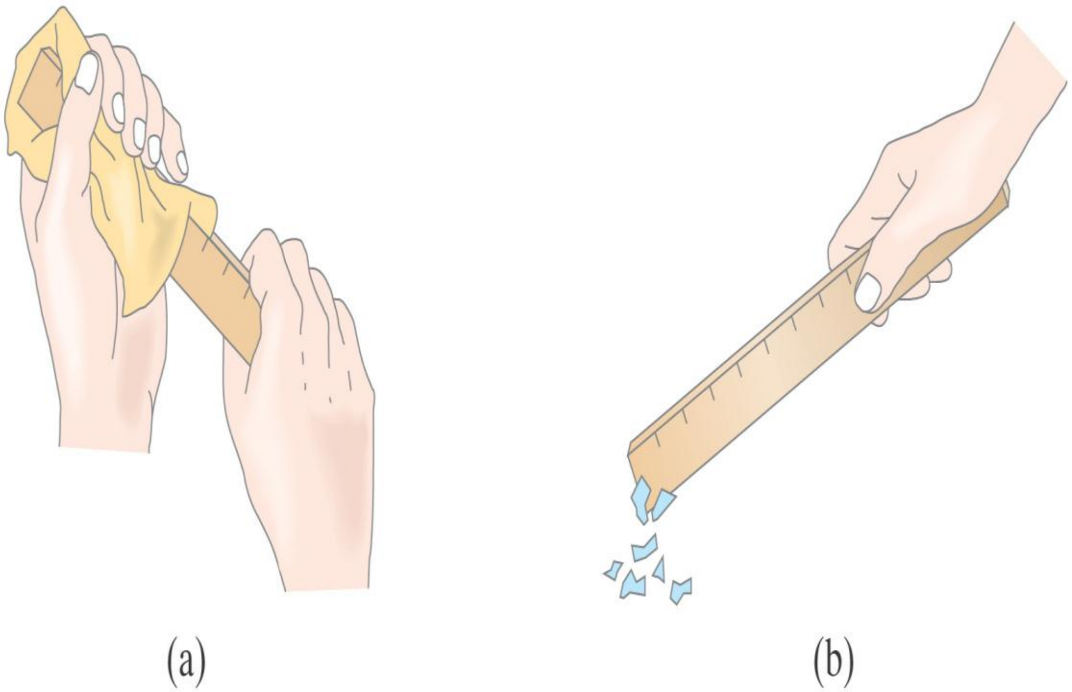
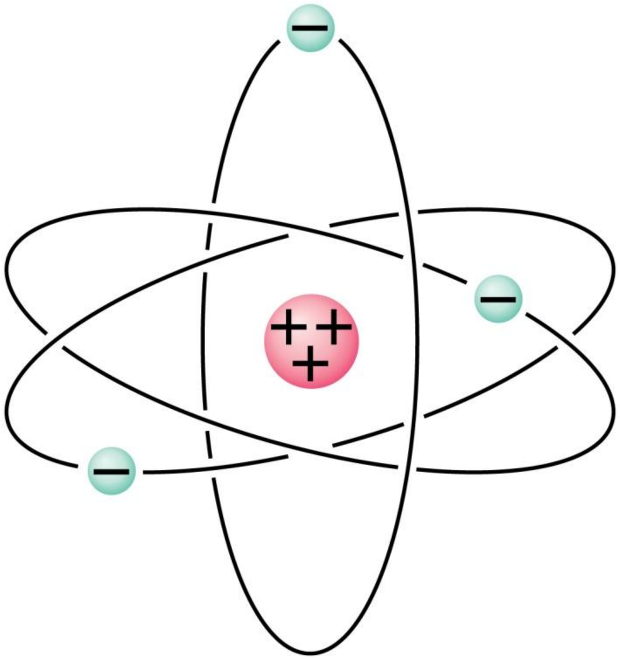
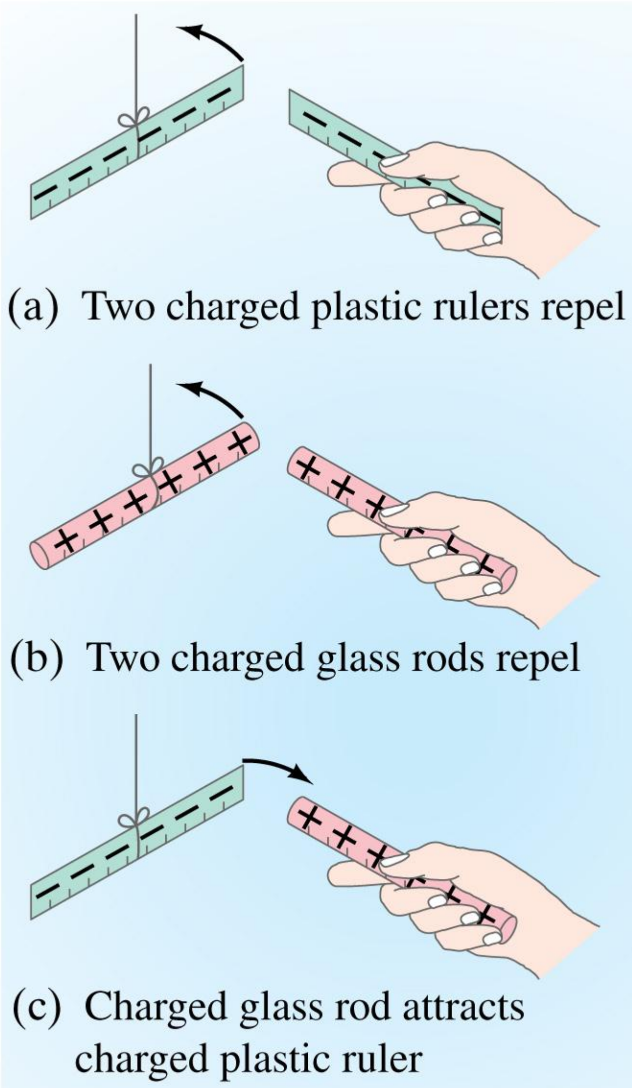
Chapter 16
Electric Forces & Electric Fields

What are the electrons doing?







Negatively charged objects have gained excess electrons

Positively charged objects have lost electrons – have excess positive

elementary charge is quantized e = 1.6 x 10^{-19} C

proton q= + 1.6 x 10^{-19} C

electron q= – 1.6 x 10^{-19} C

16.3 Insulators and Conductors

Conductor:

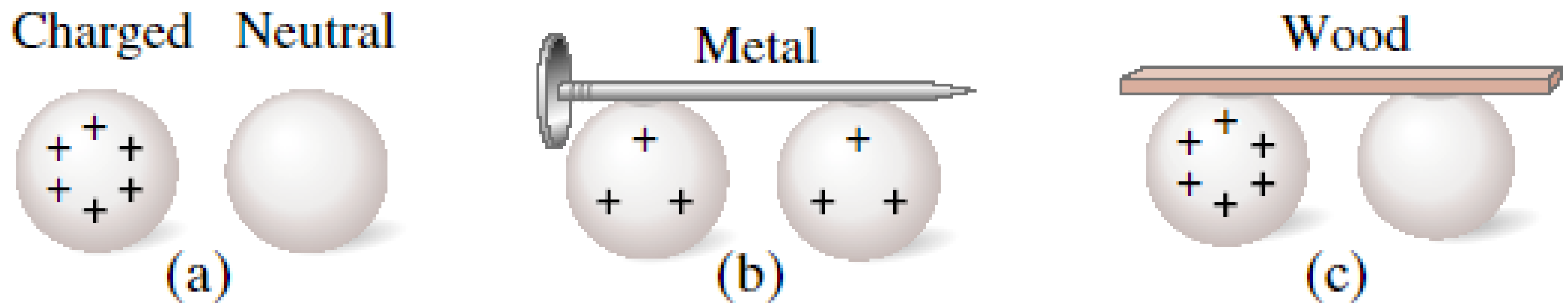
Charge flows freely

Metals

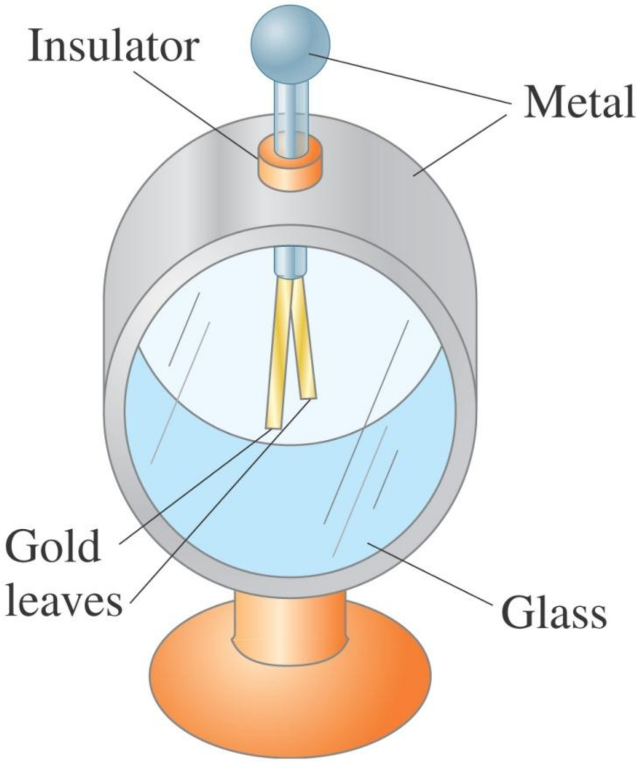
Insulator:

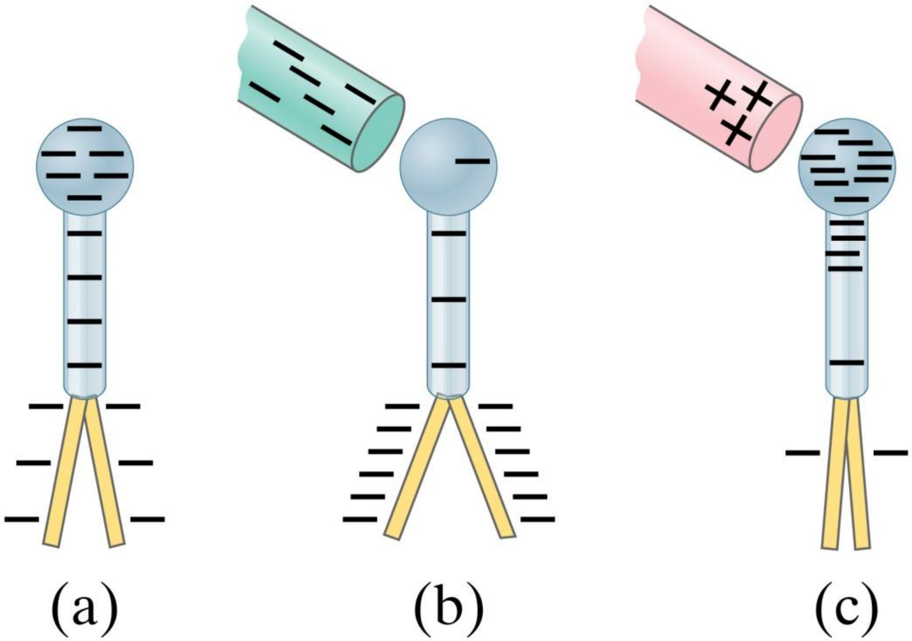
Almost no charge flows

rubber, plastic, wood,



The Electroscope





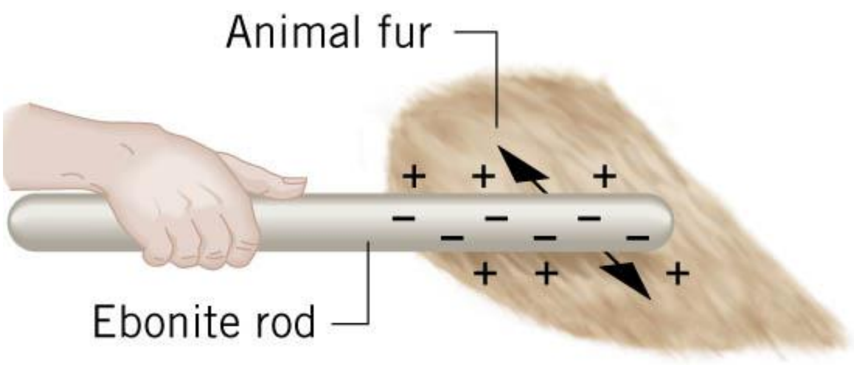
Grounding

- Neutralizing electric charge on an object by providing a path for excess charge to be transferred to Earth
- Electrical equilibrium reached by:
  – excess electrons leaving to ground
  – lack of electrons being replenished by ground
  – touching charged object with hand
  – touching it to plumbing fixture

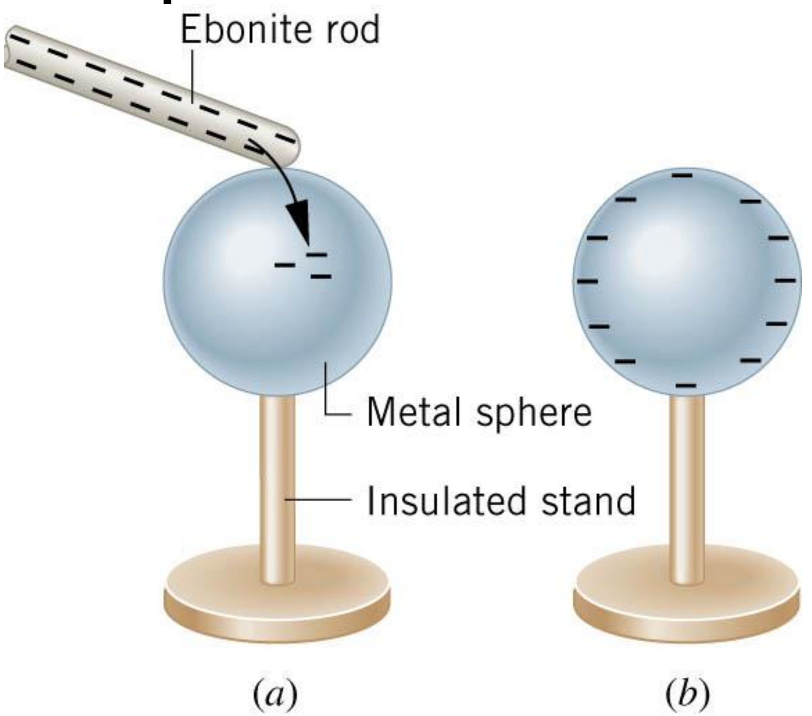
Not the correct way to ground

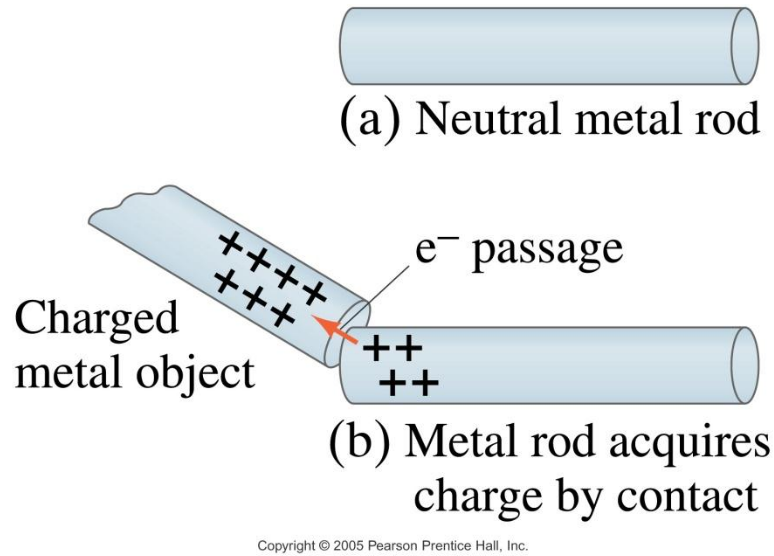
3 methods of charging an object

1. Friction – rubbing contact that transfers electrons from one object to another



2. Conduction – touching a charged object to another to transfer electrons between objects

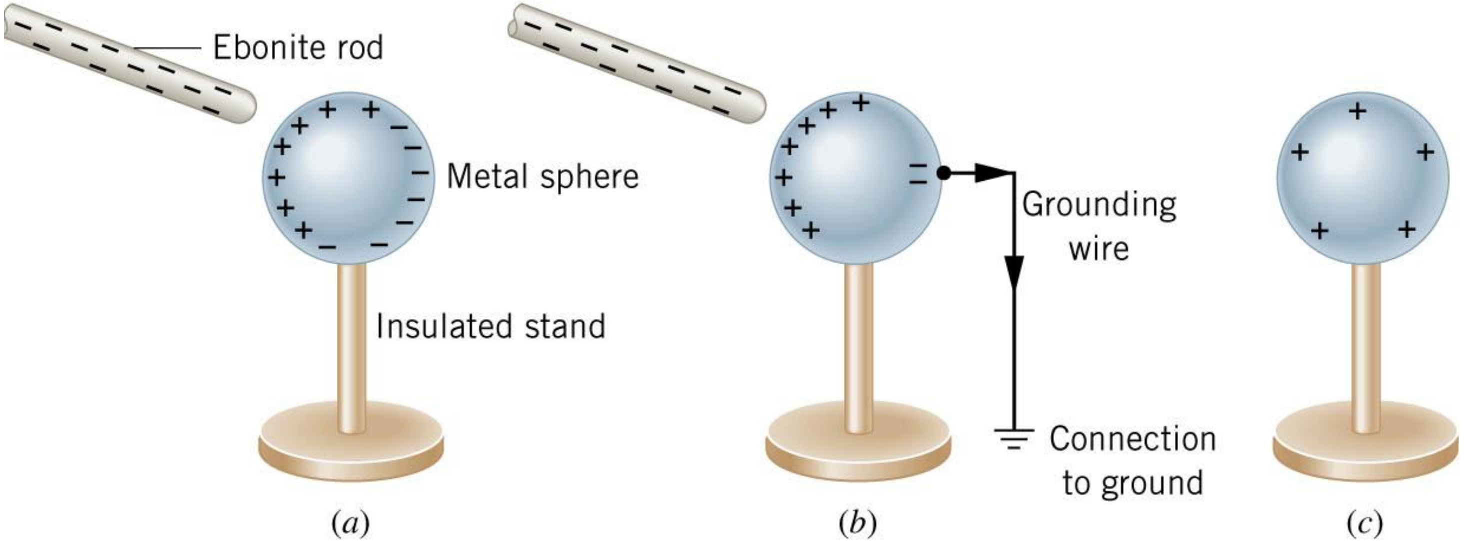




Charge distributes across a symmetrical object uniformly

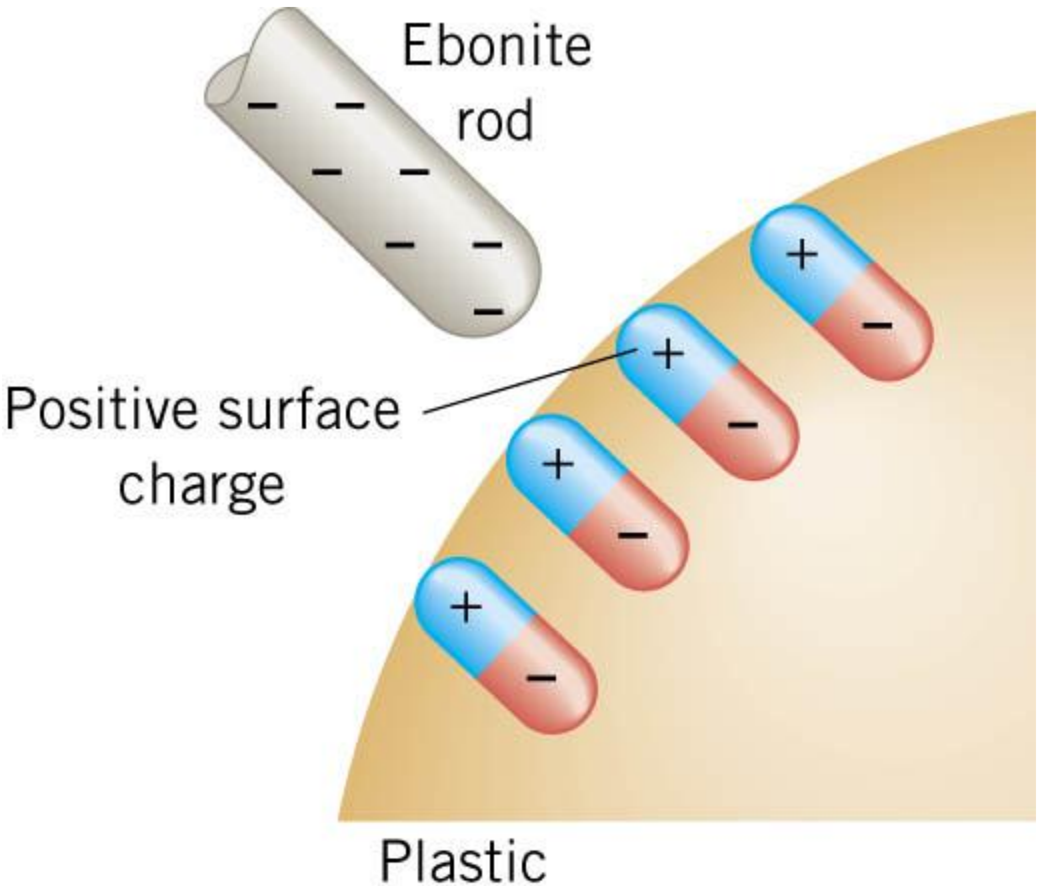
3. Induction

- no contact between charged object and the object acquiring charge
- charged object repels like charges out of object to ground or another object
- results in charged object with opposite sign



Redistribution of charge

- An electrically charged object attracts a neutral object



attraction only

Neutral object

[water jet]

Coulomb's Law of Electrostatic Force

- Inverse square law similar to gravitational force law
- Force = vector quantity
- Magnitude of force same on both charges

$$F = \frac{kq_1q_2}{r^2}$$

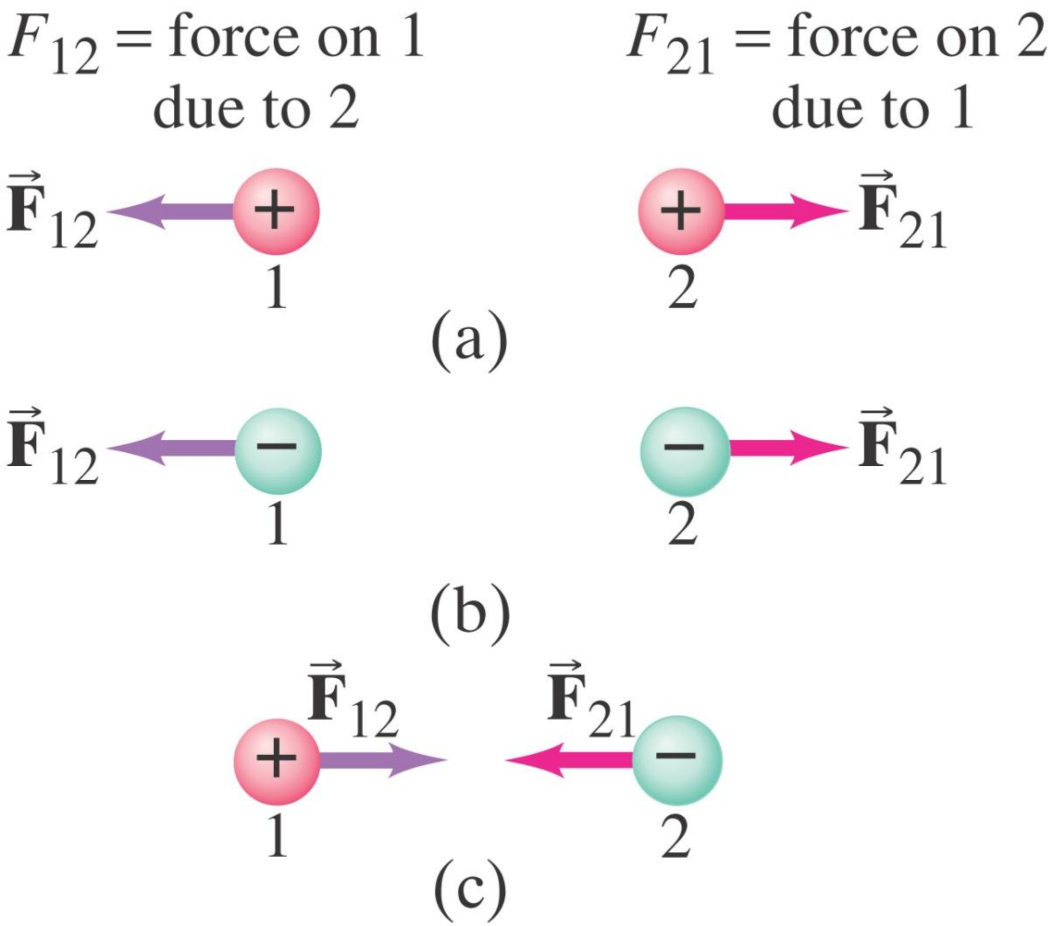
r = separation distance between charges

must be in meters

q_1 q_2 must be in coulombs not μC

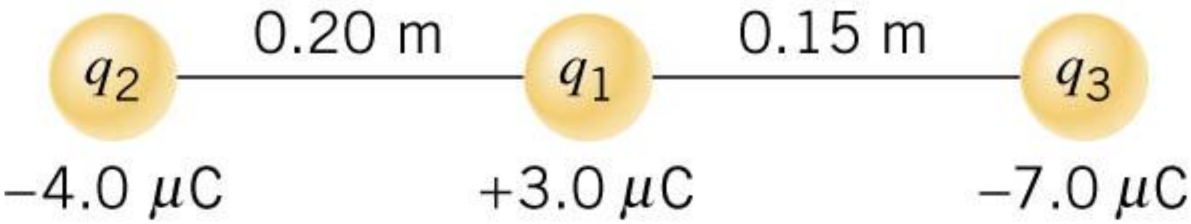
- Direction:
  - use magnitude of charge NOT sign in your force calculations
  - attraction or repulsion based on signs – draw vector diagrams!
- k = proportionality constant $9 \times 10^9 Nm^2/C^2$

Draw vector diagrams to determine net force



Net Force = Vector Sum

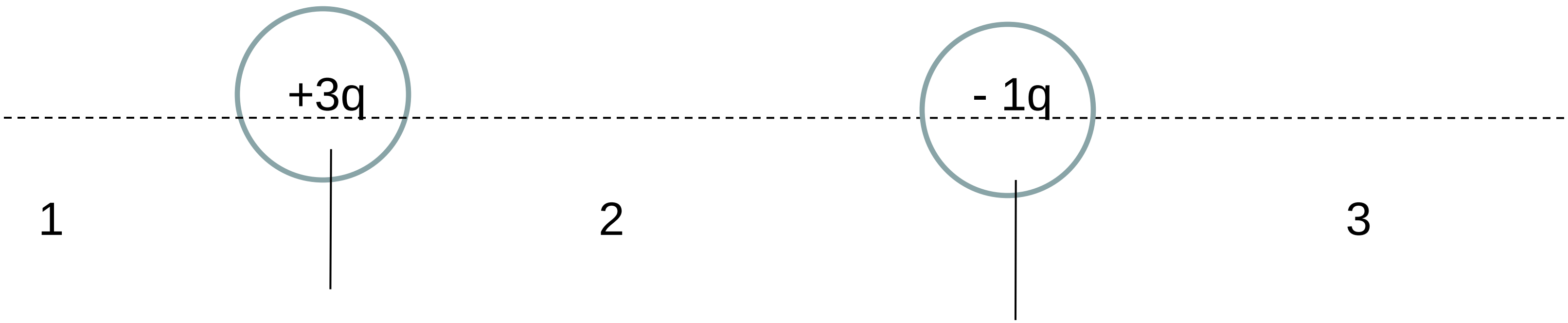
Example 4 – draw vector diagrams using force law for vector directions



(a)

(b) Free-body diagram for q_1

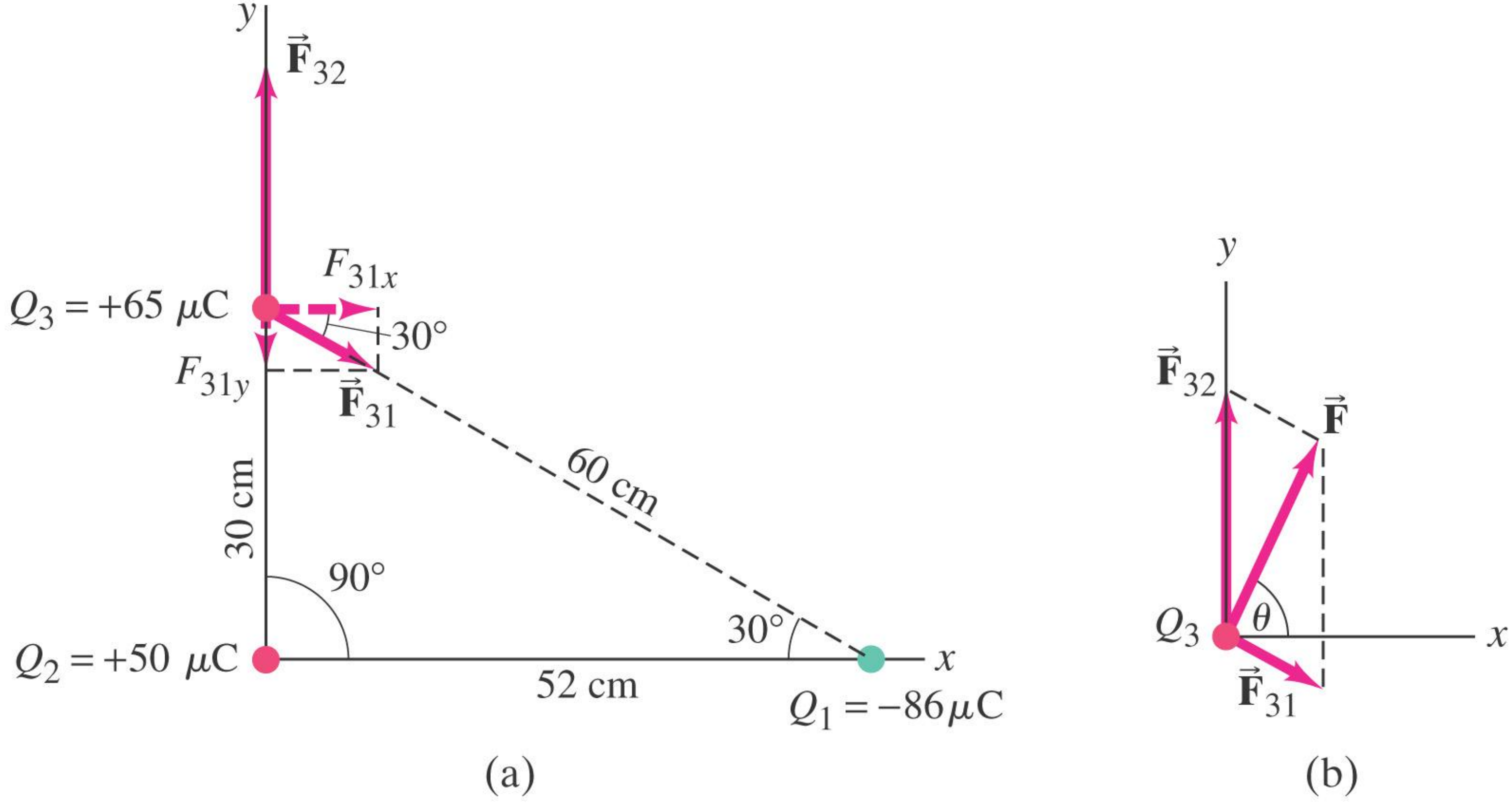
In which region can a +4q charge be in equilibrium?



16.5 Coulomb's Law

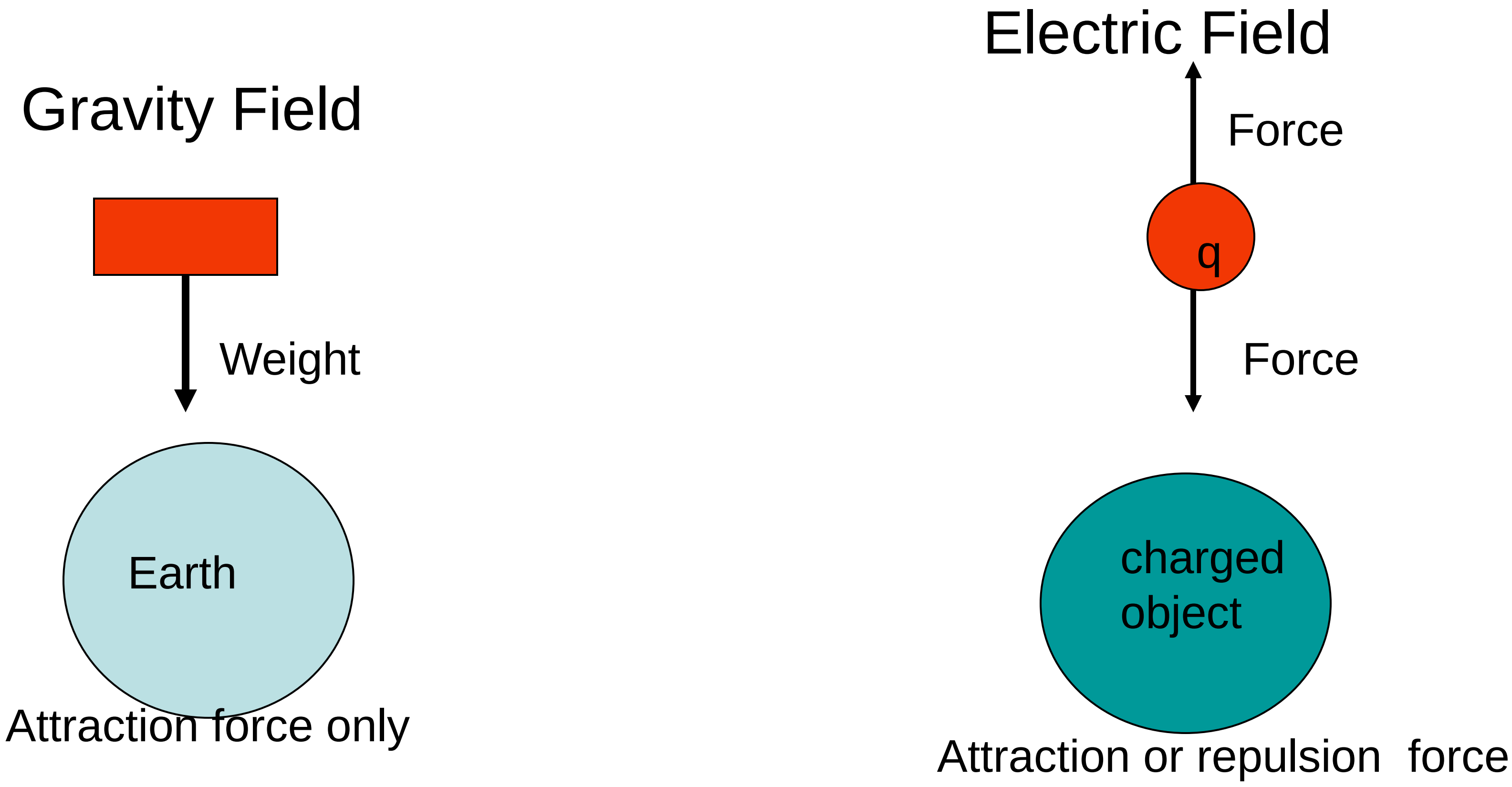
Coulomb's law strictly applies only to point charges.

Superposition: for multiple point charges, the forces on each charge from every other charge can be calculated and then added as vectors.



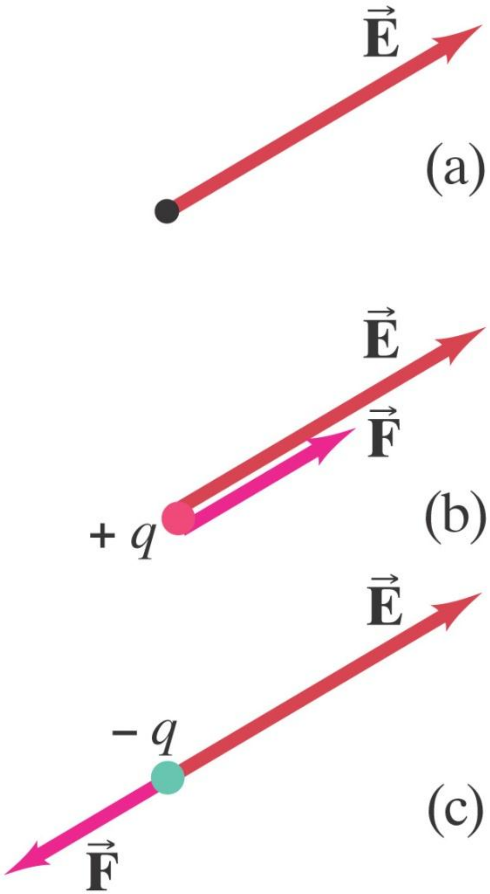
Electric Field

- Fields exert forces on objects put in them



Fields are a property of the space around the charged object that creates them

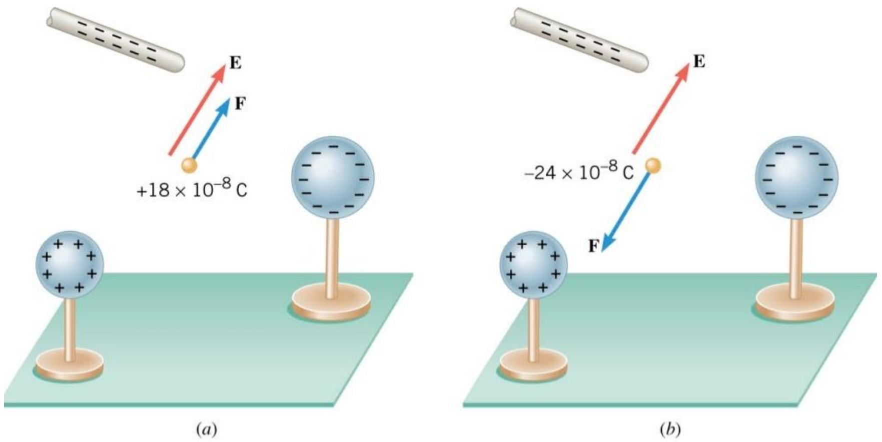
Test for presence of electric field



- Place a small positive test charge in field
- ratio of force on charge to amount of test charge = field strength
- direction of field is direction of force on + test charge
- using a – charge changes force not field direction

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

Electrons move opposite to field



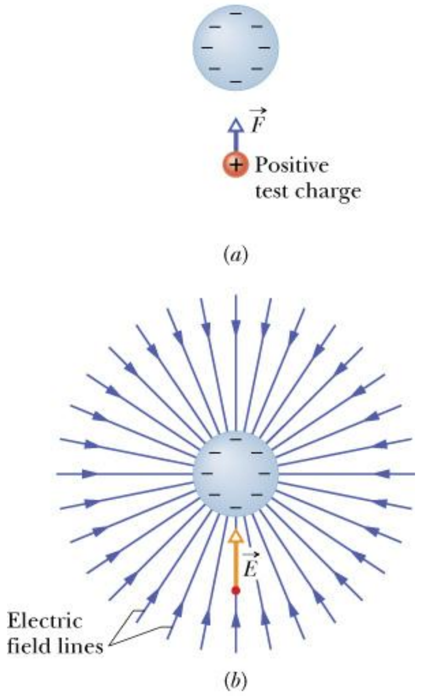
Force on a charge placed in the field

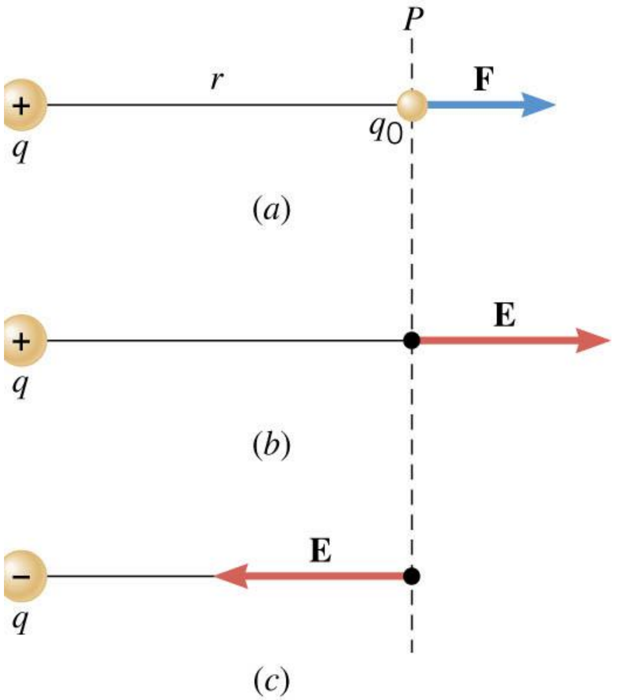
$$\vec{F} = q\vec{E}$$

Electric Field Strength

- Independent of any charge placed in field to test for field strength
  - Field strength is independent of force and test charge: greater test charge results in greater force
- property of the field not of the test charge
- field strength E depends on amount of charge on object that creates the field
- vector quantity – points in the direction that a POSITIVE test charge moves in field
- Units: $\frac{Newtons\ (\mathrm{N})}{Coulomb\ (\mathrm{C})}$

Electric field strength at P depends on

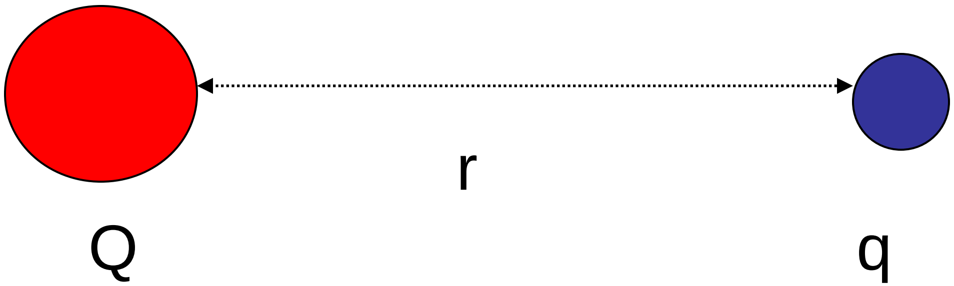




1) amount of charge on the object creating the field

2) distance r that point P is away from the object creating the field

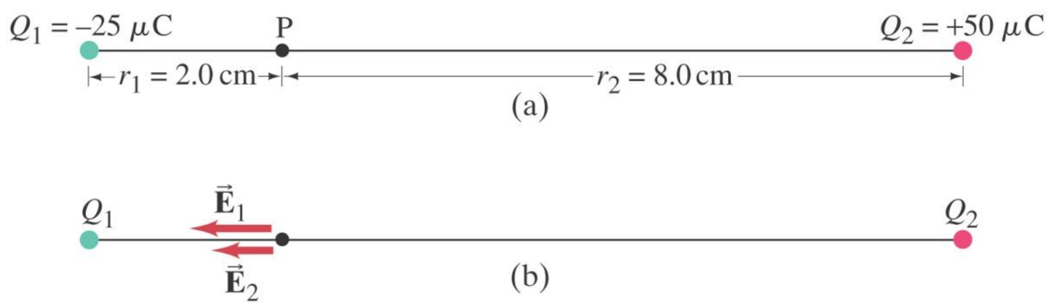
Field strength due to a point charge



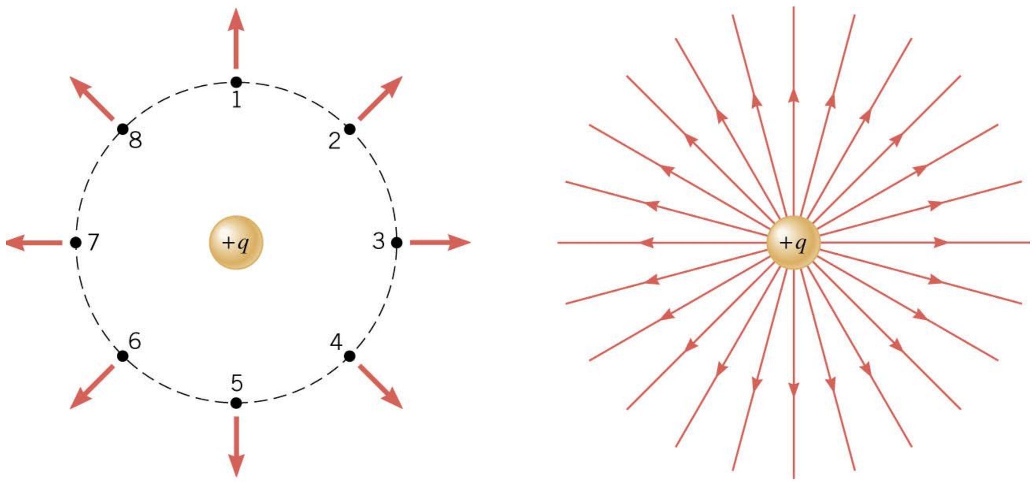
$$E = \frac{\left(\frac{kQq}{r^2}\right)}{q} = \frac{kQ}{r^2}$$

Q is charge creating the electric field

- Superposition principle applies when finding resultant electric field due to several charges
- Draw diagram with E vectors based on + test charge
- Be careful for +/– signs of charge Q



Electric Field Lines



(a) (b)

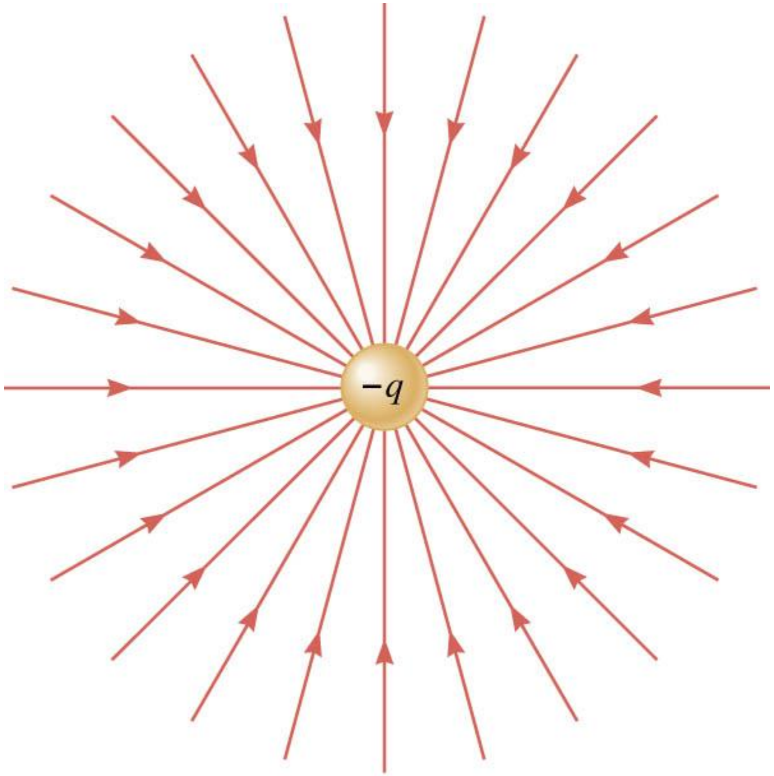
- property of point in space
- field exists whether test charge in in field or not

Electric field lines point AWAY from a positively charged object

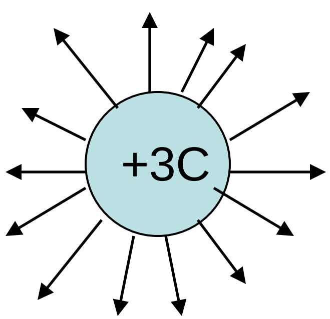
Point charges create NON-UNIFORM electric field

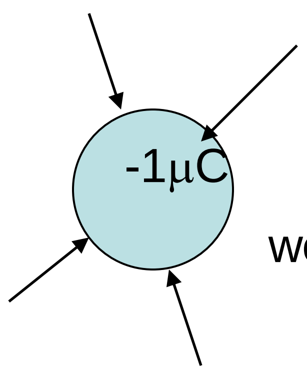
varies in both magnitude and direction

Electric Field Lines: Imaginary Map Lines

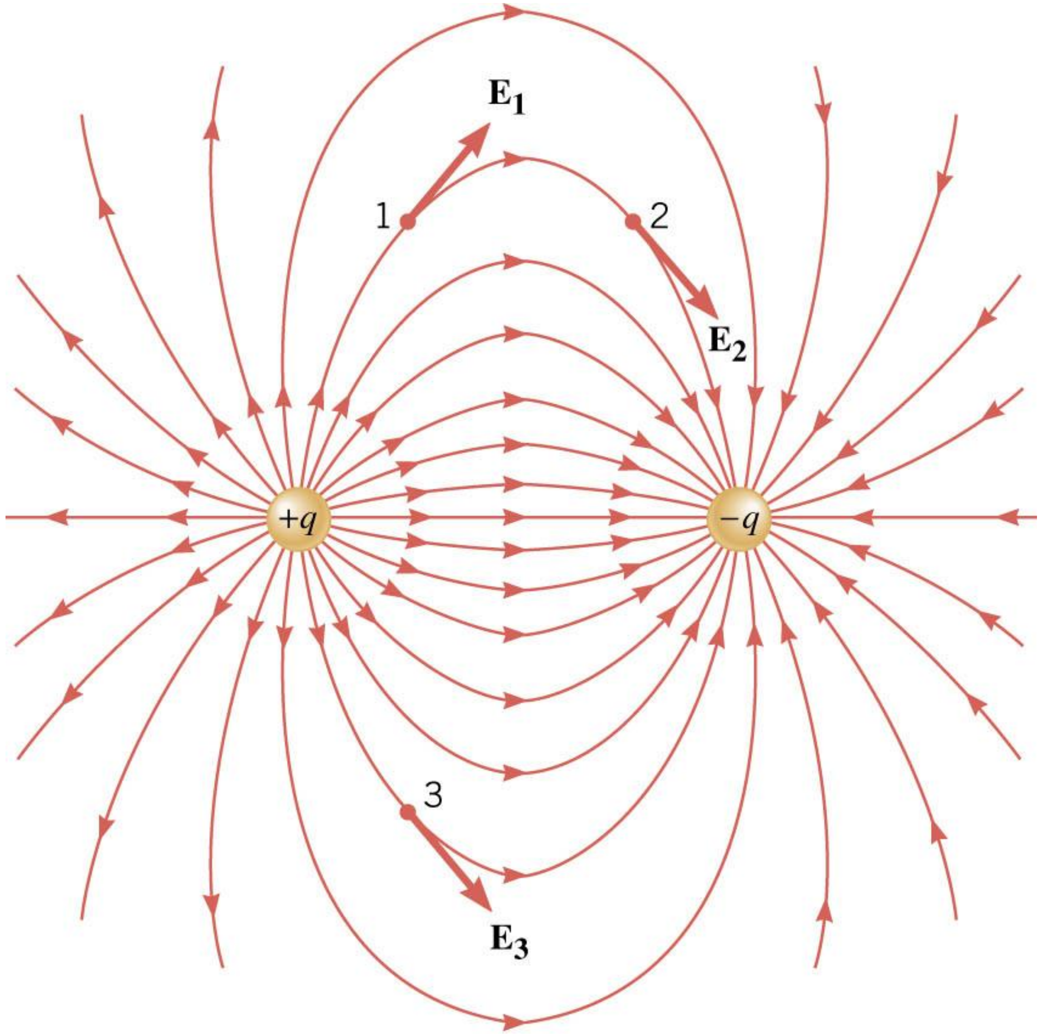


- Electric field lines point IN towards a negatively charged object
- Lines point in direction a small positive test charge would move if placed in the field
- Strength of field indicated by number and spacing of field lines



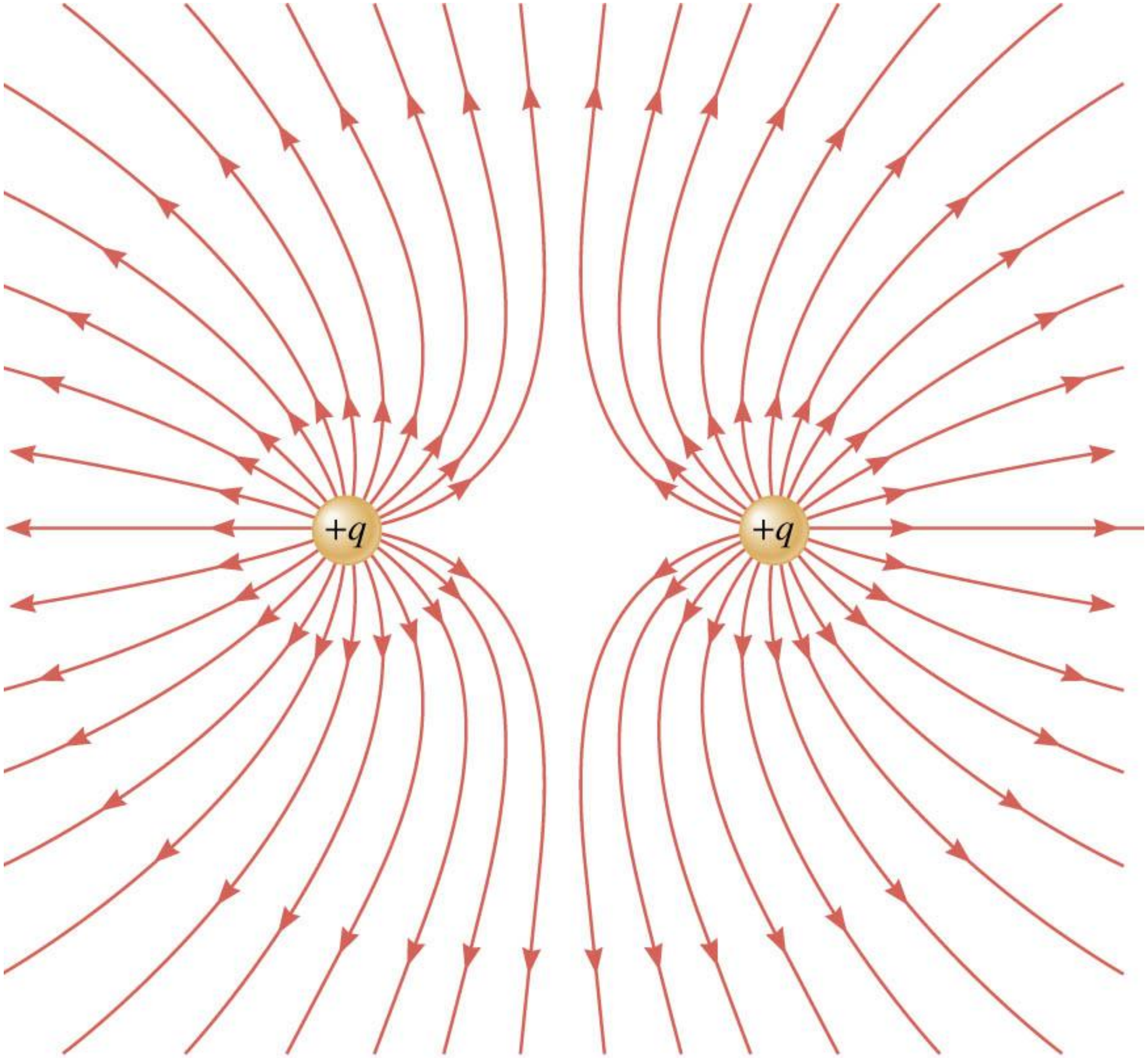


Electric Field = Resultant of all field lines present



point away from +
and in toward –

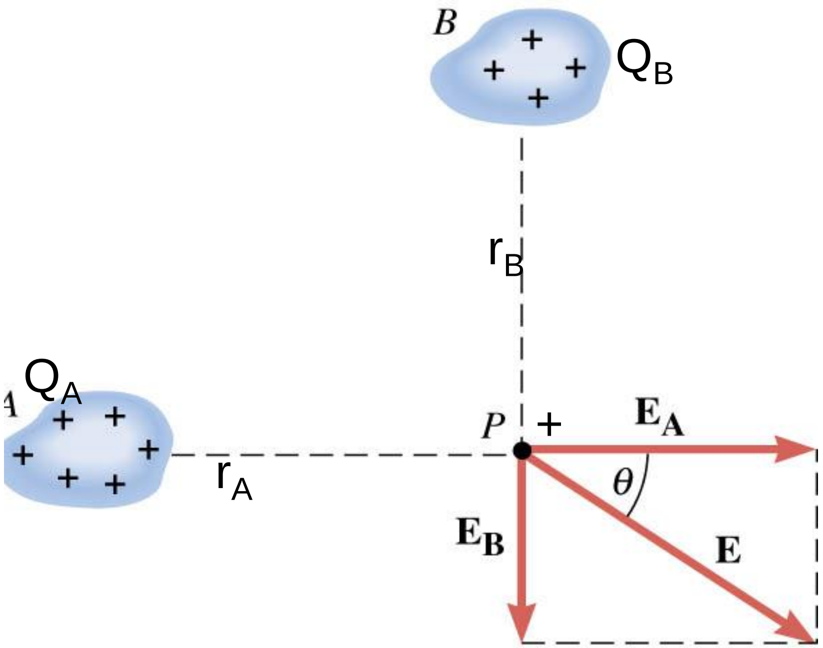
Electric field is tangent to field line at any point



Field Lines

- direction + charge moves if placed in field

Net electric field at point P

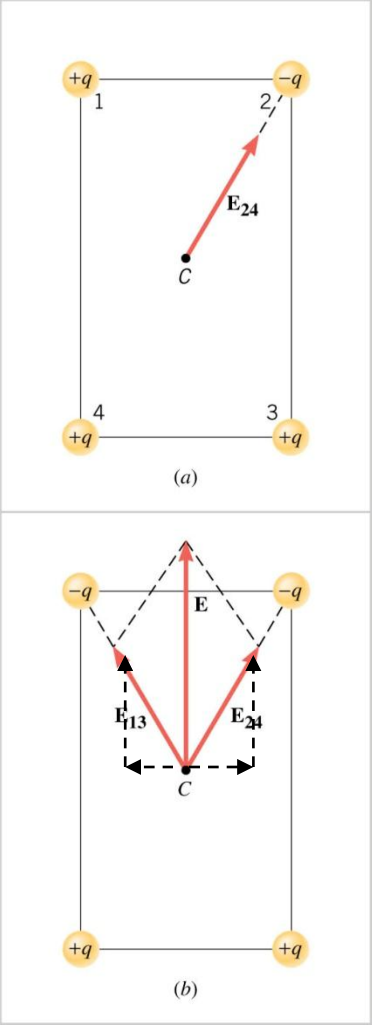


$$E_A = \frac{kQ_A}{{r_A}^2}$$

$$E_B = \frac{kQ_B}{{r_B}^2}$$

- you will need to be able to identify direction of electric field
- draw an imaginary + at point P and determine which way it would move as a result of the field from A or from B
- Electric field is NON-uniform surrounding point charges

Net field = vector sum



4 field vectors present at C. E_3 cancels E_1 E_4 and E_2 sum up to yield E_{24}

(b) 4 field vectors present

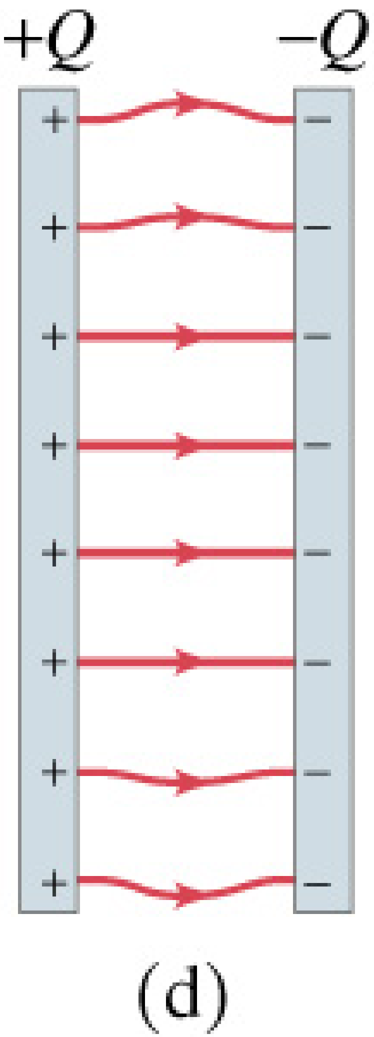
E_1 and E_3 sum up to yield E_{13}

E_2 and E_4 sum up to yield E_{24}

E_{13} and E_{24} sum up to yield E pointing straight up:

x components cancel, y components add

Electric Field between oppositely charged parallel plates



Electric field

- points from + plate to – plate

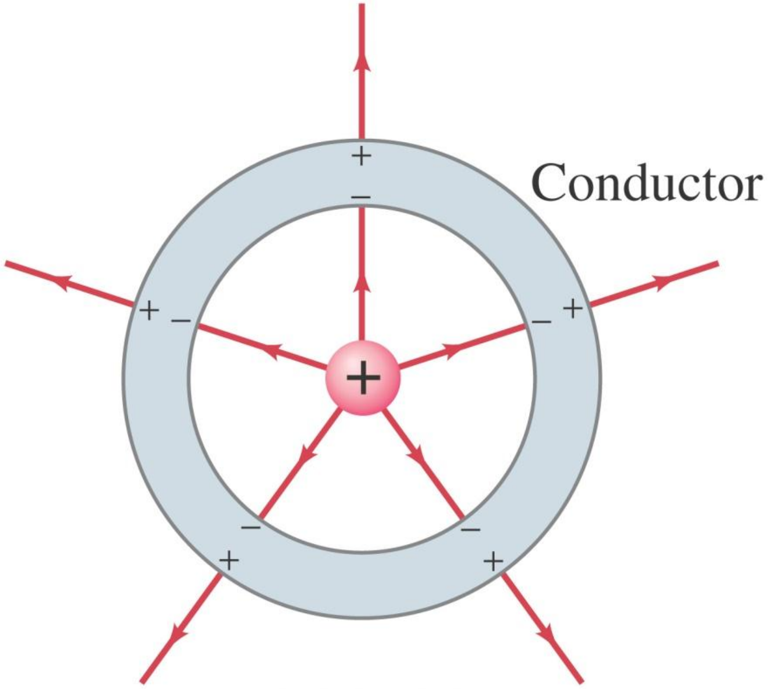
- is uniform at all points between the plates

    - E has same magnitude at all points

    - Field lines are parallel

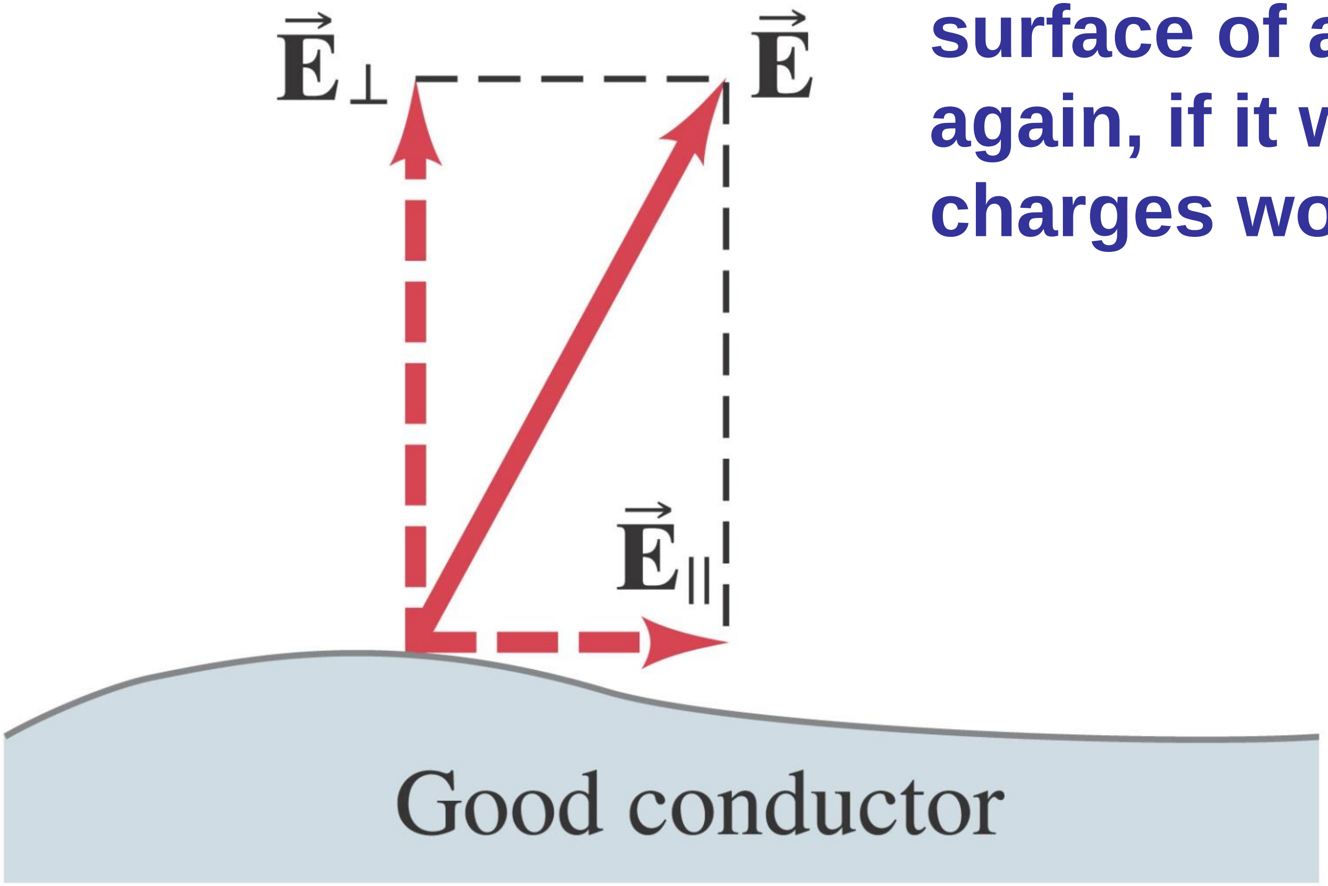
16.9 Electric Fields and Conductors

The static electric field inside a conductor is zero – if it were not, the charges would move.



The net charge on a conductor is on its surface.

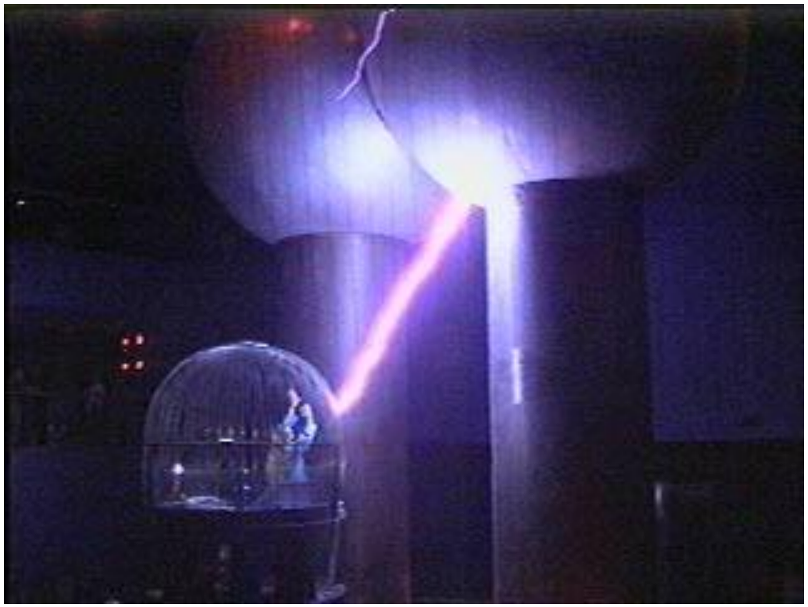
16.9 Electric Fields and Conductors

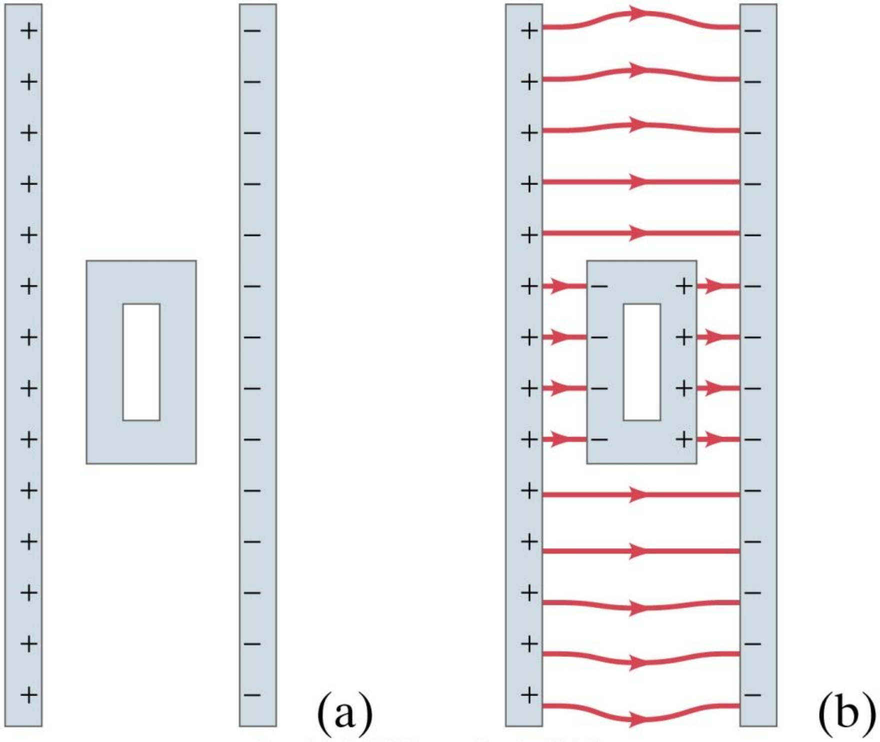


The electric field is perpendicular to the surface of a conductor – again, if it were not, charges would move.

Faraday cage

charge goes to outside of metal placed in electric field





[high power line worker]

Motion in an electric field

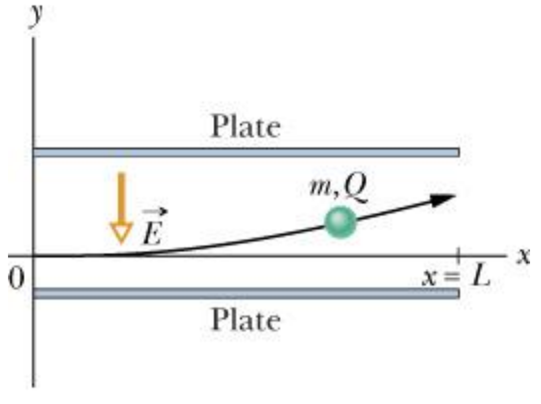
When a charged particle enters an electric field, it experiences a force:

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

Does an electron or a proton experience a greater acceleration when placed in a uniform electric field

$$q\vec{E} = m\vec{a} \Rightarrow \vec{a} = \frac{q\vec{E}}{m}$$

+/– plate?



- proton is 10,000 times more massive than electron
- same force on both
- electron experiences greater acceleration