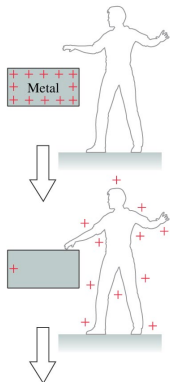


Discharging



Charges spread through the metal + human system.

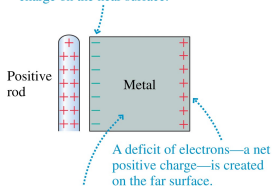
Very little charge is left on the metal.

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- Place two conductors in contact with each other and the charge gets shared.
- A human is composed mainly of salty water, making us good conductors (Na^+ and Cl^- ions).
- For example, touch a positively charged conductor, donate electrons to the metal and share the net positive charge over your combined surfaces. You become positively charged.
- The earth is a giant conductor which we can purposely share charge with - through **grounding**.
- Moist air is also a conductor – a poor one. Charged objects in air slowly lose their charge.

Charge Polarization

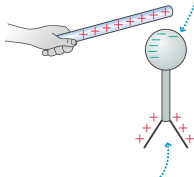
- (a) The sea of electrons is attracted to the rod and shifts so that there is excess negative charge on the near surface.



The metal's net charge is still zero, but it has been *polarized* by the charged rod.

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- (b) The electroscope is polarized by the charged rod. The sea of electrons shifts toward the positive rod.

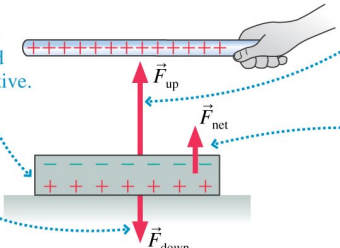


Although the net charge on the electroscope is still zero, the leaves have excess positive charge and repel each other.

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- We understand that objects can have a net positive or negative charge. However, why do neutral objects get attracted to charged objects without touching?
- The presence of a charged object can **polarize** another object.
- The object is neutral, but positive and negative charges become separated.
- The positive ions also attract the surface electrons, quickly creating an equilibrium and ensuring that the object de-polarizes once the charged rod is removed.

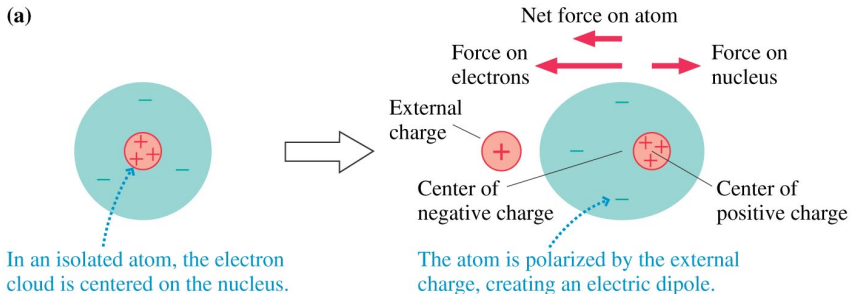
Charge Polarization

1. The charged rod polarizes the neutral metal, causing the top surface to be negative and the bottom surface to be positive.
 2. The rod exerts an upward attractive force on the excess electrons at the top surface.
 3. The rod also exerts a downward repulsive force on the excess positive ion cores at the bottom surface.
 4. Because electric force decreases with distance, $F_{\text{up}} > F_{\text{down}}$. Thus there is a net upward force on the neutral metal that attracts it to the positive rod!
- 
- The diagram illustrates the process of charge polarization. A positively charged rod, held by a hand, is positioned above a neutral metal block. The rod is marked with '+' signs. The metal block shows negative charges (electrons) concentrated on its top surface, indicated by '-' signs, and positive charges (ion cores) concentrated on its bottom surface, indicated by '+' signs. Four force vectors are shown: \vec{F}_{up} (a large red arrow pointing up from the top surface), \vec{F}_{down} (a red arrow pointing down from the bottom surface), and \vec{F}_{net} (a smaller red arrow pointing up from the center of the block). Dotted blue lines connect the numbered text descriptions to the corresponding parts of the diagram.

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- The slight charge separation caused by polarization creates a net force on the object.
- If electric forces decrease with distance, then the net force will be attractive: the attraction of the closer negative charges is greater than the repulsion of the farther positive charges.
- Net attraction also occurs if the rod is negatively charged: because then the polarization is reversed.
- A neutral object is attracted to a charged object!

The Electric Dipole

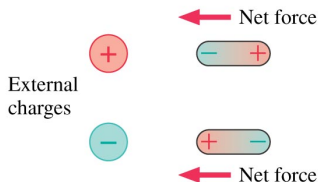


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- So far we have been talking only about conductors. But we know that a charged rod will pick up paper (an insulator).
- In this case the charge will polarize the atoms.
- The atom forms an **electric dipole**

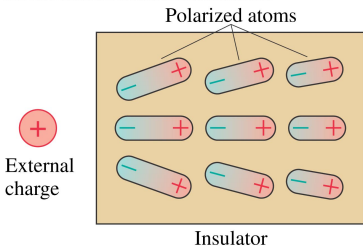
The Electric Dipole

(b)



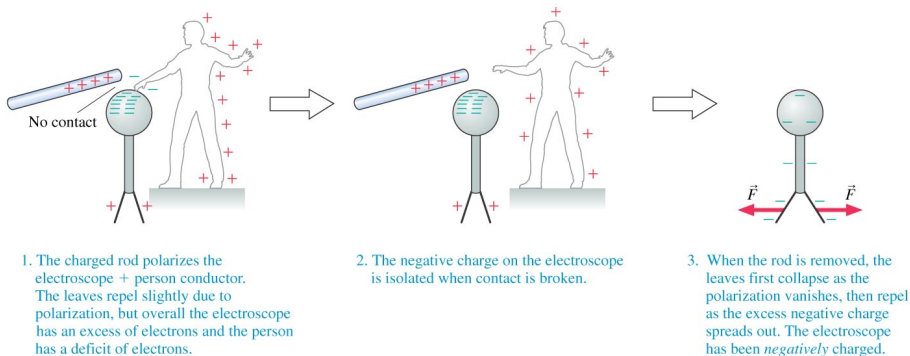
Electric dipoles can be created by either positive or negative charges. In both cases, there is an attractive net force toward the external charge.

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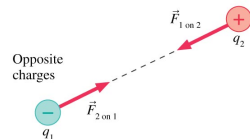
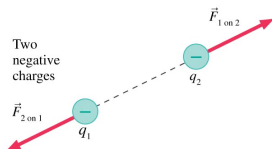
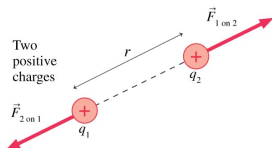
- So, an insulating medium can be polarized.
- Each individual atom is polarized leading to a net force of attraction.

Charging by Induction



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Coulomb's Law (26.4)



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- We need a quantitative understanding of these attractive and repulsive forces.
- Coulomb's Law states

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{K|q_1||q_2|}{r^2}$$

Where the direction of F is along the line connecting the two particles, like particles repel and opposites attract.

- K is the **electrostatic constant** and is

$$K = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2$$

Coulomb's Law

- We can instead define the **permittivity constant** as

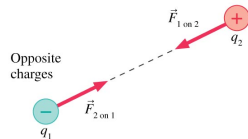
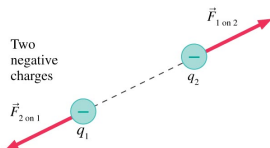
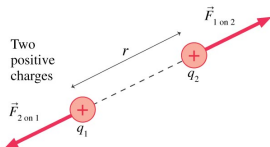
$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

- This allows us to re-write Coulomb's Law as

$$F = \frac{1}{4\pi\epsilon_0} \frac{|q_1||q_2|}{r^2}$$

- This is the standard way of writing Coulomb's law because it is mathematically convenient, as we will see later.
- In vector form:

$$\vec{F}_{1 \text{ on } 2} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{1 \text{ to } 2}$$



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Observations About Coulomb's Law

- 1 Coulomb's Law applies only to point charges.
- 2 Coulomb's Law applies only to **electrostatics**
- 3 Electric forces, like other forces, can be superimposed

$$\vec{F}_{\text{net on } j} = \vec{F}_{1 \text{ on } j} + \vec{F}_{2 \text{ on } j} + \vec{F}_{3 \text{ on } j} + \cdots$$