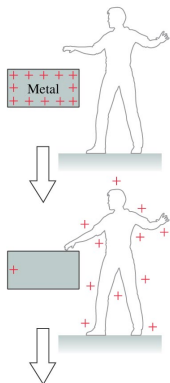


Discharging



Charges spread through the metal + human system.

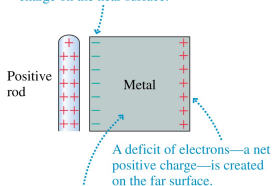
Very little charge is left on the metal.

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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.

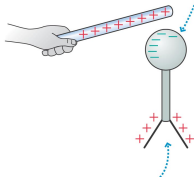
Charge Polarization

- (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.

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

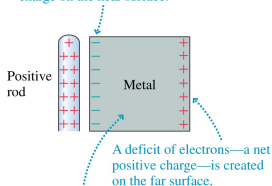


Although the net charge on the electroscope is still zero, the leaves have excess positive charge and repel each other.

- We understand that objects can have a net positive or negative charge. However, why do neutral objects get attracted to charged objects without touching?

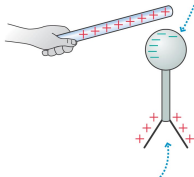
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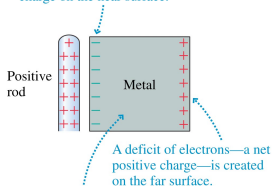


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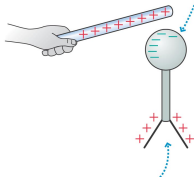
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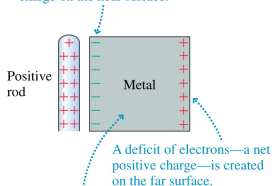


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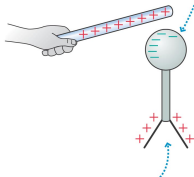
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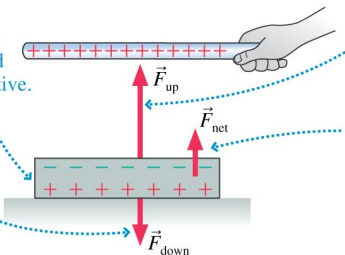
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- The presence of a charged object can **polarize** another object.
- The object is neutral, but positive and negative charges become separated.
- The positive ions also attract the surface electrons, quickly creating an equilibrium and ensuring that 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.

3. The rod also exerts a downward repulsive force on the excess positive ion cores at the bottom surface.



2. The rod exerts an upward attractive force on the excess electrons at the top surface.

4. Because electric force decreases with distance, $F_{up} > F_{down}$. Thus there is a net upward force on the neutral metal that attracts it to the positive rod!

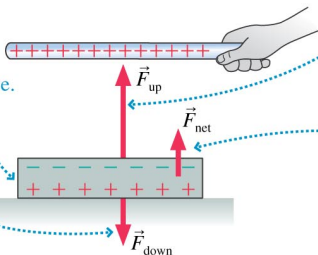
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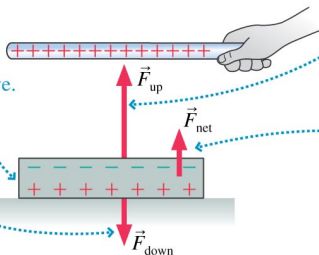
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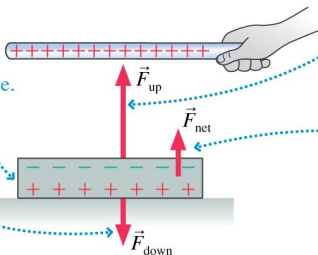
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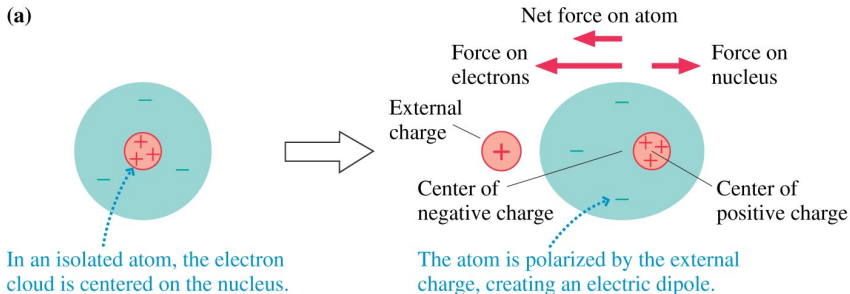
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- Net attraction also occurs if the rod is negatively charged: because then the polarization is reversed.
- A neutral object is attracted to a charged object!

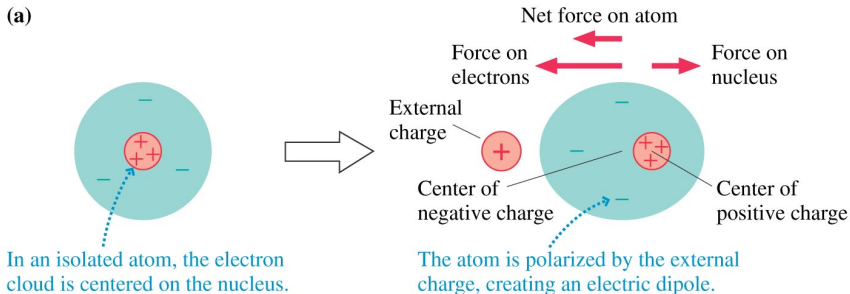
The Electric Dipole



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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).

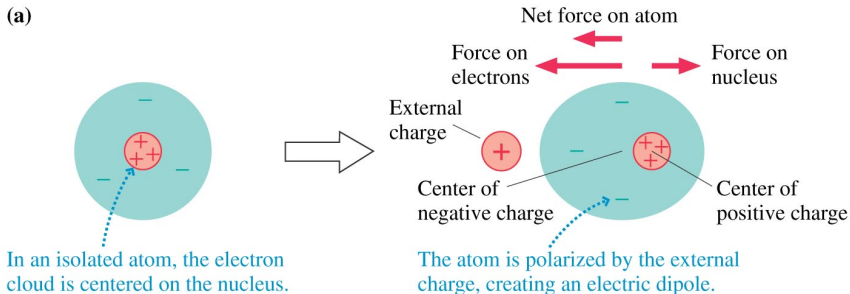
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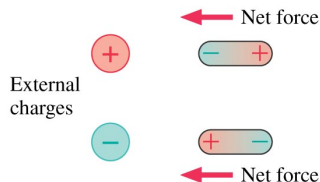


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- In this case the charge will polarize the atoms.
- The atom forms an **electric dipole**

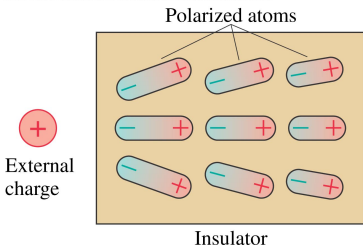
The Electric Dipole

(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.

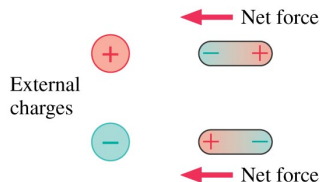
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- So, an insulating medium can be polarized.

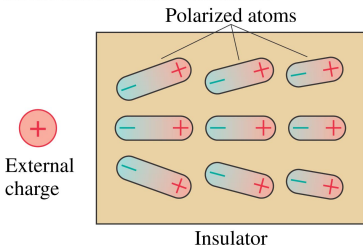
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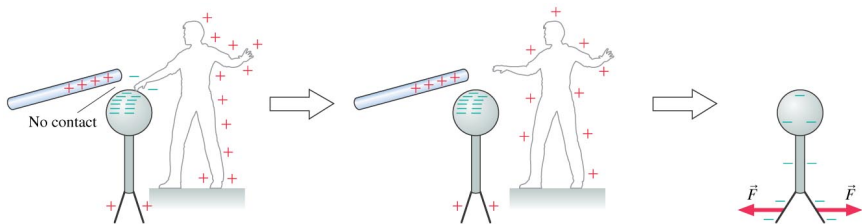
Electric dipoles can be created by either positive or negative charges. In both cases, there is an attractive net force toward the external charge.

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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



1. The charged rod polarizes the electroscope + person conductor. The leaves repel slightly due to polarization, but overall the electroscope has an excess of electrons and the person has a deficit of electrons.

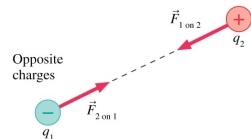
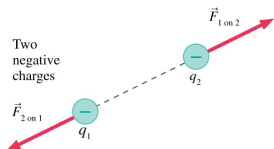
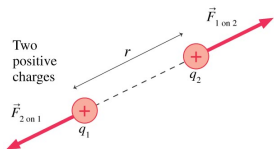
2. The negative charge on the electroscope is isolated when contact is broken.

3. When the rod is removed, the leaves first collapse as the polarization vanishes, then repel as the excess negative charge spreads out. The electroscope has been *negatively* charged.

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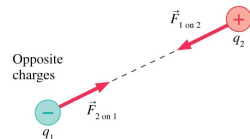
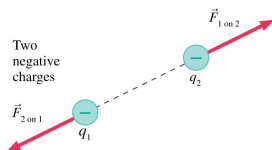
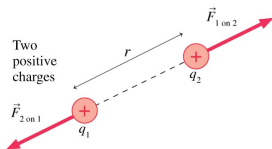
Coulomb's Law (26.4)

- We need a quantitative understanding of these attractive and repulsive forces.



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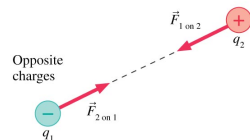
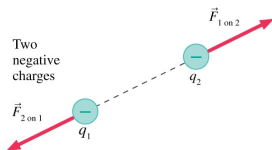
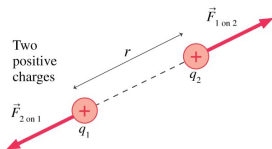
- We need a quantitative understanding of these attractive and repulsive forces.
- Coulomb's Law states

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

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

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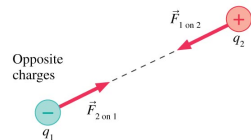
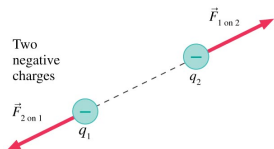
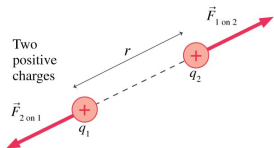
- K is the **electrostatic constant** and is

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

Coulomb's Law

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

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



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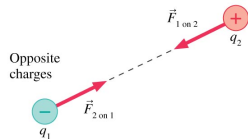
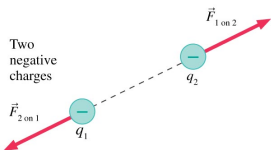
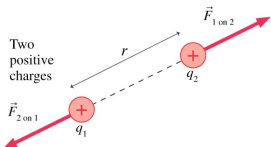
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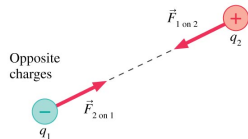
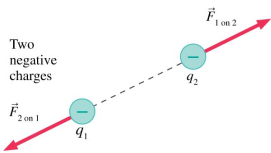
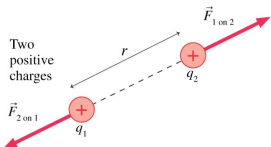
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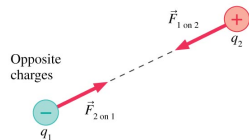
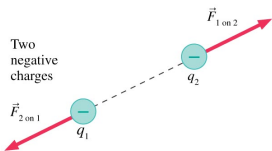
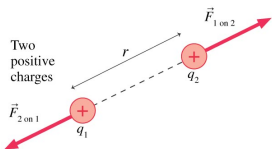
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- In vector form:

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

Observations About Coulomb's Law

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- 3 Electric forces, like other forces, can be superimposed

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