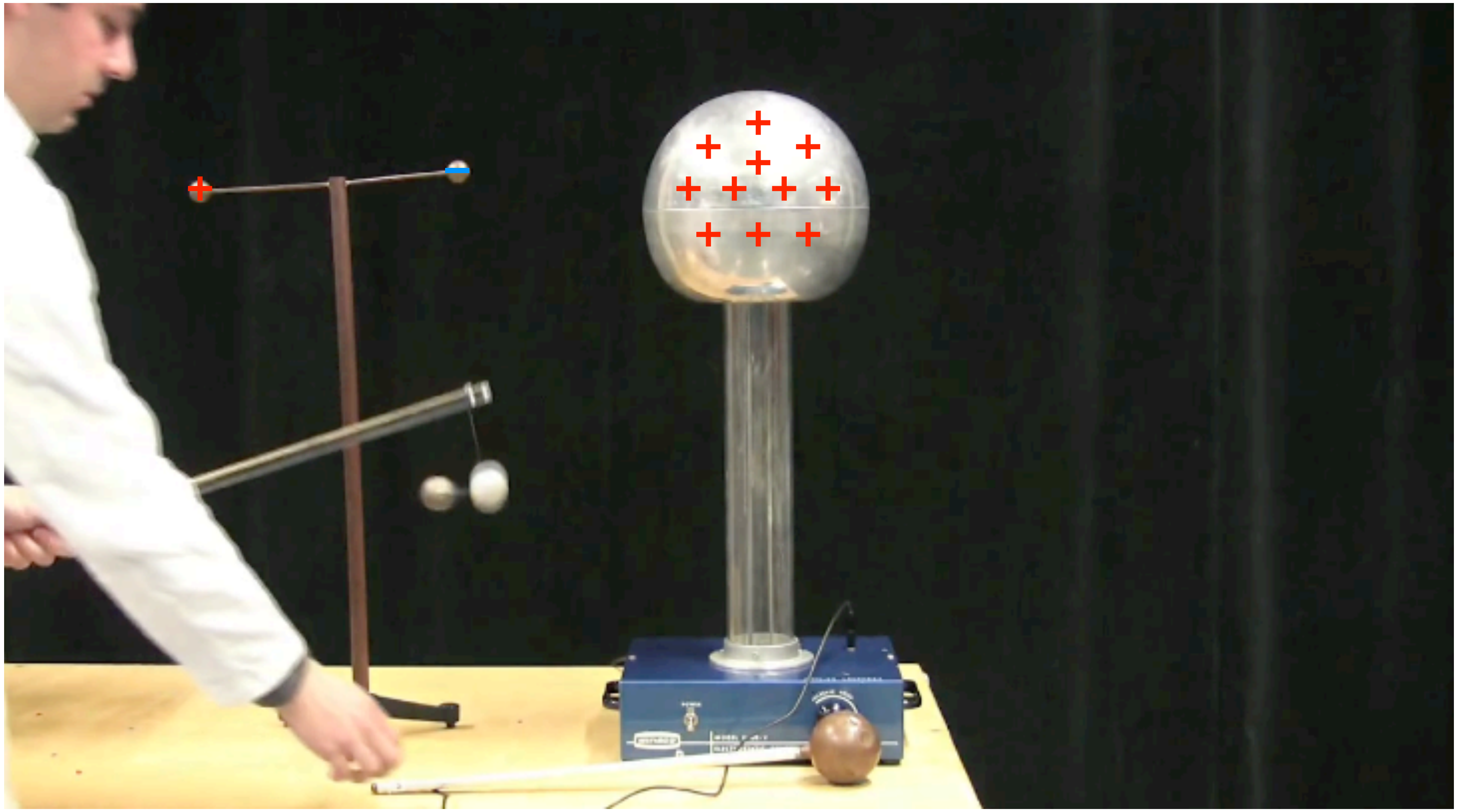

polarization of insulators

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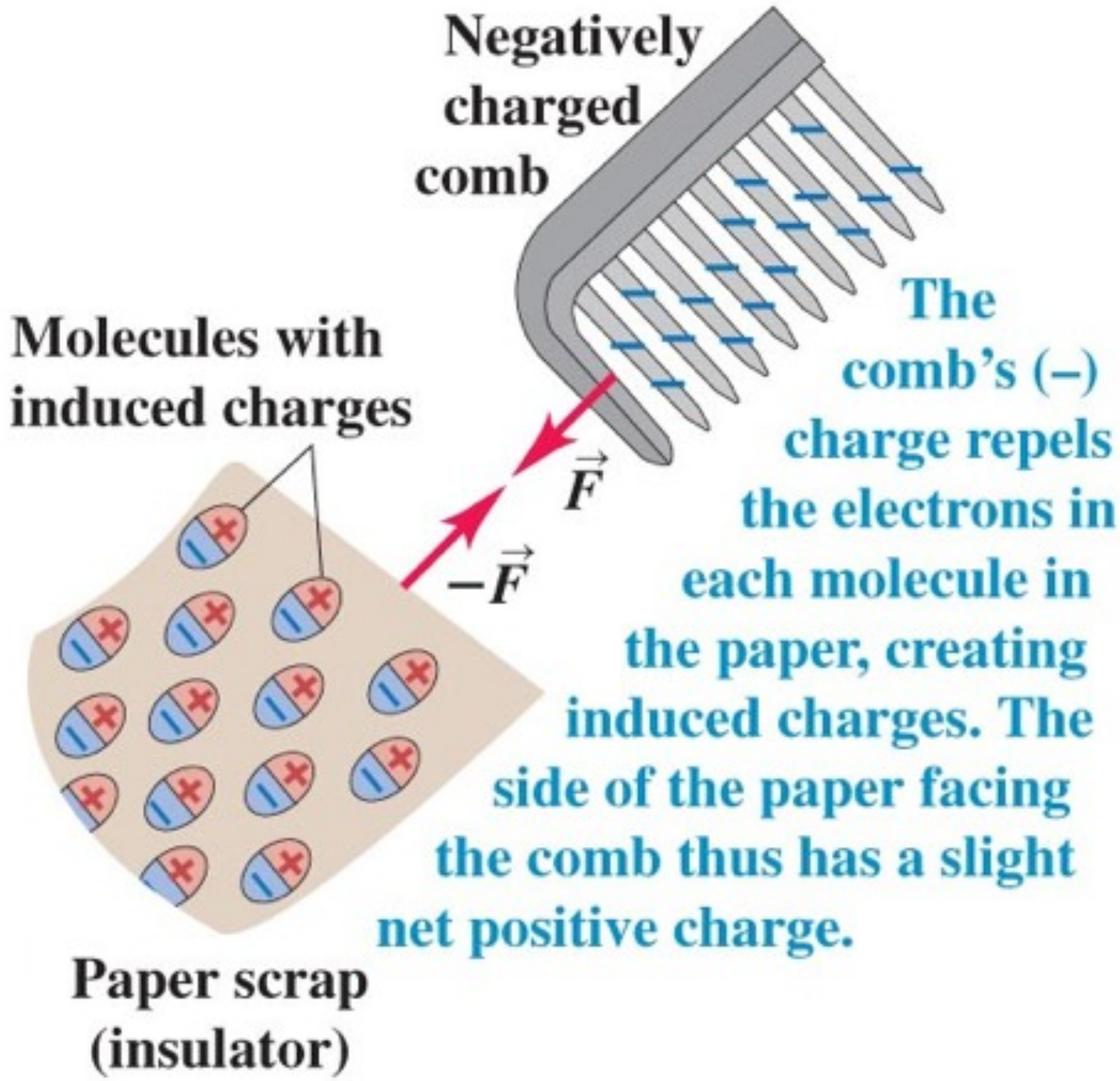
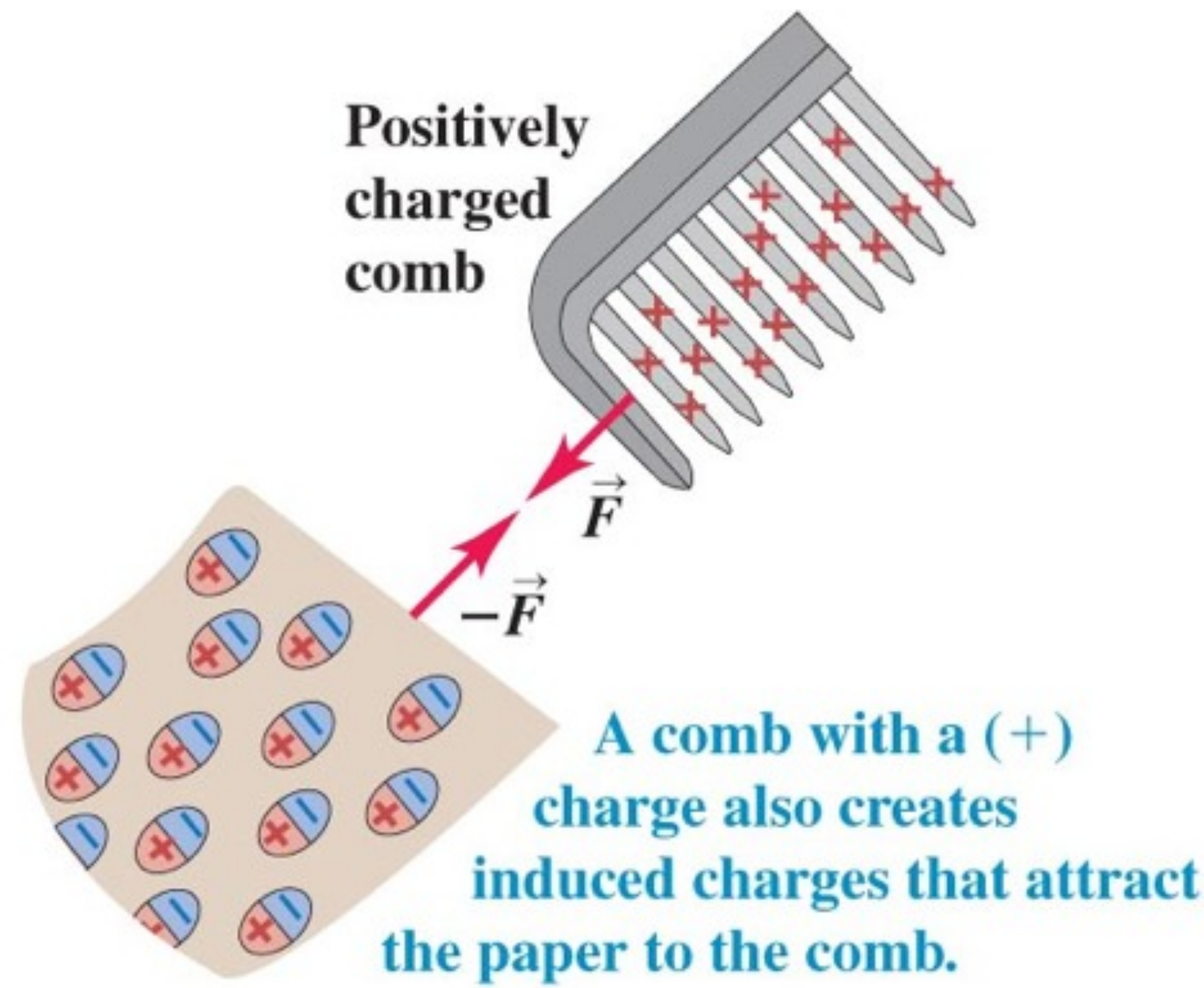




conservation of charge

➜ the total charge in a closed system is conserved

➜ we can move charge around, but we can't create or destroy it

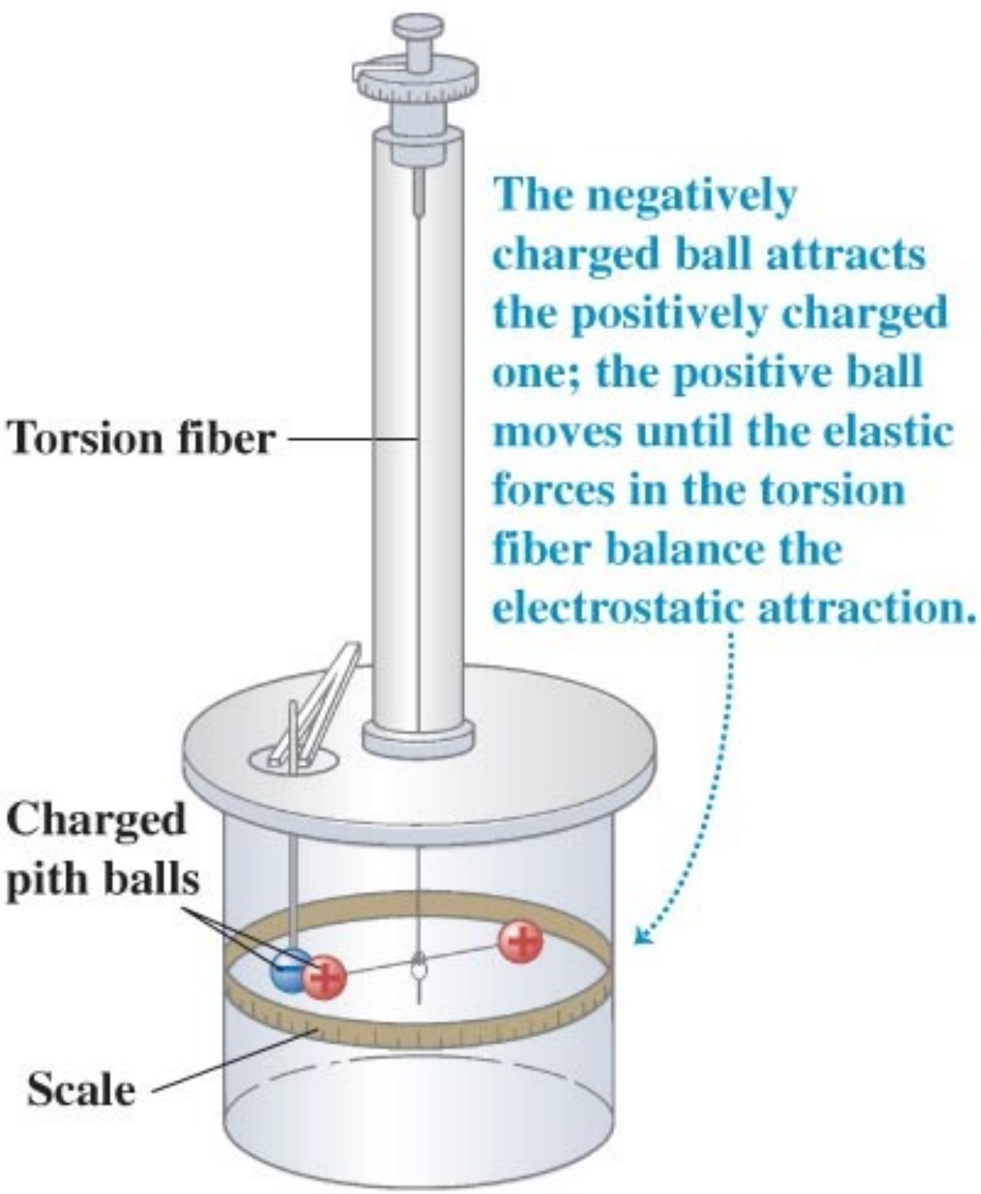
➜ the unit of electrical charge is the Coulomb

➜ 1 Coulomb is a **lot** of charge

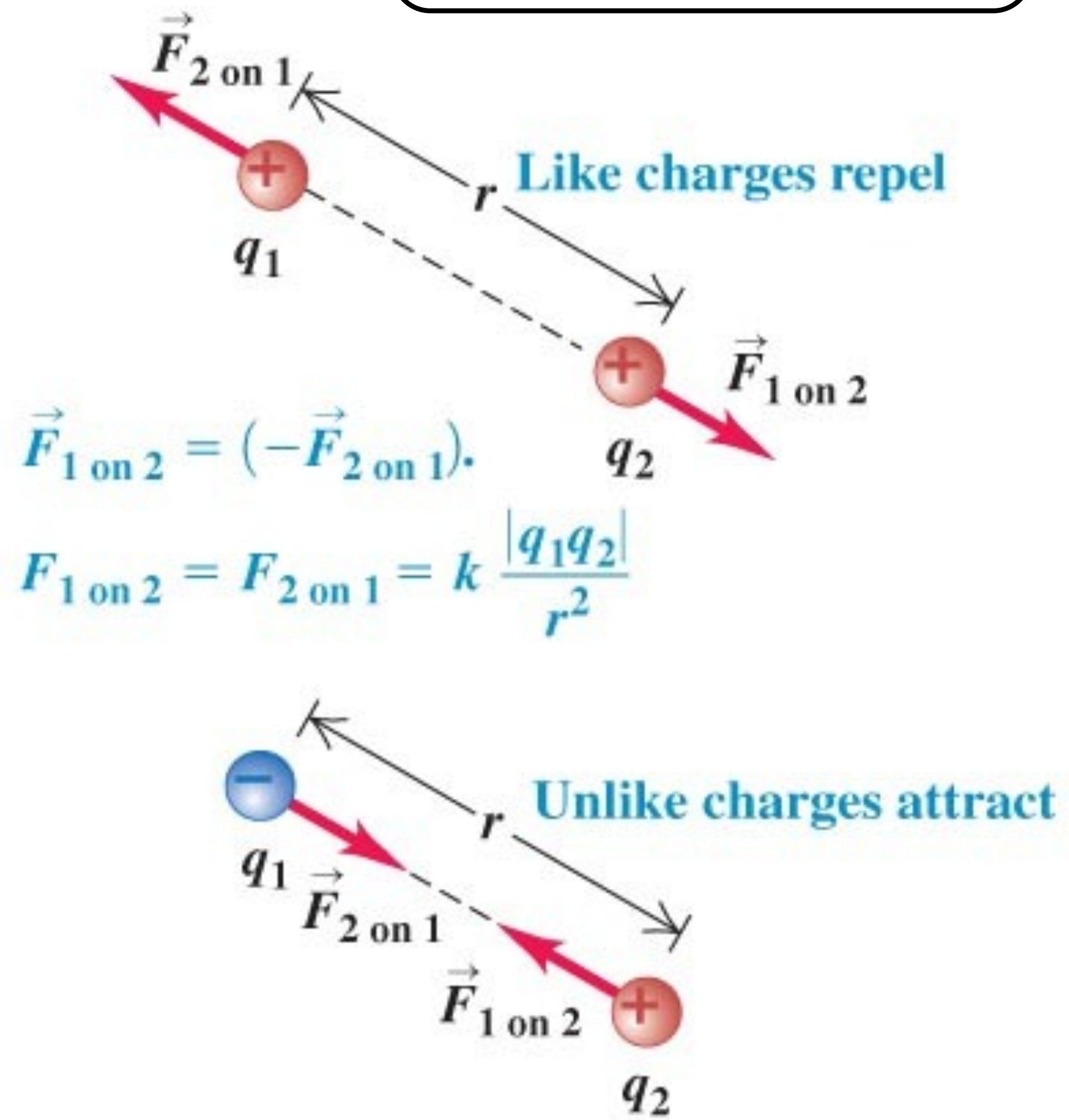
➜ the charge of a proton (or electron) seems to be the minimum allowed unit of charge in nature, $e = 1.60217653(14) \times 10^{-19}$ C

the force between charges - Coulomb's law

$$F = k\,\frac{|q_1\, q_2|}{r^2}$$



(a) A torsion balance of the type used by Coulomb to measure the electric force



(b) Interaction of like and unlike charges

the force between charges - Coulomb's law

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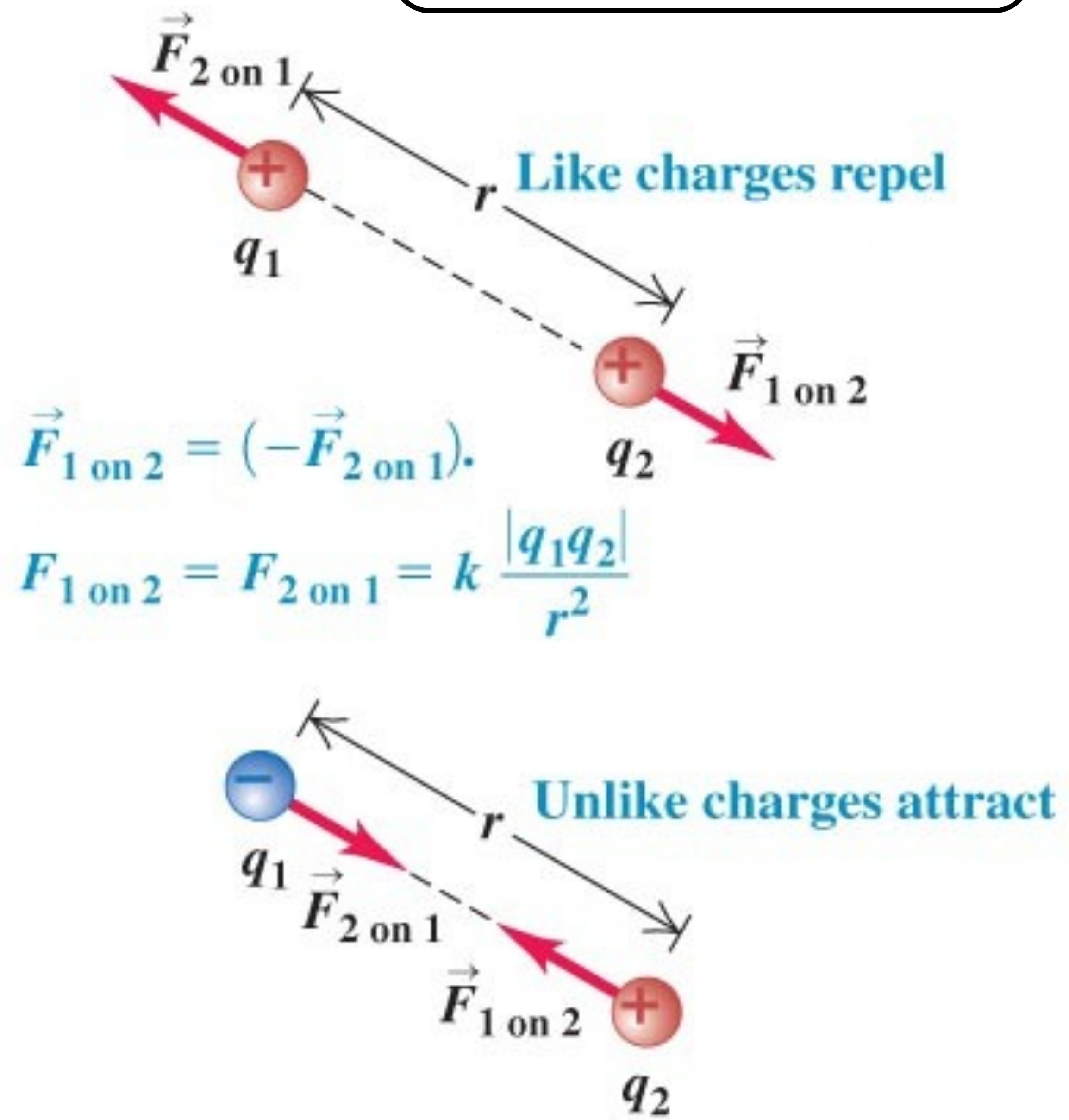
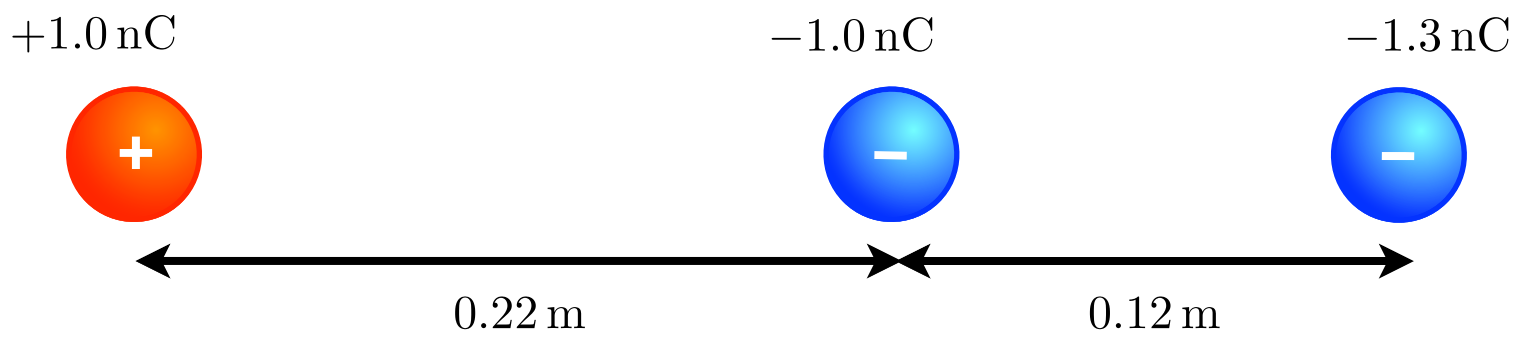


(b) Interaction of like and unlike charges

$$k = 8.99 \times 10^9\,\mathrm{Nm^2/C^2}$$

the force between charges - Coulomb's law

Three charges are fixed in position on a line as shown.



What is the magnitude and direction of the total electrostatic force on the middle charge ?

the force between charges - Coulomb's law

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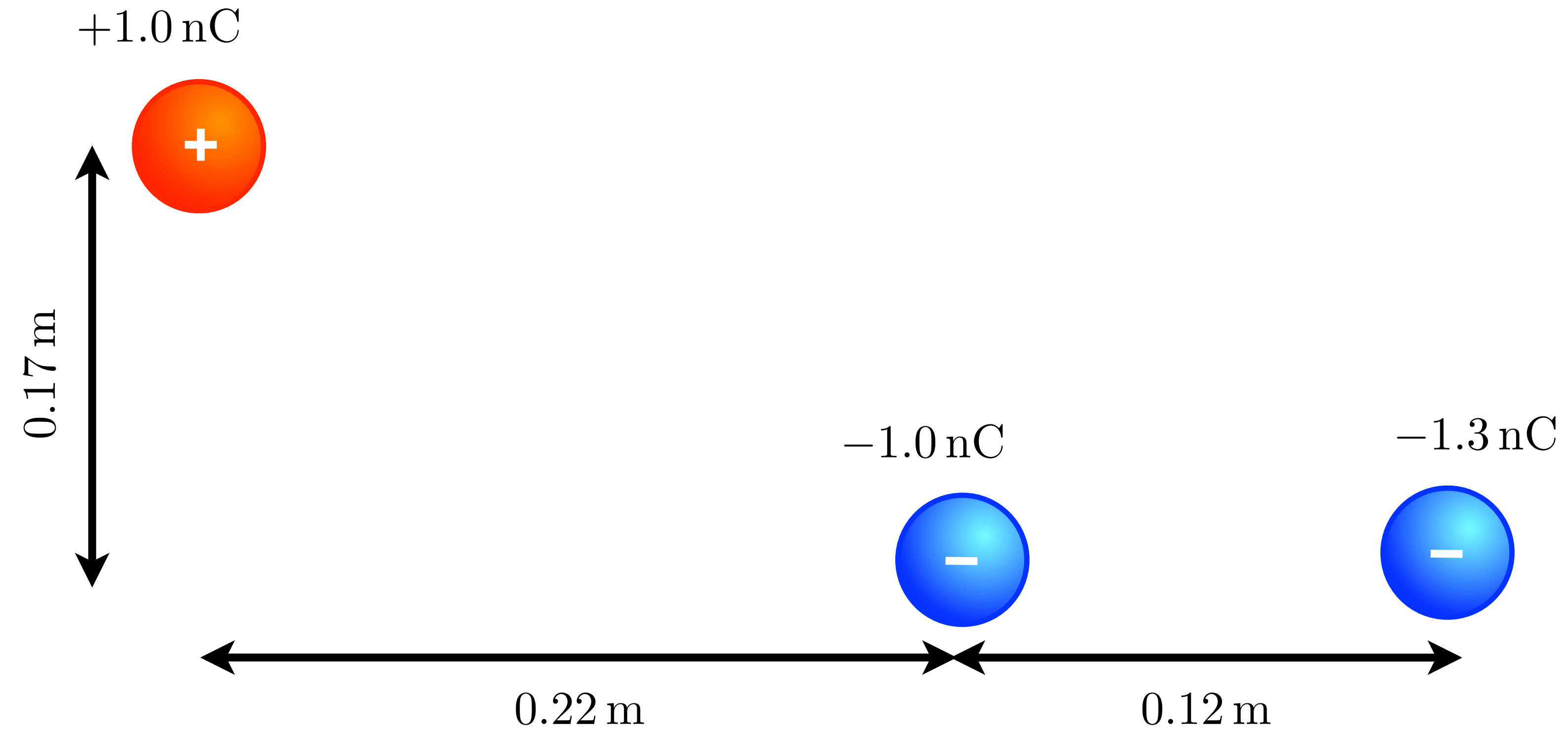

What is the magnitude and direction of the total electrostatic force on the -1.0 nC charge ?

the electric field

suppose we set up the two charges as shown

the electric field

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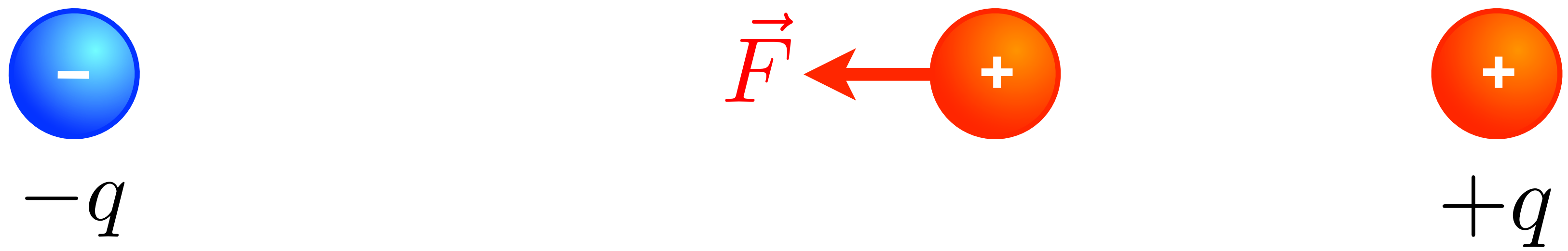

a third charge placed in between feels a force

how does it know the other charges are there ?

the charges produce an ‘**electric field**’

the electric field

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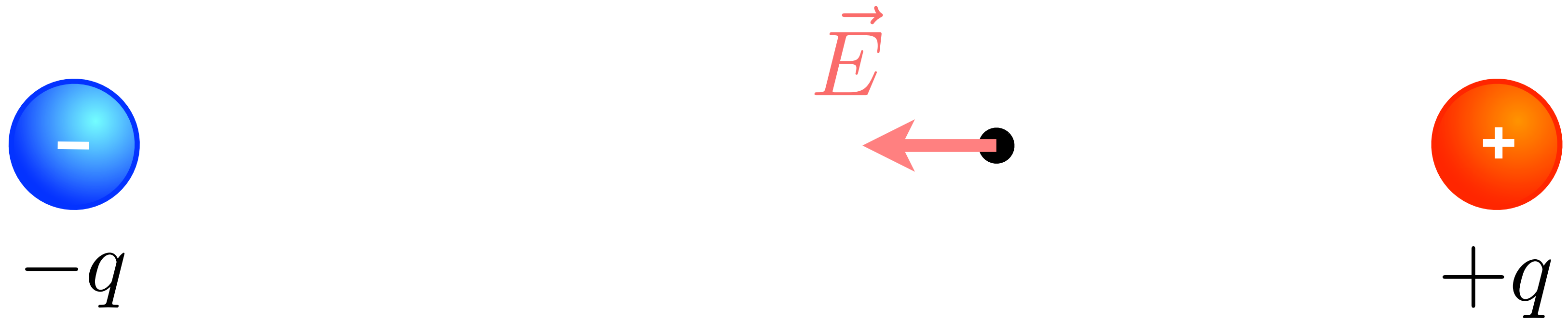


a third charge placed in between feels a force

how does is know the other charges are there ?

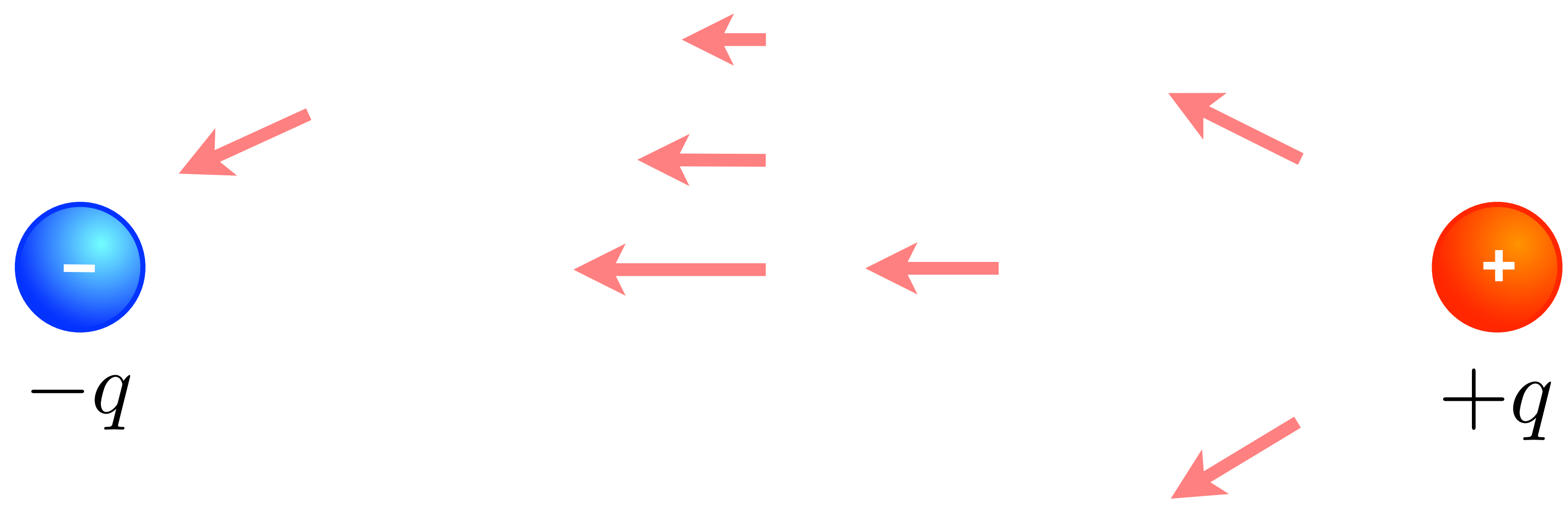
the charges produce an **'electric field'**

at every point in space there is a vector $\vec{E}$

a charge *q* placed at that position feels a force $\vec{F} = q\vec{E}$

the electric field

suppose we set up the two charges as shown



the charges produce an '**electric field**'

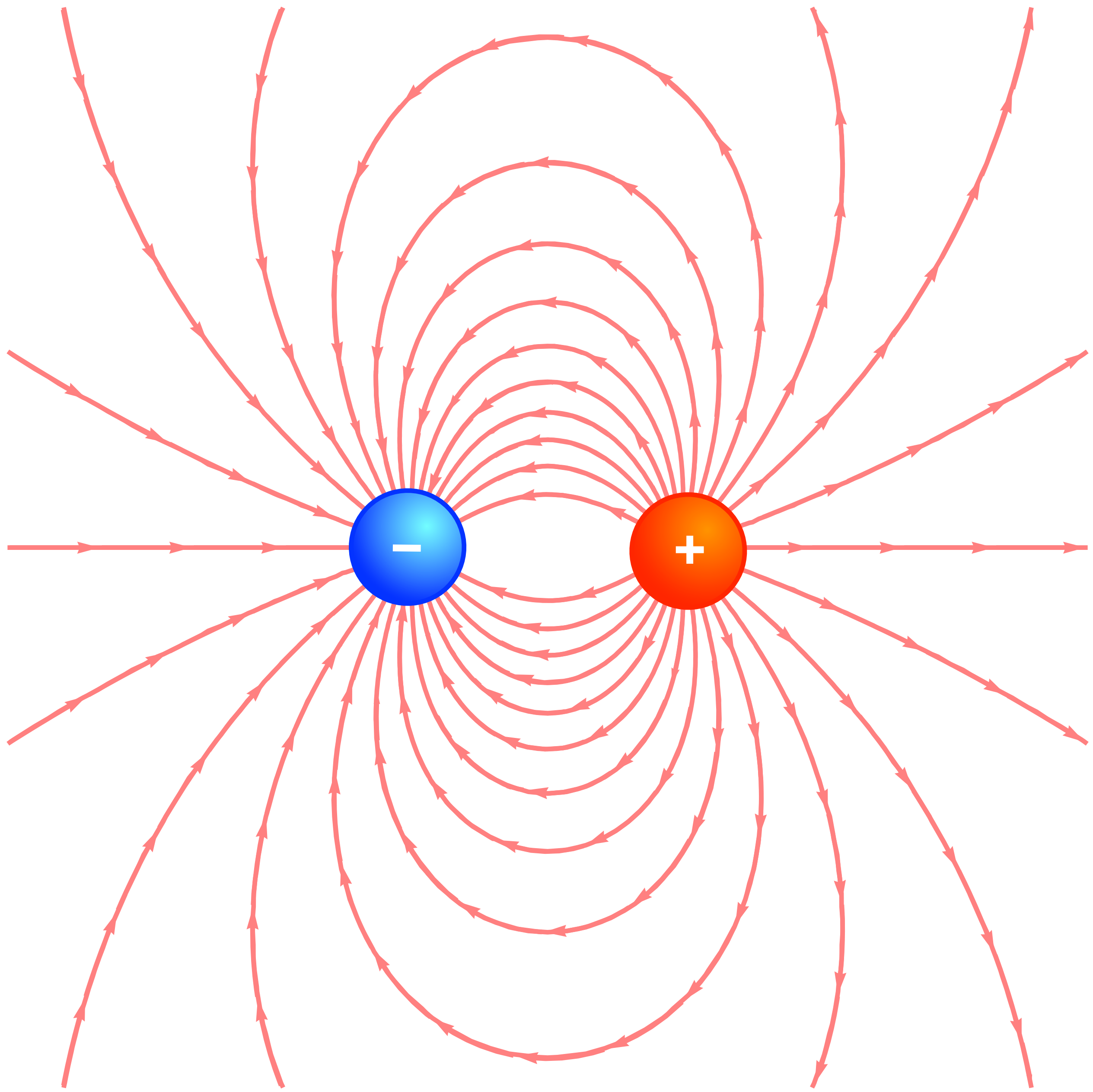
at every point in space there is a vector $\vec{E}$

$$\vec{E} = \lim_{q \to 0} \frac{\vec{F}}{q}$$

put a 'test charge' at each point, measure the force it feels and divide out its charge

the electric field

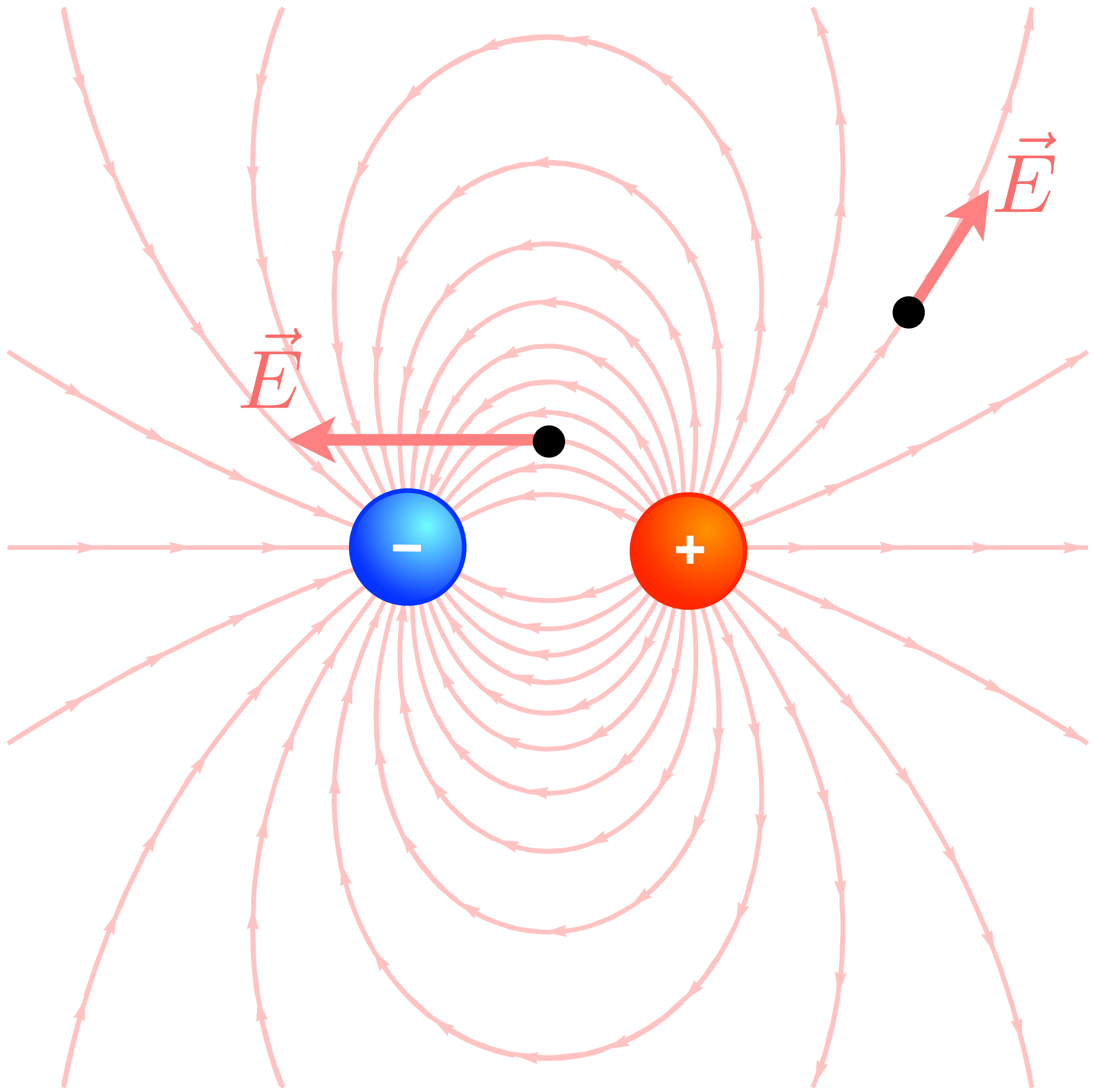
electric field line diagram



arrows show direction of E-field, density of lines shows magnitude of E-field

the electric field

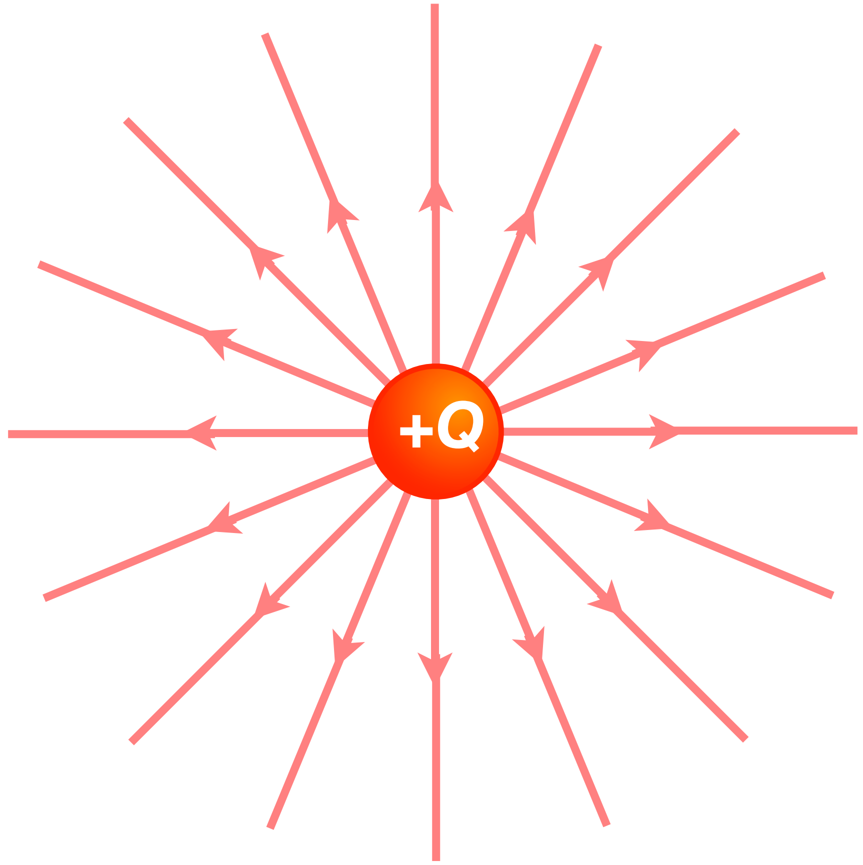
electric field line diagram



arrows show direction of E-field, density of lines shows magnitude of E-field

lines only begin and end on charges

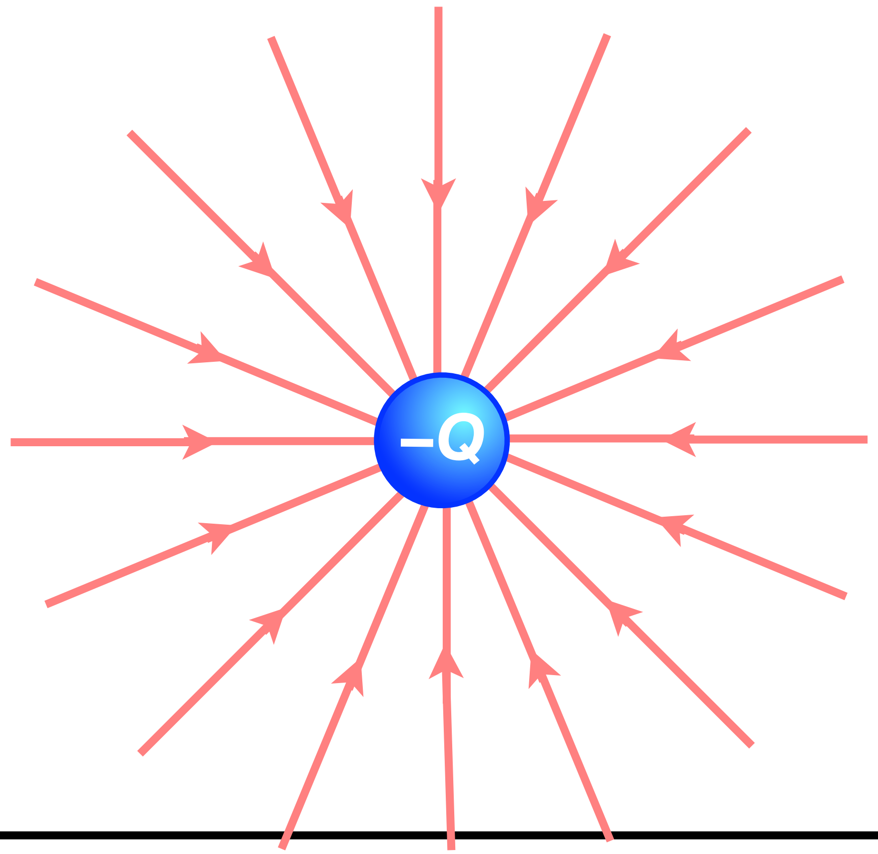
the electric field from a point charge



$$F = k\frac{|qQ|}{r^2}$$

$$\vec{E} = \lim_{q\to 0}\frac{\vec{F}}{q}$$

$$\boxed{E = k\frac{|Q|}{r^2}}$$



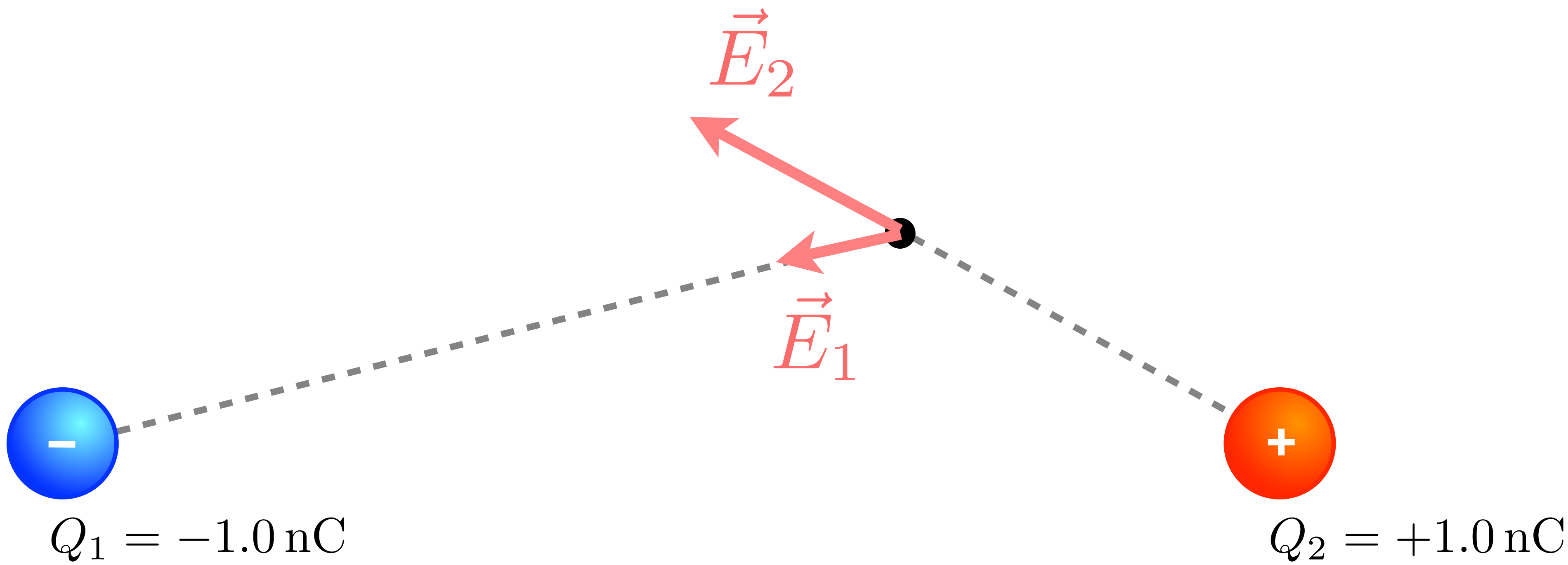
$$k = 8.99\times 10^9\,\mathrm{Nm^2/C^2}$$

superposition of electric fields

the total electric field at any point is the vector sum of the electric fields from all the point charges around it

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots$$

e.g.



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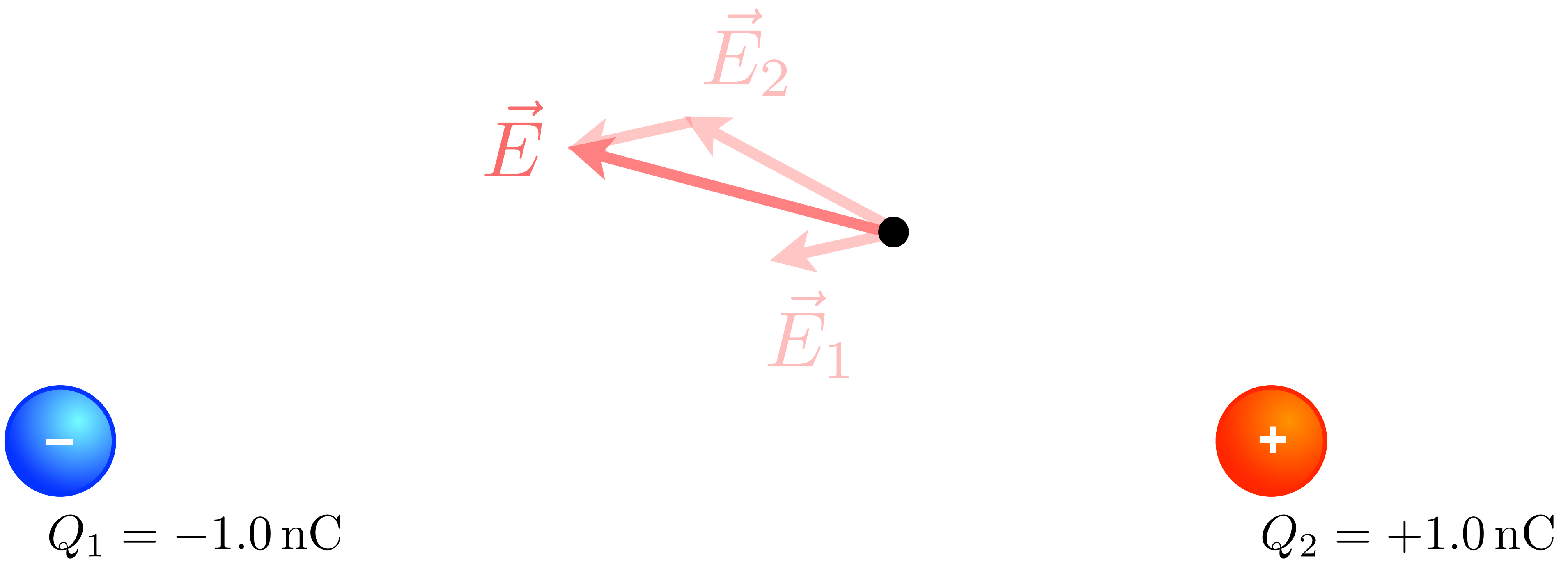

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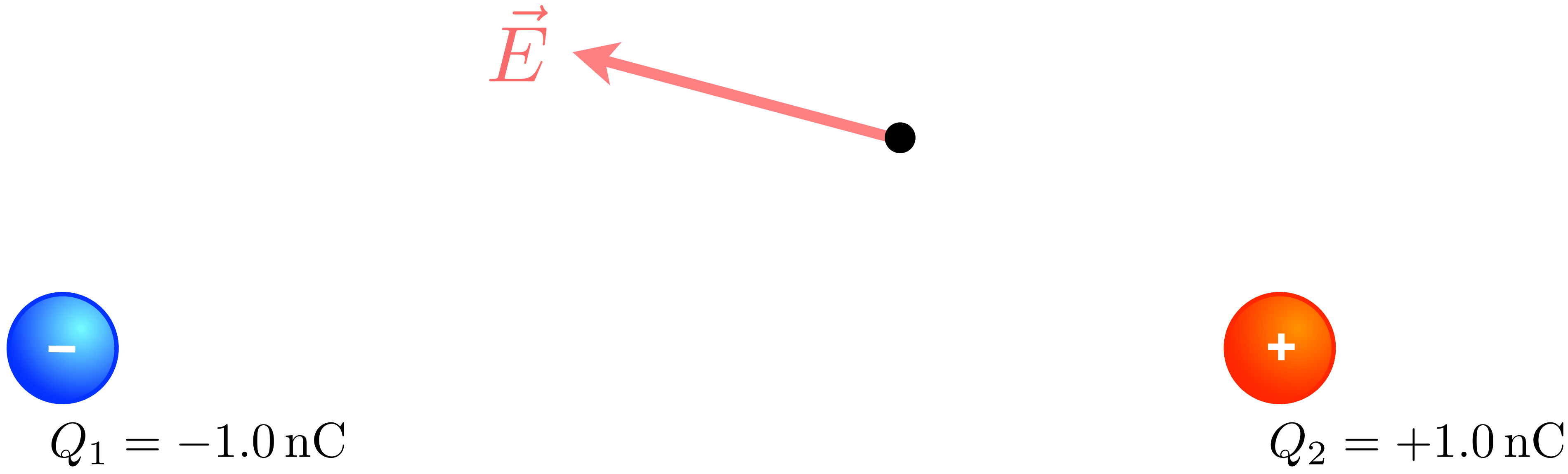
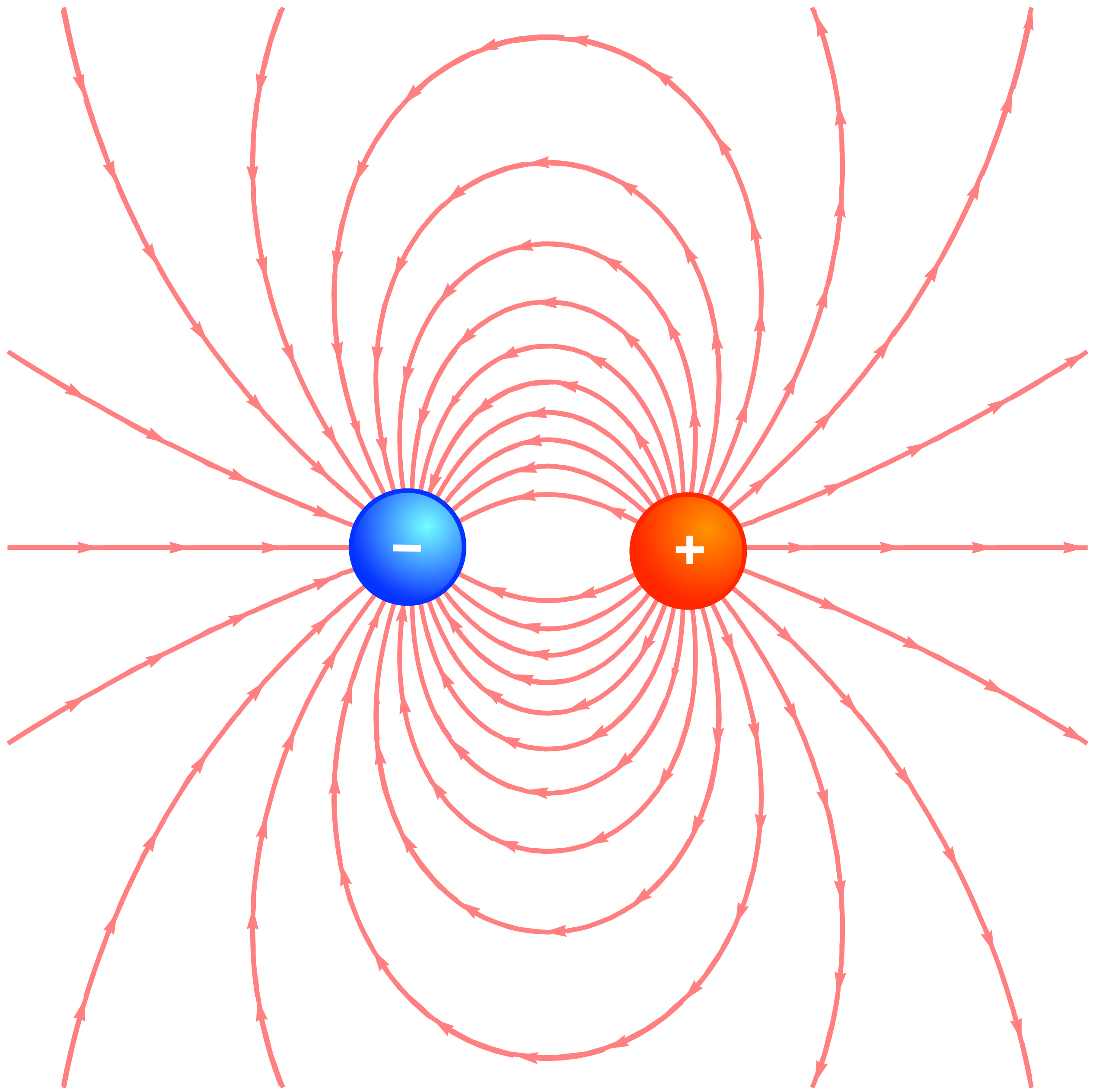


the electric field

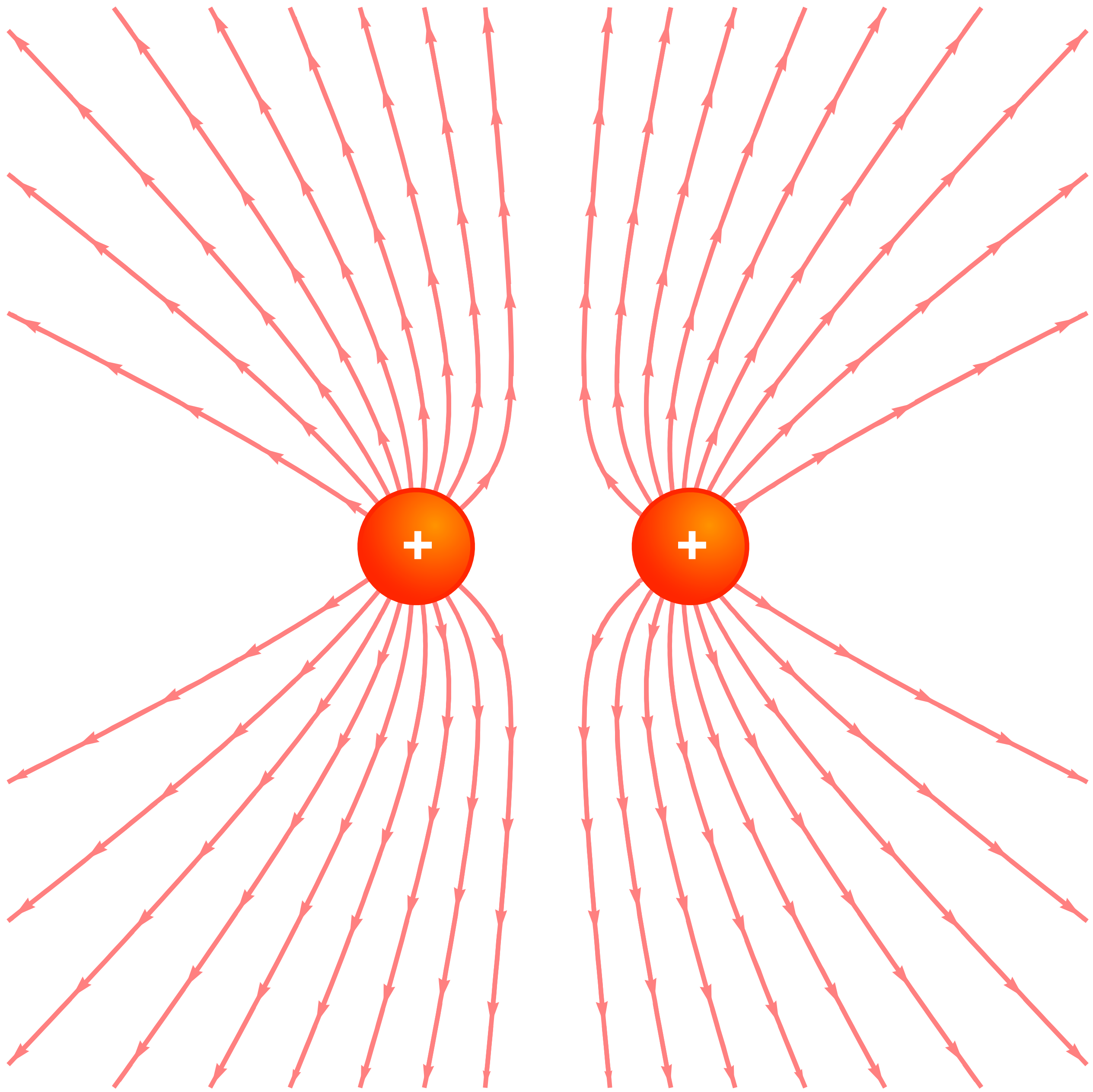
electric field line diagram



arrows show direction of E-field, density of lines shows magnitude of E-field

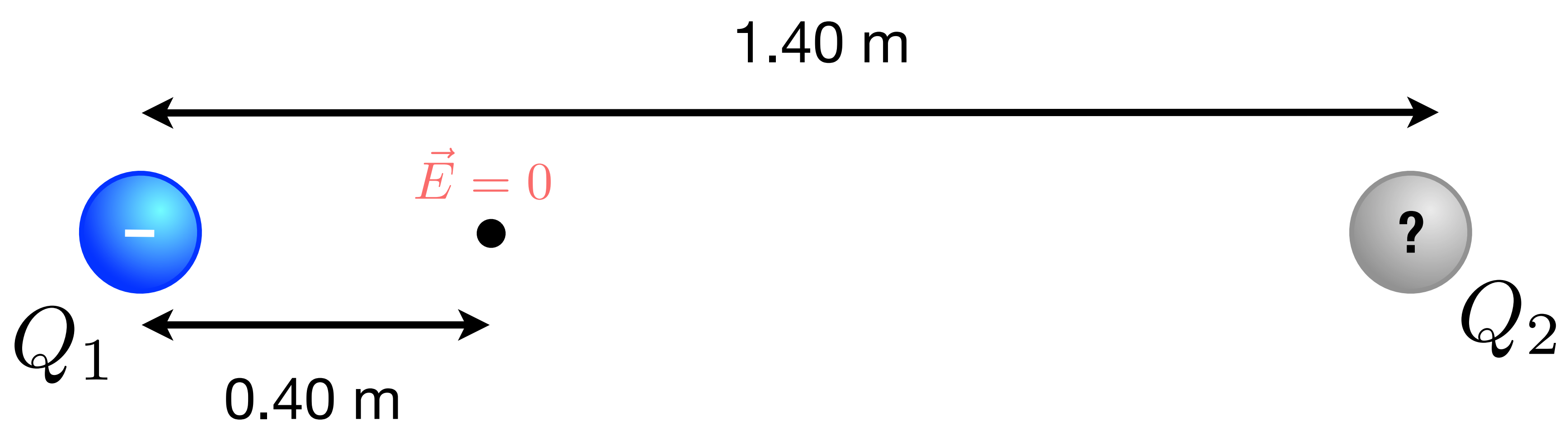
the electric field

two equal positive charges



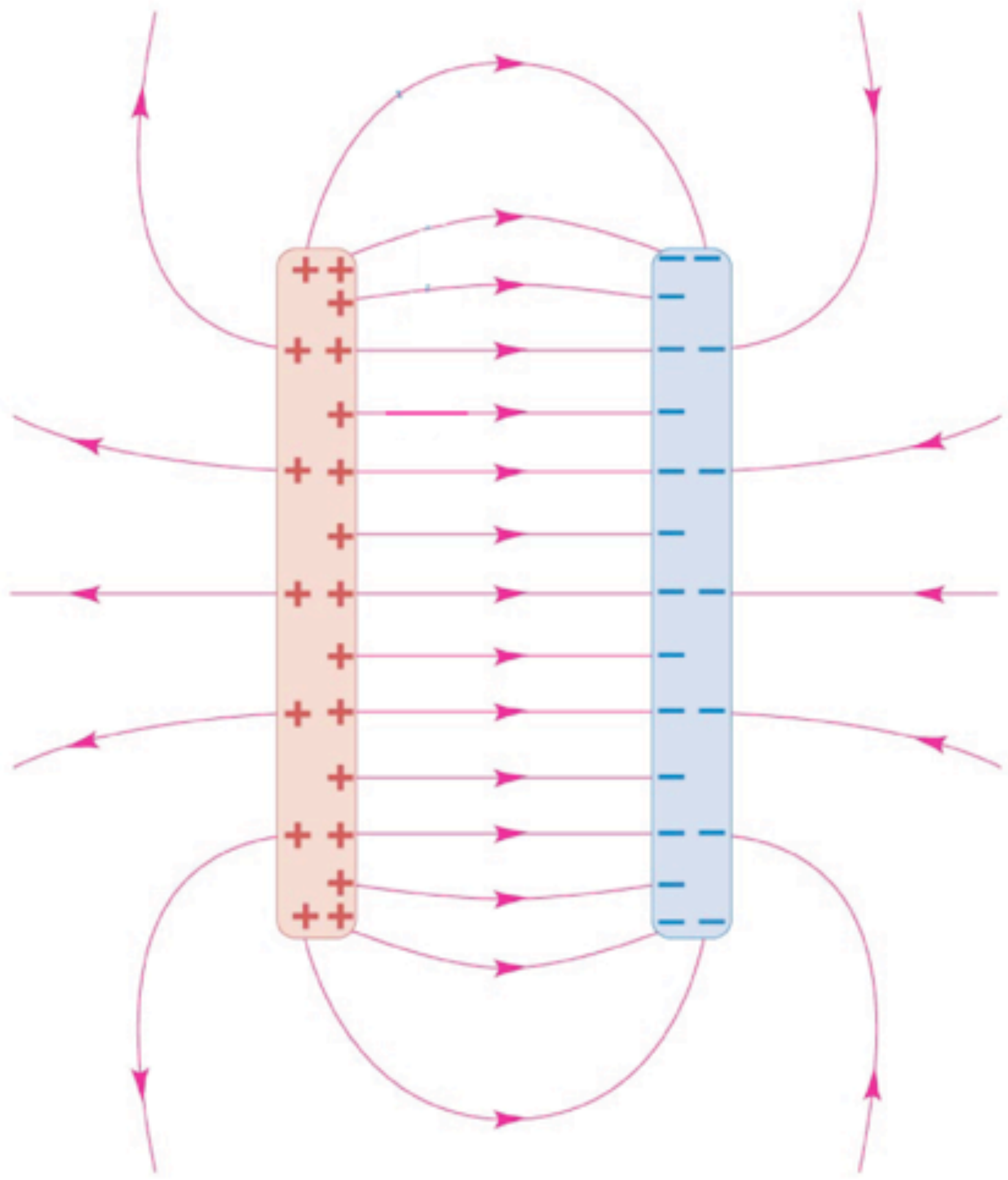
two charges

Two charges are separated by a distance of 1.40 m. The electric field produced by the two charges is found to be zero a distance of 0.40 m from the left charge along the line joining the two charges. Find Q_2 .



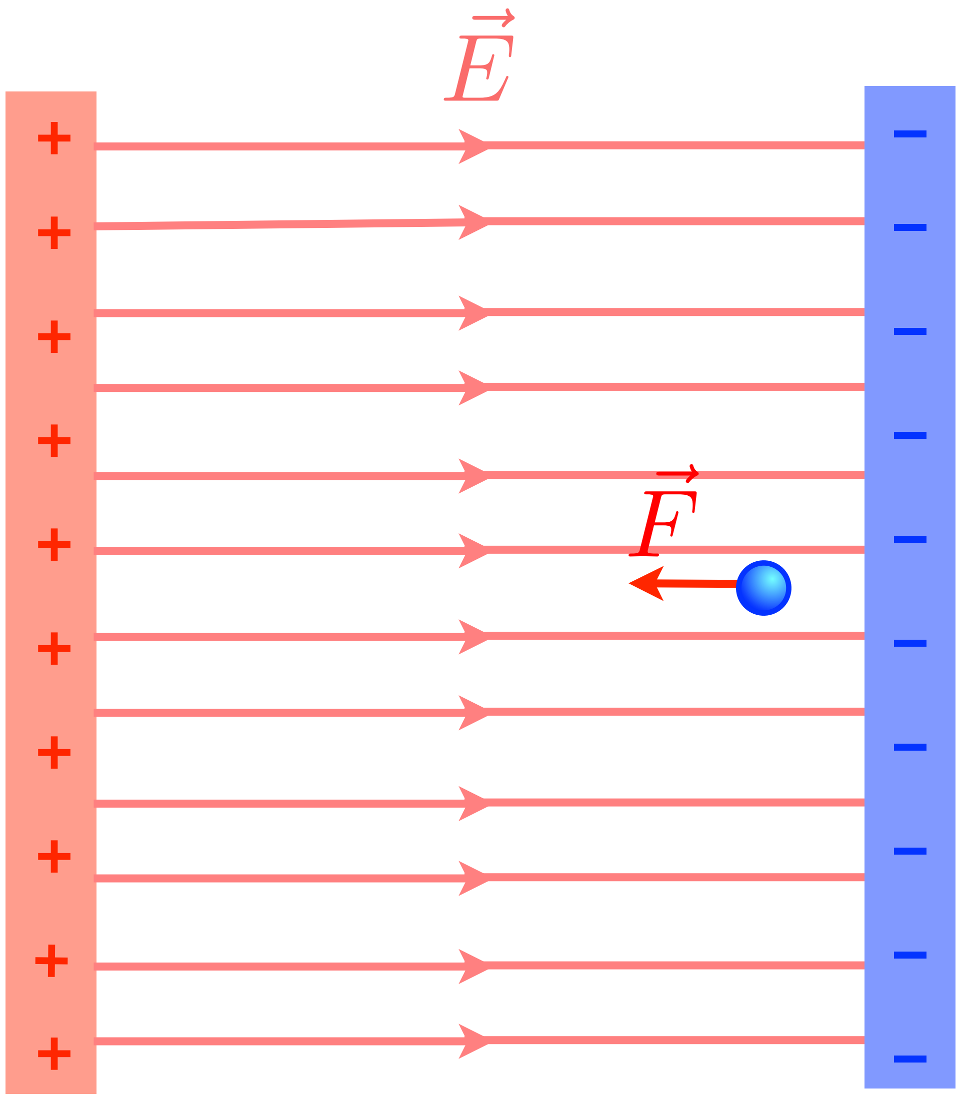
$$Q_1 = -1.0\,\mu\mathrm{C}$$

electric field configurations - charged parallel plates



large charged parallel plates cause an almost uniform field in the gap between them

electron in a capacitor



An electron escapes from the negative plate of a capacitor producing a uniform electric field of magnitude $2.00{\times}10^{3}$ N/C.

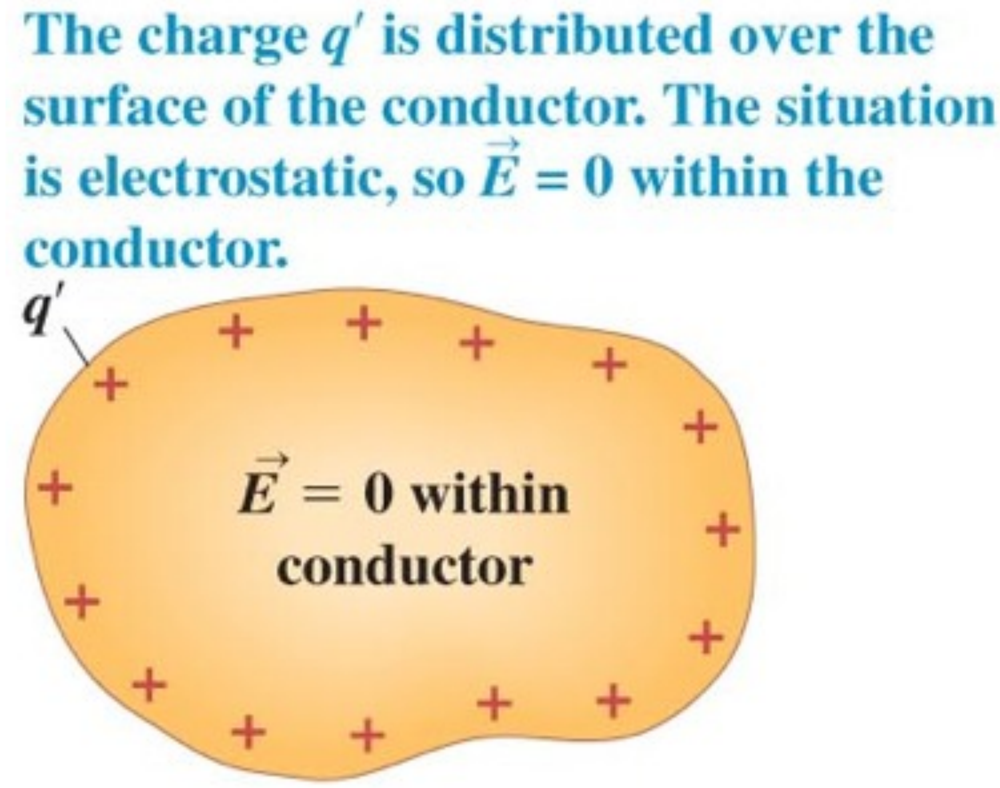
Starting from rest, the electron takes $2.00{\times}10^{-8}$ seconds to travel to the positive plate. How far apart are the capacitor plates ?

electric field in a conductor

inside a conducting material, the electric field must be zero in an electrostatic situation

imagine it wasn't - the electric field would cause forces on the 'free' charges and they'd accelerate, so the situation wouldn't be static

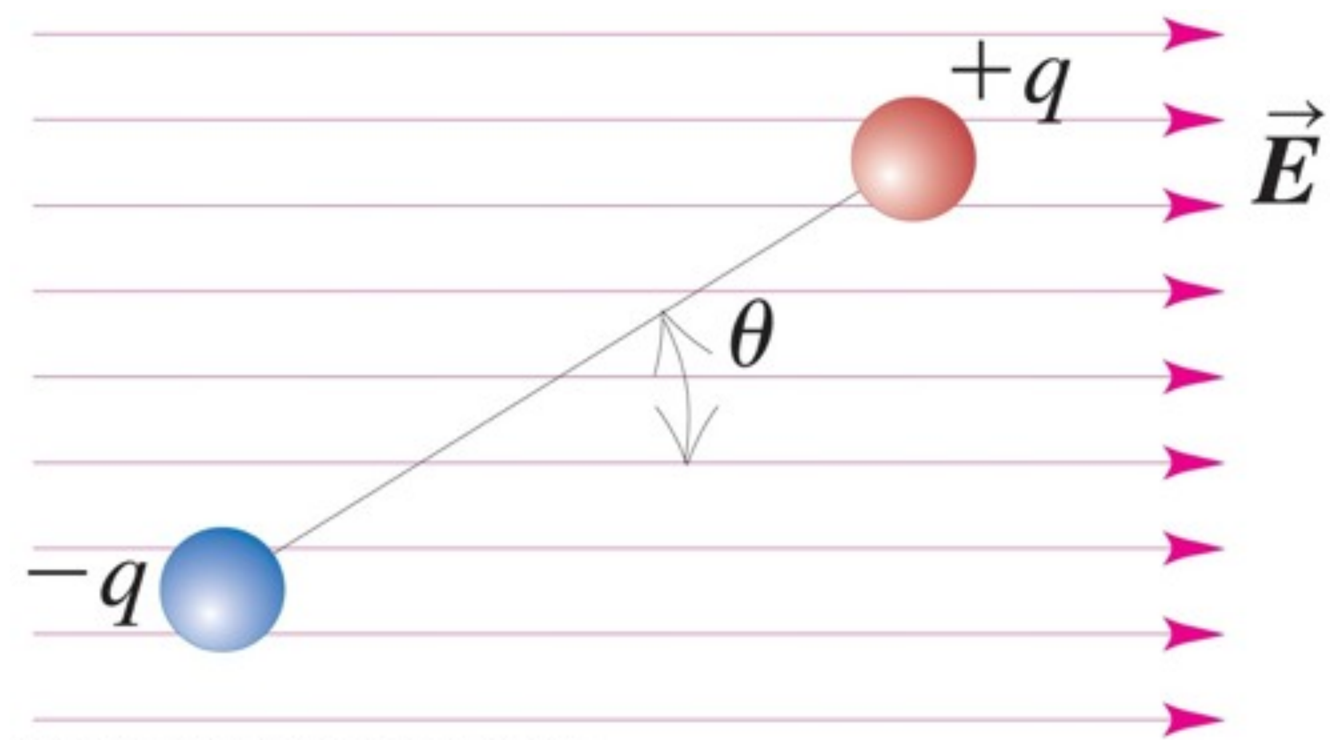
the 'free' charges will always rapidly rearrange themselves to produce zero ***E***-field inside the conductor



(a) Solid conductor with charge q'

electric dipole in a uniform electric field

a dipole is shown - it is easy to see that the total force on the dipole is zero



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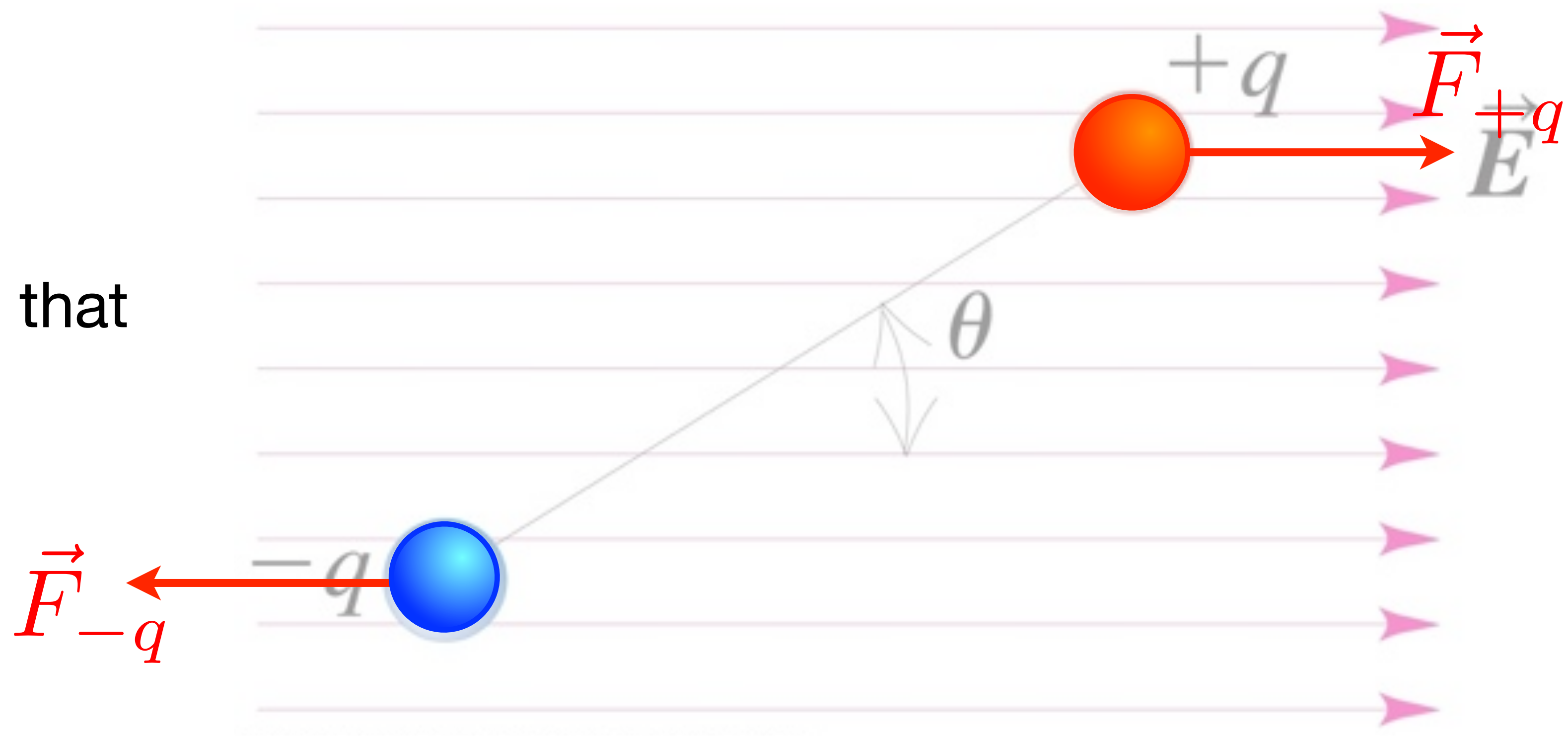

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but there is a torque on the dipole that'll cause it to rotate

$$\tau = 2qEd\sin\theta$$

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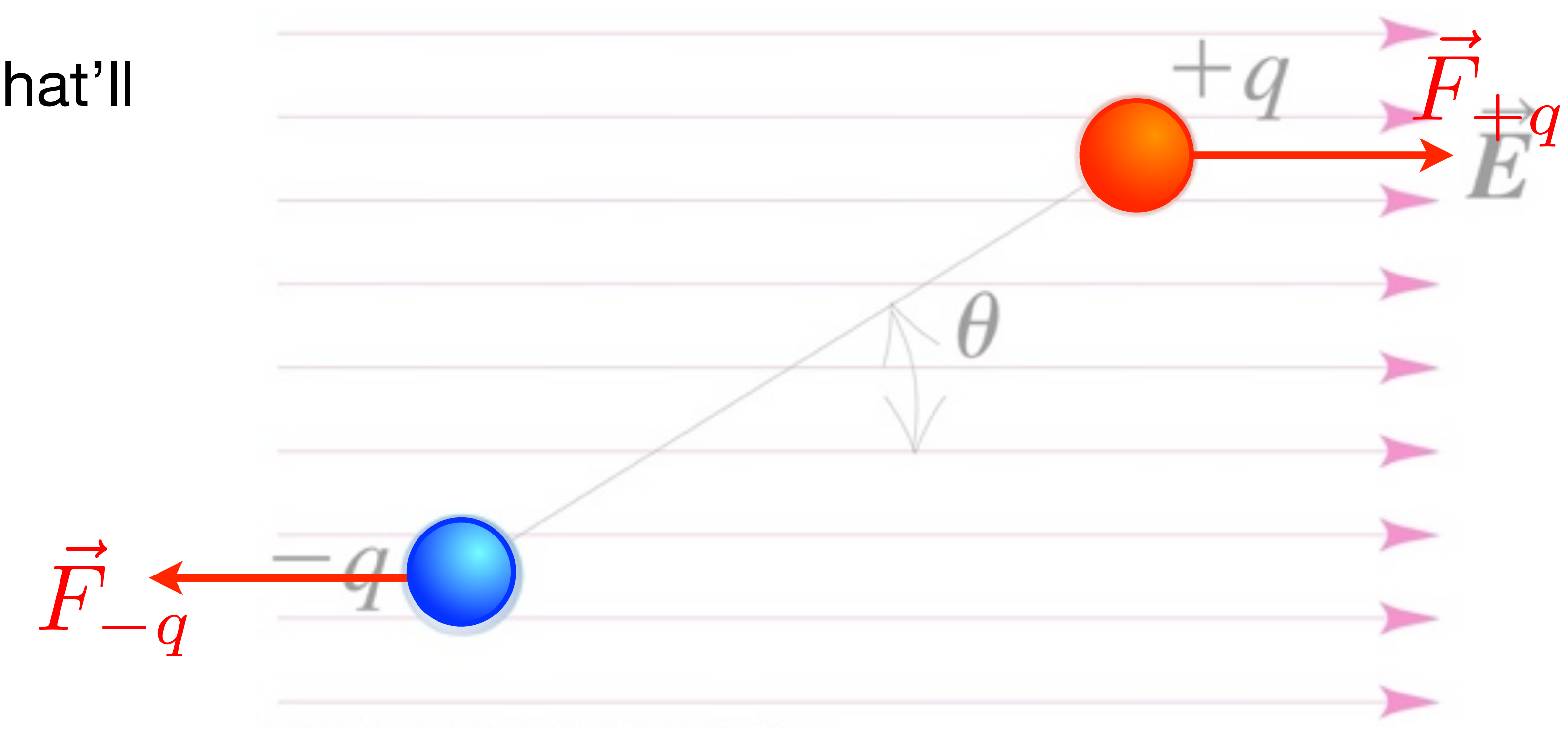
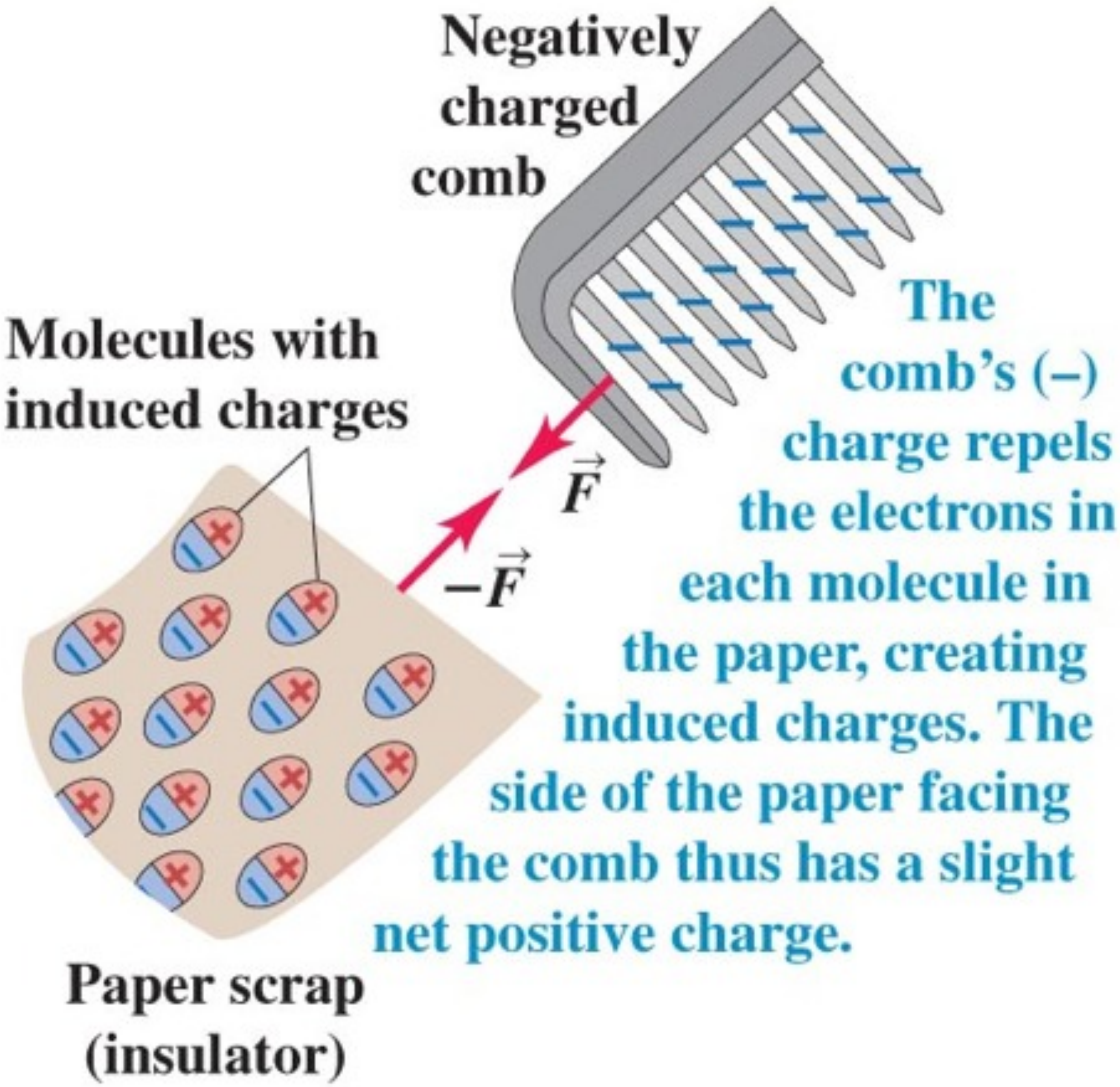
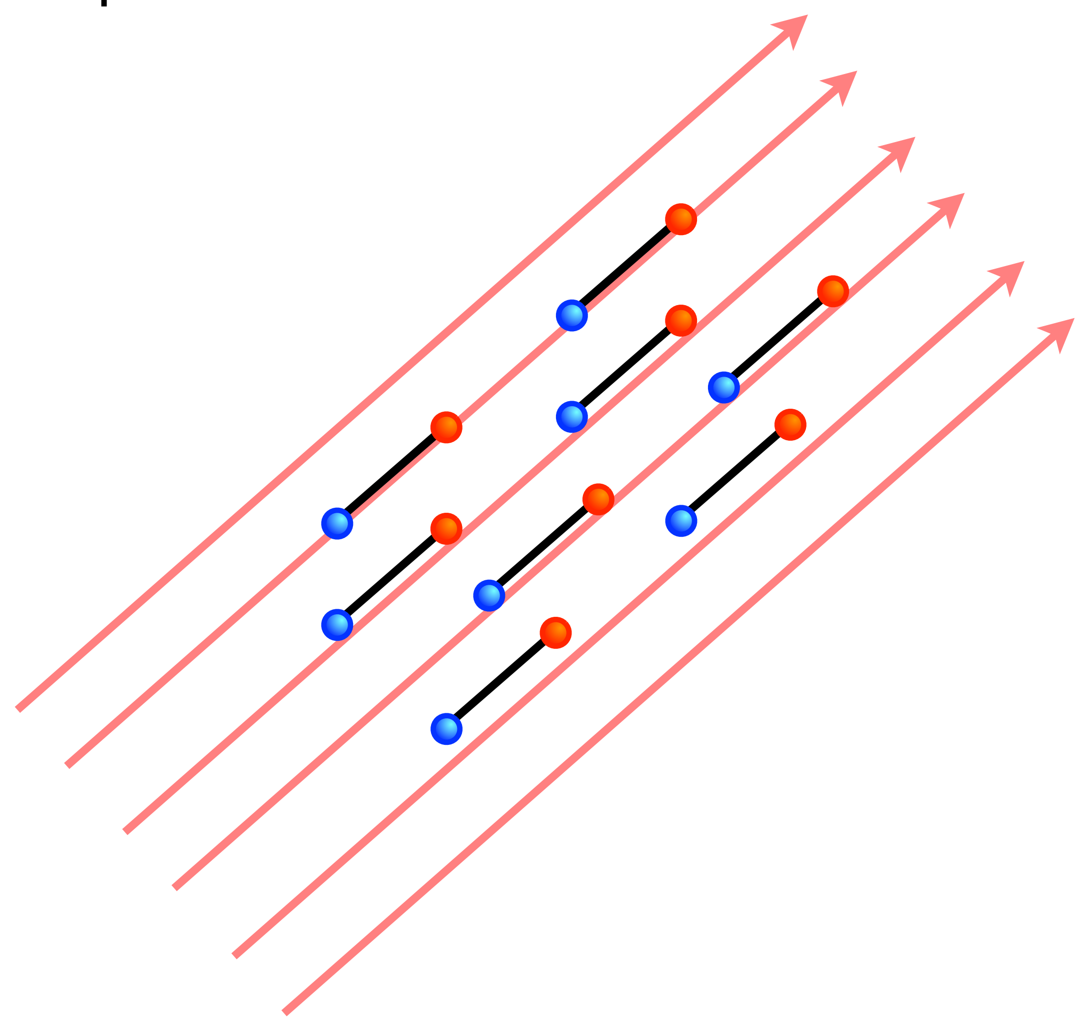


two orientations feel zero torque :

polarization of insulators

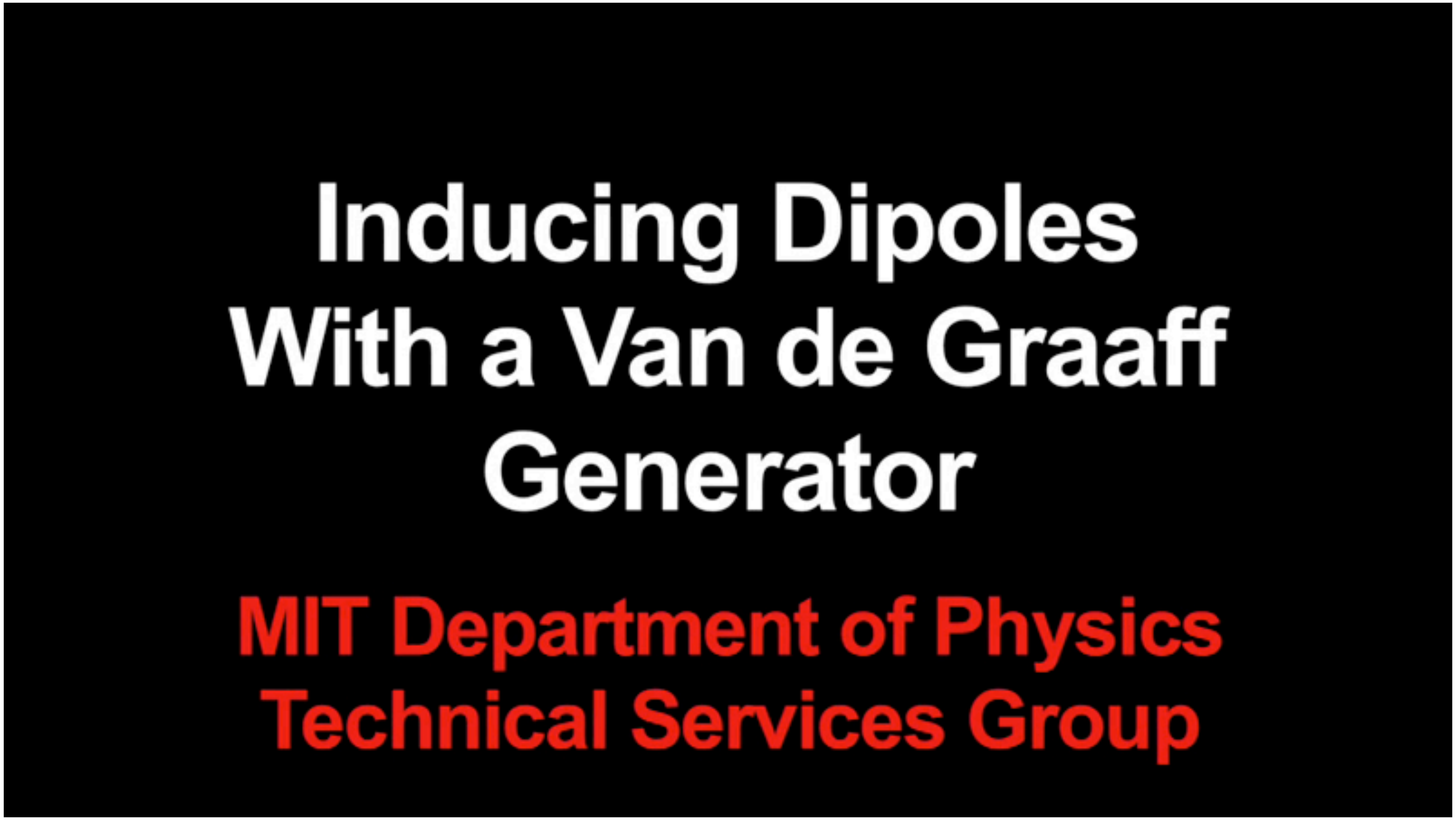


an insulating material made from 'polar' molecules which behave like electric dipoles can thus be polarized



electric dipole in an electric field

➜ use induction to form a dipole
➜ watch how it lines up in the electric field from the vdG sphere



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