Applied Physics for Engineers

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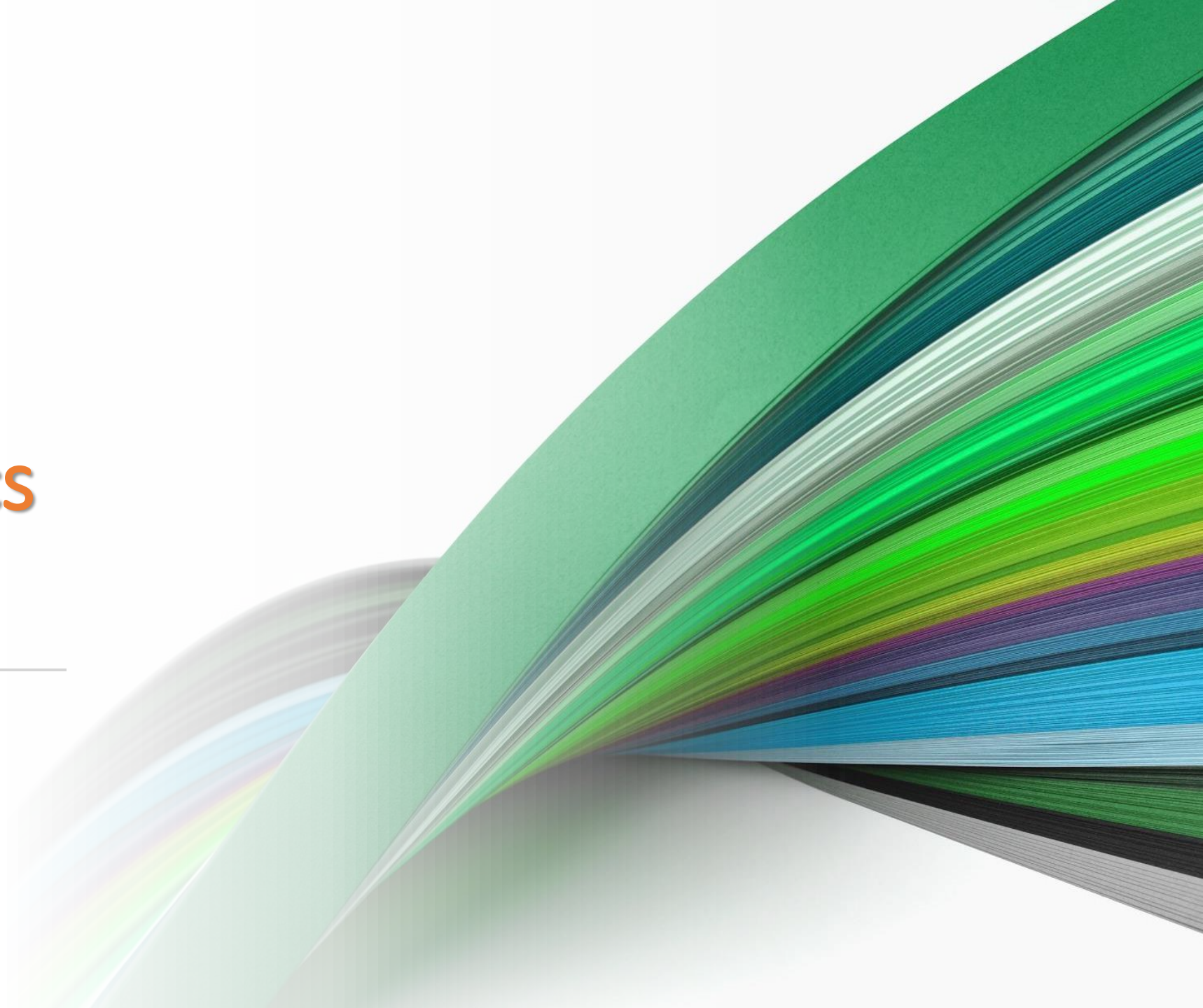


Learning Objectives

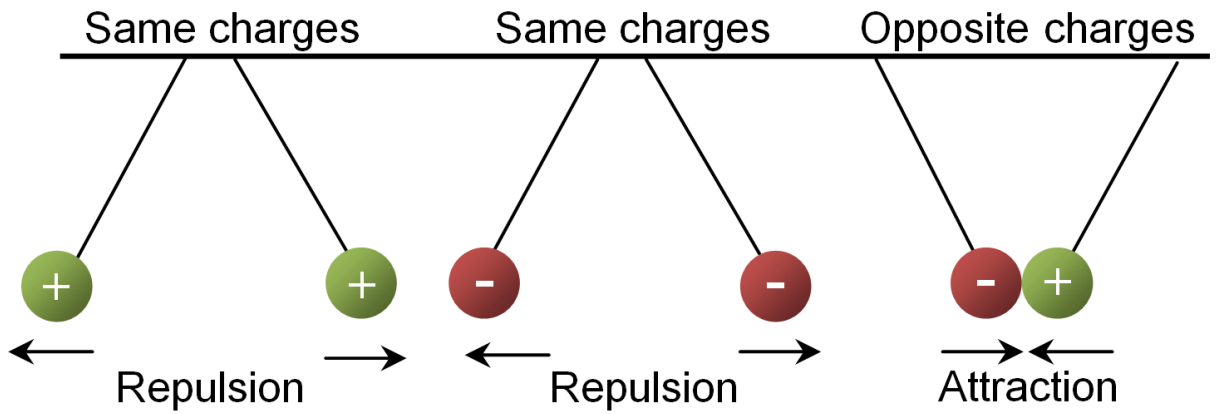
Concepts of electromagnetism and optics underlying the engineering applications.

Explain and analyze the applicability of electromagnetism and optics in engineering applications

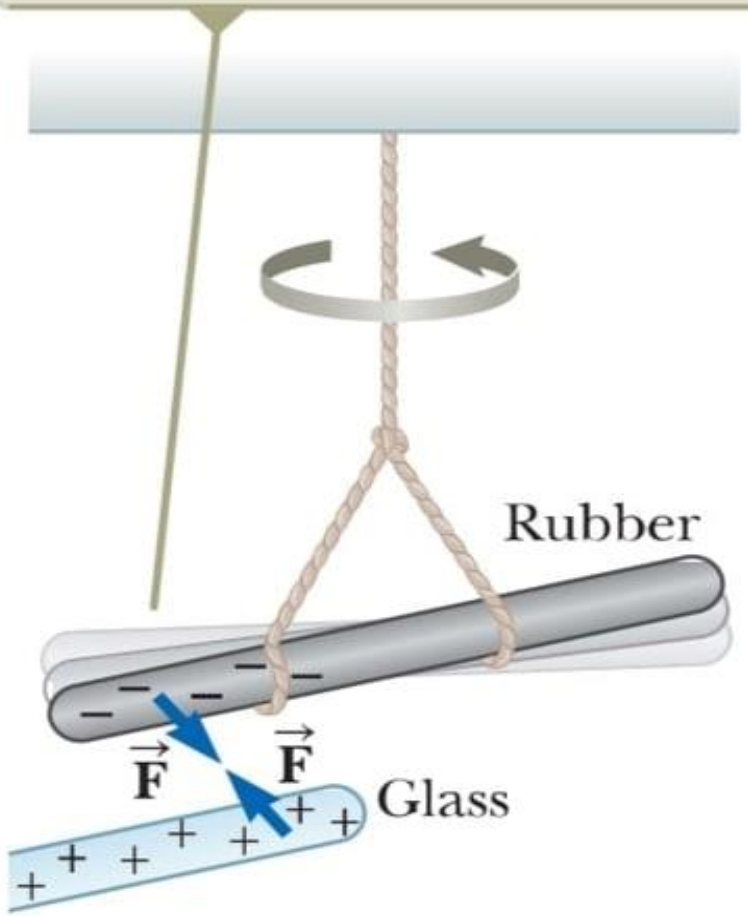
Construct a solution of an engineering problem by *applying* Maxwell's equations and laws of optics

Electrostatics

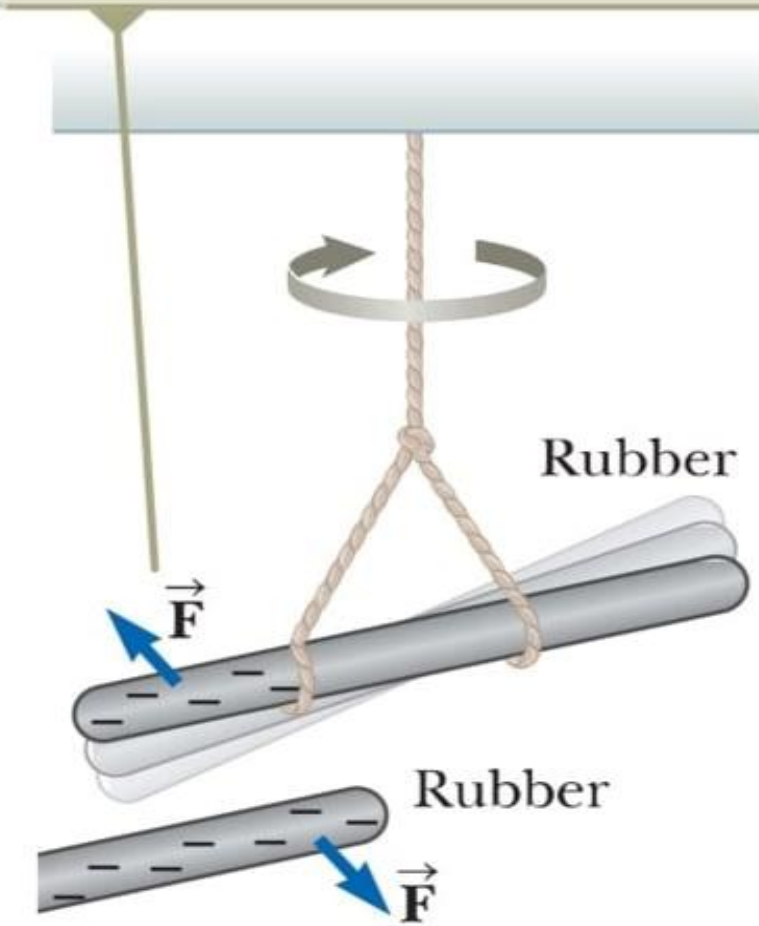
- Electrostatics is the study of electric charge at rest
- Electric charge is intrinsic property of fundamental particles
- Two Types of electric charge
  - Positive charge (A proton has a positive charge)
  - Negative charge (An electron carries negative charge)
- Like Charges repel each other
- Unlike charges attract each other



A negatively charged rubber rod suspended by a string is attracted to a positively charged glass rod.



A negatively charged rubber rod is repelled by another negatively charged rubber rod.



Transfer of charge

In an atom, number of electrons and protons are same, so it has no net charge.

Electrons revolve around the nucleus, while protons and neutrons are tightly packed in the nucleus.

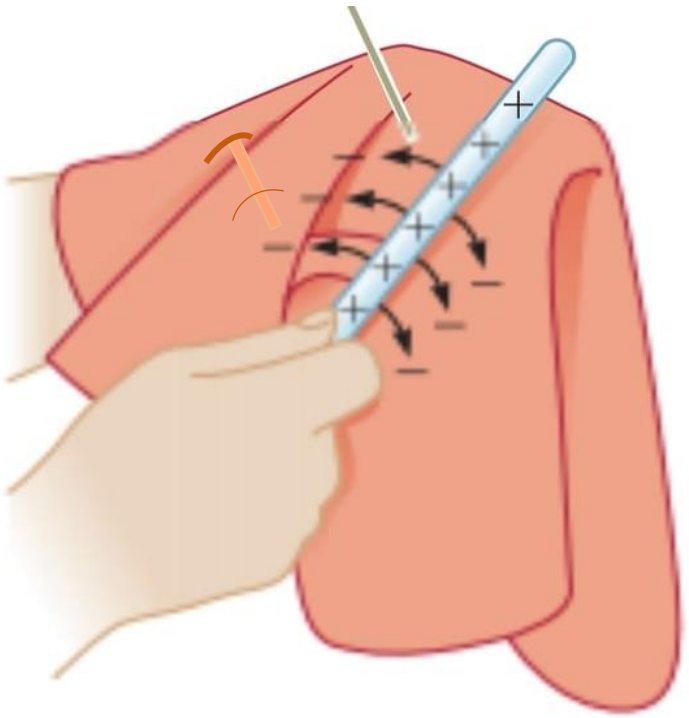
Conductors – Electrons move freely (i.e copper, iron)

Insulators – Electrons don't move freely, or the atoms have very few or no free electrons (i.e Rubber, plastic)

Conduction of charge

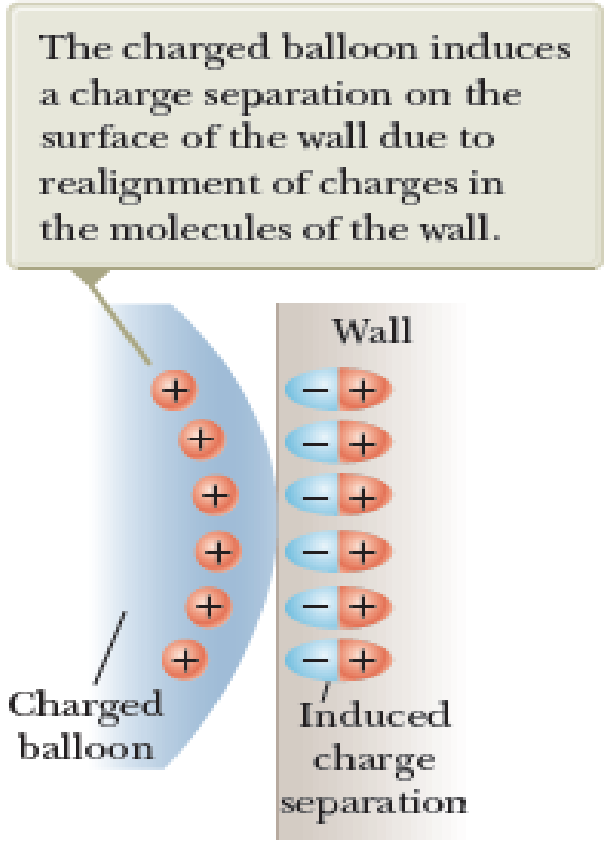
Transfer of charge on an object by rubbing.

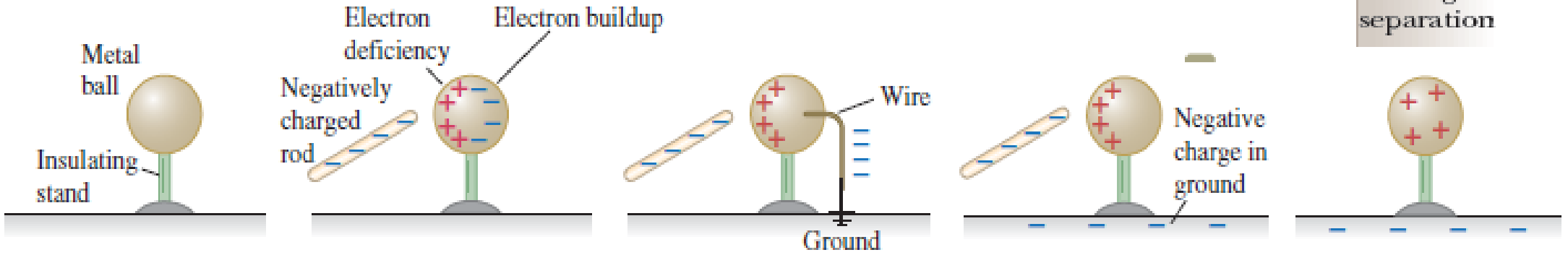
- Glass rod when rubbed by a silk cloth, silk gets negatively charged (negative charge transfer to silk)
- Rubber rod when rubbed with fur cloth, the rod gets negatively charged (negative charge transfer to rubber rod)



Induction of Charge

- Transfer of charge without any contact; i.e, a charged object is brought near a neutral object (conductor or insulator) as shown in figure below.
- When the conductor is charged, the charge distribute evenly on it
- When an insulator is charged, the charge does not move.





(a) Uncharged metal ball

(b) Negative charge on rod repels electrons, creating zones of negative and positive **induced charge**.

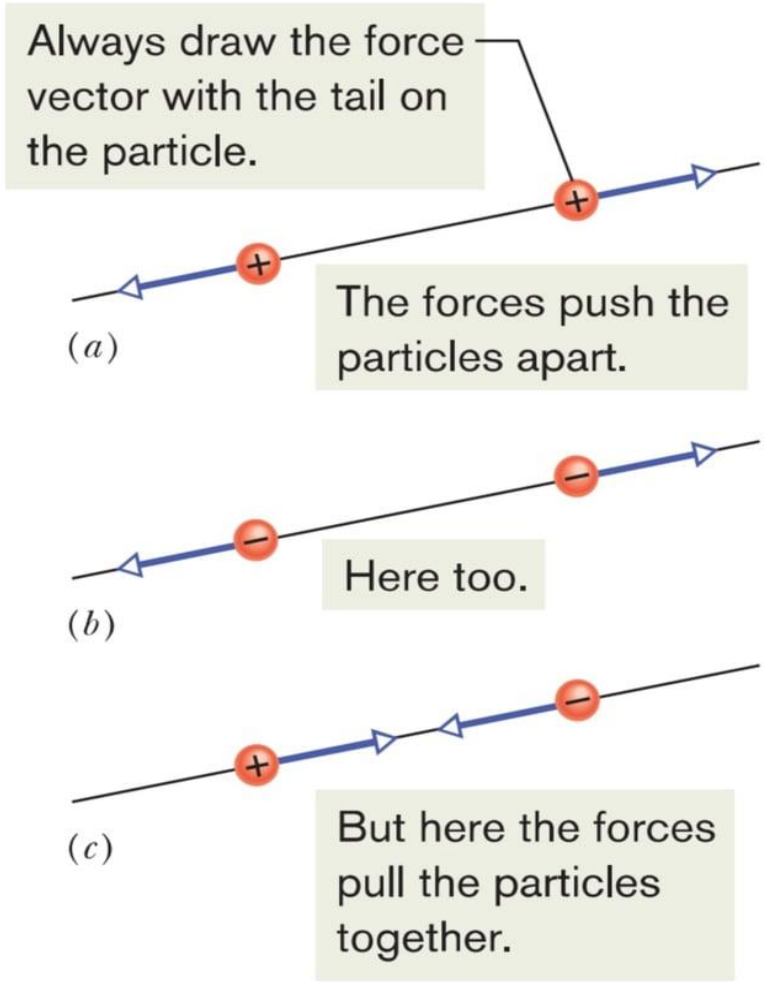
(c) Wire lets electron build-up (induced negative charge) flow into ground.

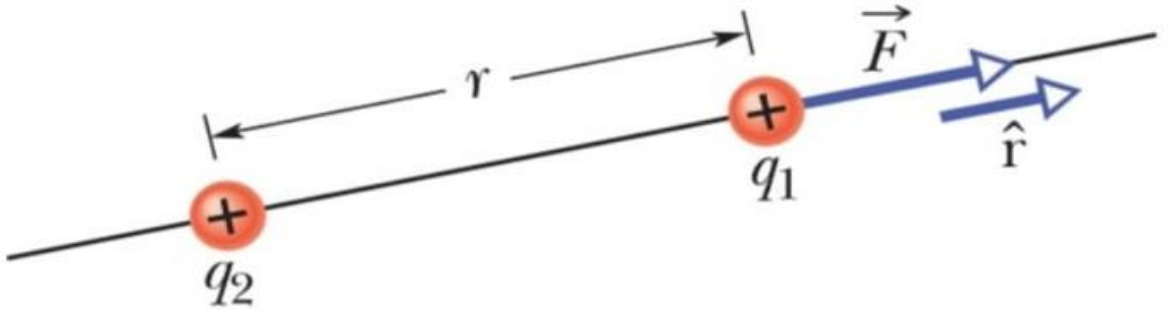
(d) Wire removed; ball now has only an electron-deficient region of positive charge.

(e) Rod removed; electrons rearrange themselves, ball has overall electron deficiency (net positive charge).

Coulomb's law

- When the two charged particles are brought closer, they exert an electrostatic force on each other
- The direction of the force vectors depends upon the sign on the charges (+/-)
- Electric force is a field force (no direct contact)
- Coulomb's law determines the magnitude of electric force between two charged particles





$$\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r} \quad \text{(Coulomb's law),}$$

Where,

q_1 and q_2 is amount of charge in C

r is the separation between the particles

k is a positive constant called coulomb's constant

k is also written as $\frac{1}{4\pi\in 0}$ $=8.99\text{x}10^9\ \text{N.m}^2/\text{C}^2$

The quantity $\in_0$, called permittivity constant and is

$\in_0 = 8.85\text{x}10^{-12}\ \text{C}^2/\text{N.m}^2$

Multiple forces: Suppose we have *n* charged particles near a chosen particle called particle 1; then the net force on particle 1 is given by the vector sum

$$\vec{F}_{1,\text{net}} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \cdots + \vec{F}_{1n},$$

Charge is Quantized

Any positive or negative charge q can be written as

$$q = ne, \qquad n = \pm 1, \pm 2, \pm 3, \ldots\ldots,$$

Where e, the elementary charge, has the approximate value

$$e = 1.602 \times 10^{-19}\ C$$

When a physical quantity such as charge can have only discrete value rather than any value , we say that the quantity is quantized

Charge is Conserved

Electric charge is always conserved in an isolated system. That is, when one object is rubbed against another, charge is not created in the process. The electrified state is due to a transfer of charge from one object to the other. One object gains some amount of negative charge while the other gains an equal amount of positive charge.