Electricity and Magnetism
Charge and Conduction
Coulomb's Law

Lana Sheridan

De Anza College

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Last time

- course structure
- introduced charge

Overview

- conductors
- insulators
- induced charge
- quantization of charge
- charge conservation
- force on interacting charges

Electric Charge

Charge is an intrinsic property of subatomic particles.

Charge can be positive or negative.

Particles can also be "chargeless", ie. have zero net charge.

The unit for charge is the Coulomb, written with the symbol C.

Electric Charge on larger objects

Before there was any knowledge of atoms, charge was imagined as a kind of continuous fluid.

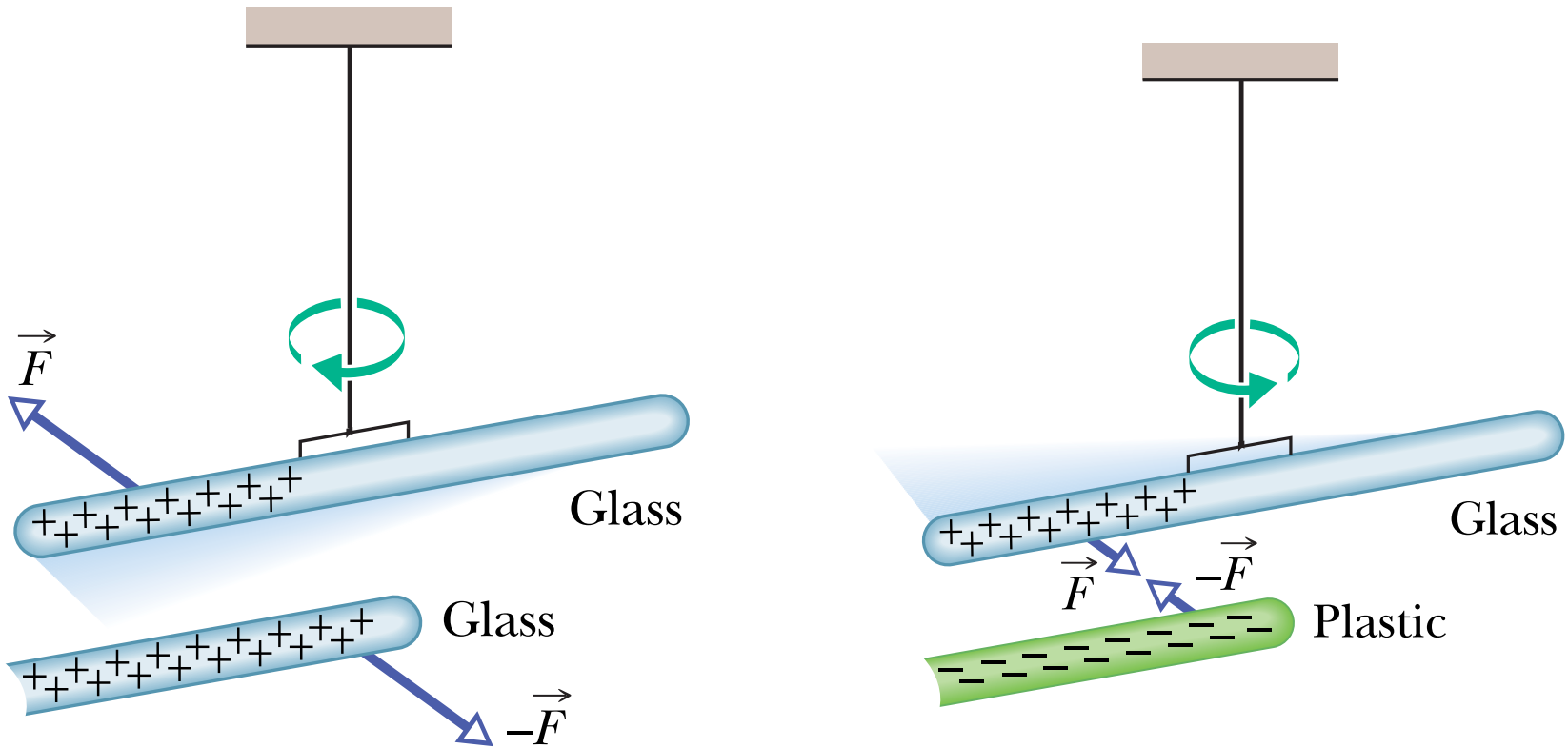
A large scale effect: In dry weather, it is easy to get a shock from static electricity.

This is due to a charge imbalance.

Charge on larger objects

Most large objects around us have (approximately) zero net charge.

Objects can become charged when rubbed against one another.



[1] Diagrams from Halliday, Resnick, Walker, 9th ed.

Electrostatic force

Charged objects exert a force on one another.

Charges with the **same** electrical sign **repel** each other.

Charges with **opposite** electrical signs **attract** each other.

Some Vocabulary

electrically neutral

An object is electrically neutral if its net charge is zero.

electrically isolated

An object is electrically isolated if it cannot exchange charge with its surroundings.

Conductors and Insulators

Some materials allow charges to flow through them easily, some do not.

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Some materials allow charges to flow through them easily, some do not.

Conductors

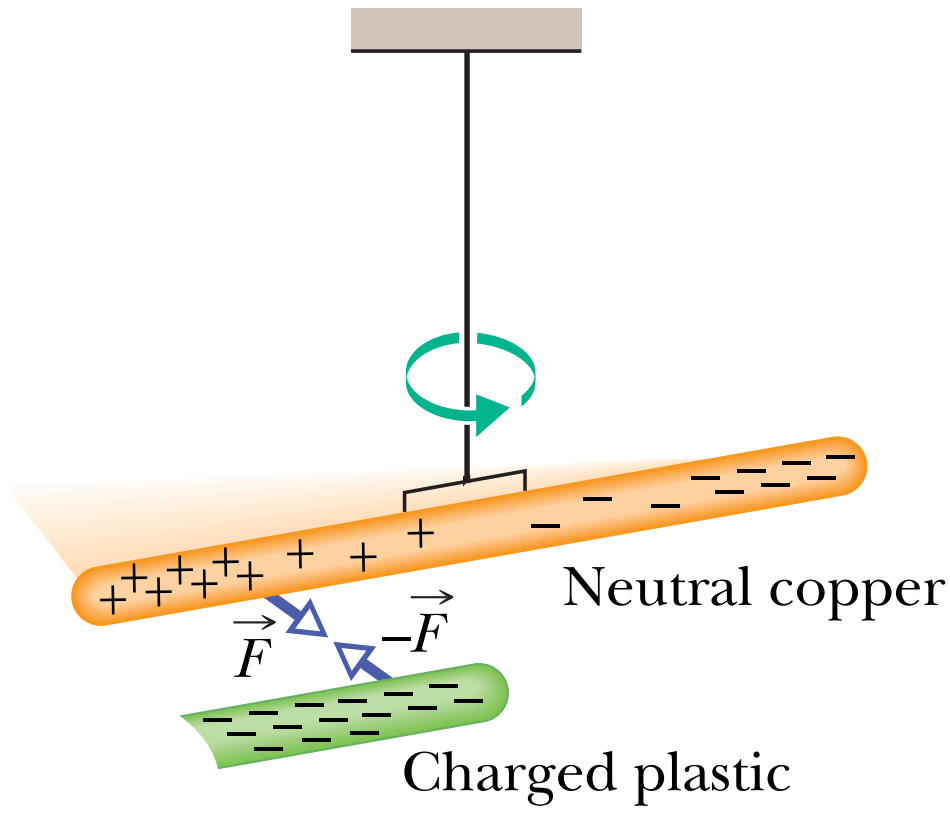
materials through which charge can move readily

Insulators

(also called nonconductors) are materials that charge cannot move through freely

Induced Charge Polarization

If a conductor is brought close to a charged object, positive and negative charges in the conductor start to separate and we say a charge is **induced** on one side of the conductor, or the conductor's charge is **polarized**.



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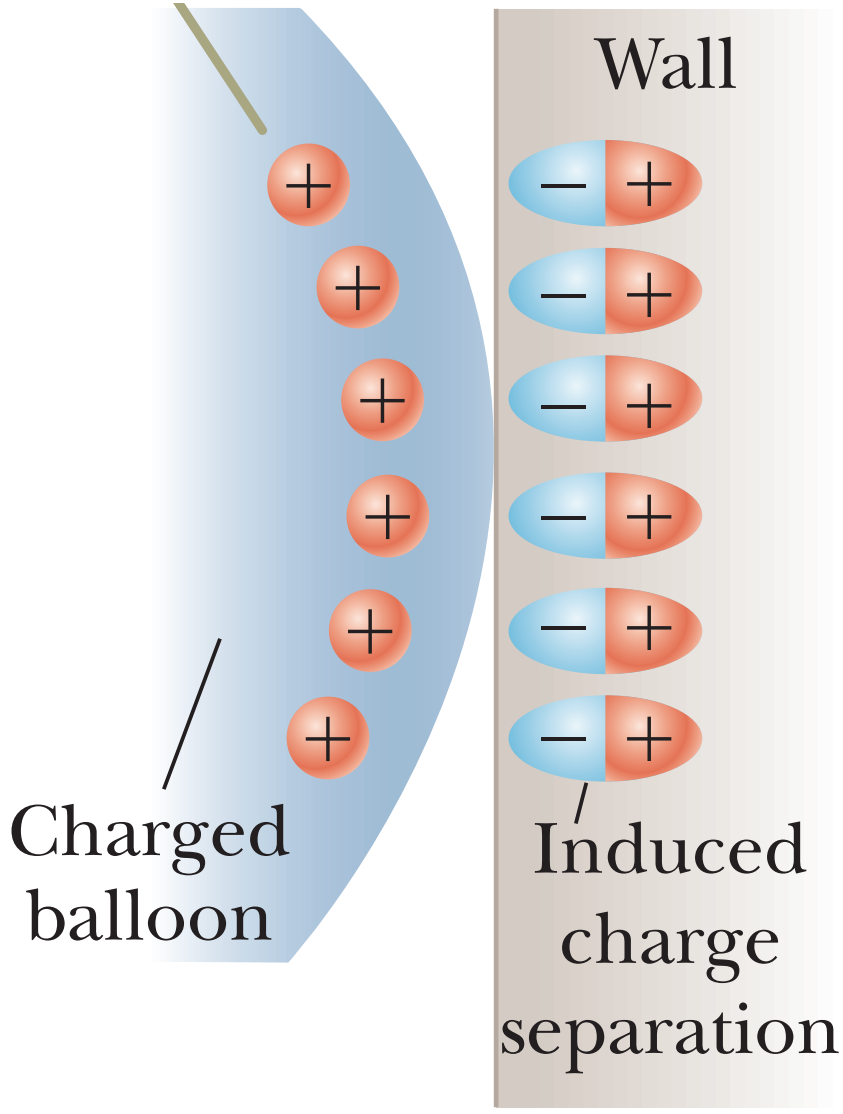


Course Tool

Kahoot

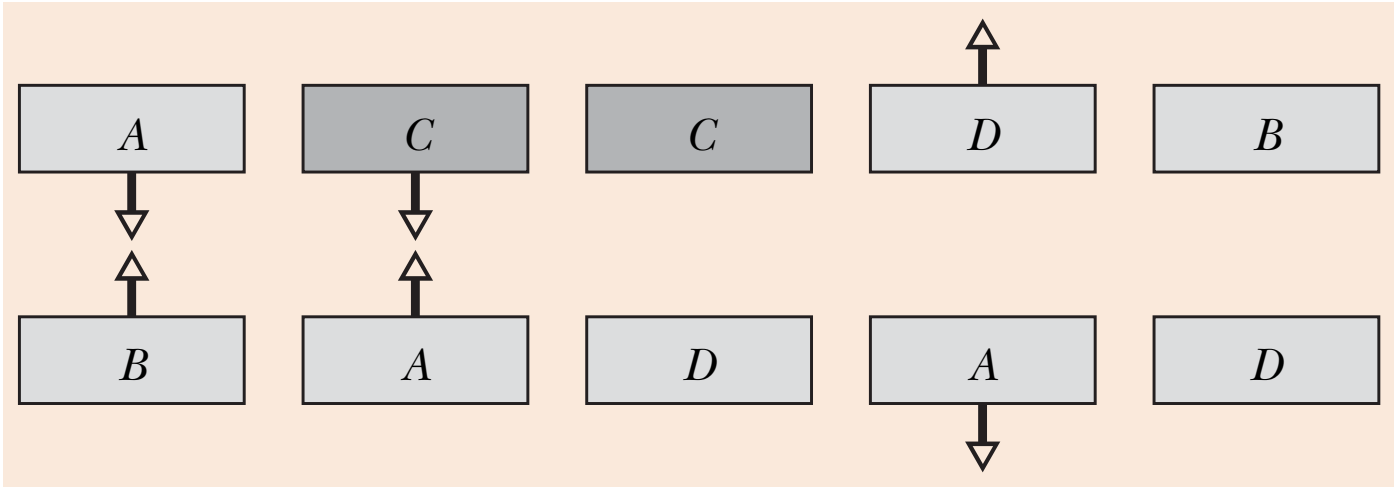
- Allows me to ask multiple choice questions or do surveys, and get real-time feedback.
- You can remain anonymous.
- You need a device connected to the internet.

Go to **https://kahoot.it**

Then: Enter the Game PIN.

Question

A, B, and D are charged pieces of plastic. C is an electrically neutral copper plate.



Plates C and D

(A) attract each other

(B) repel each other

[1] Page 564, Halliday, Resnick, Walker, 9th ed.

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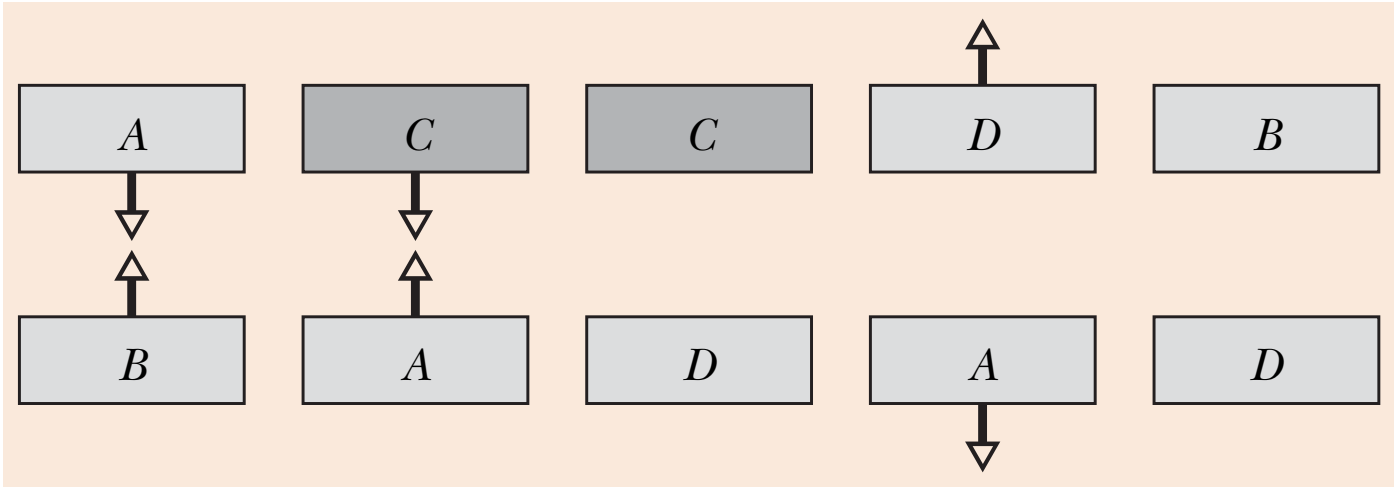

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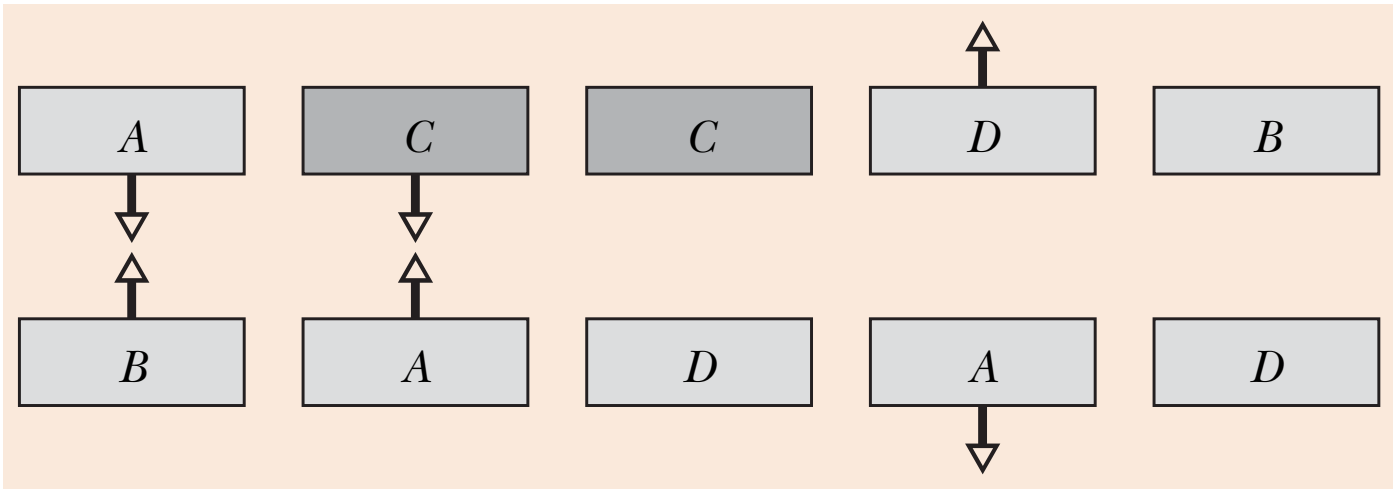

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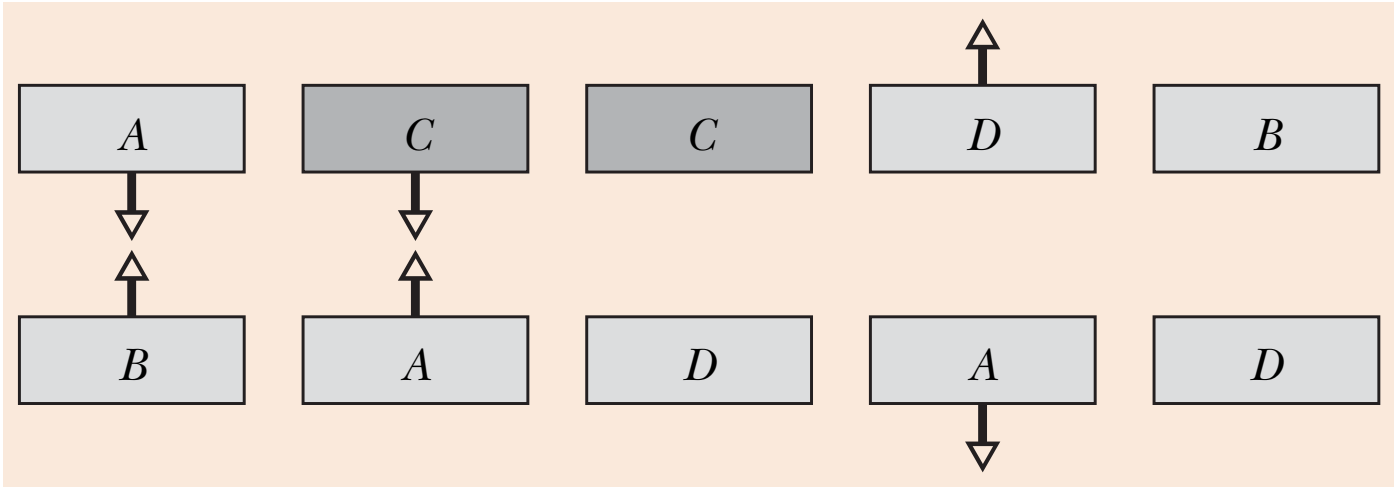

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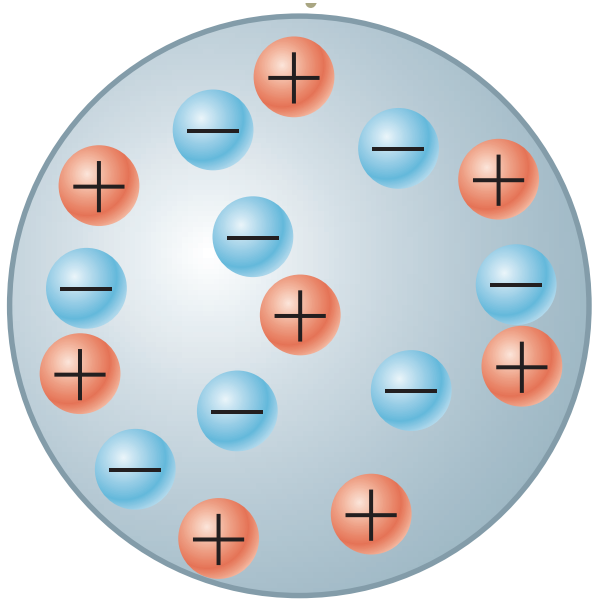
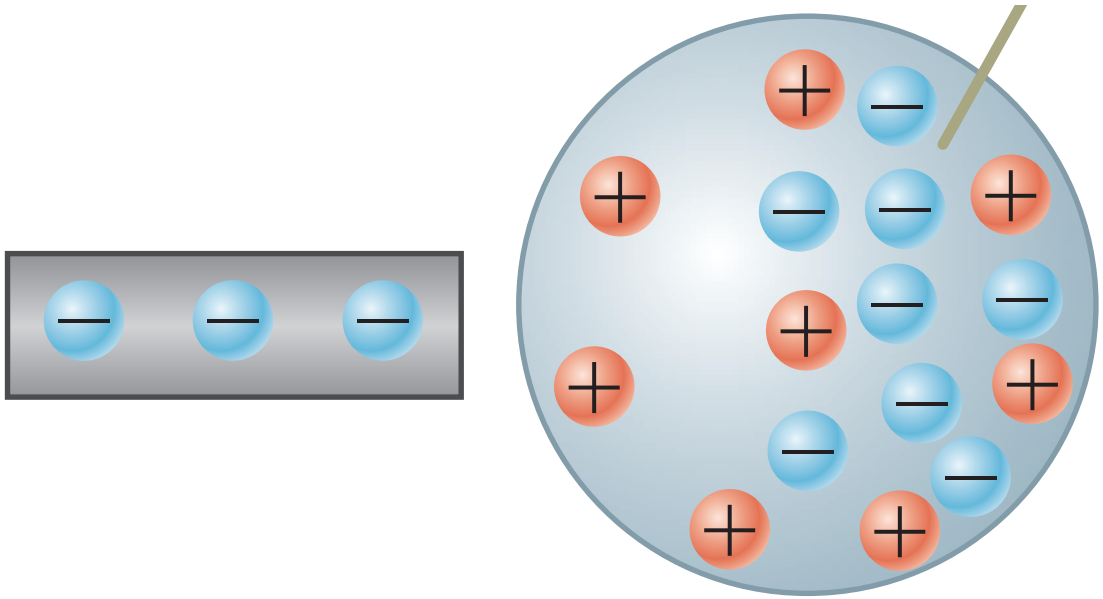
Charging by Induction



A conductor is initially neutrally charged.

[1] Figures from Serway & Jewett, 9th ed.

Charging by Induction



A (negatively) charged object is brought close, polarizing the conductor.

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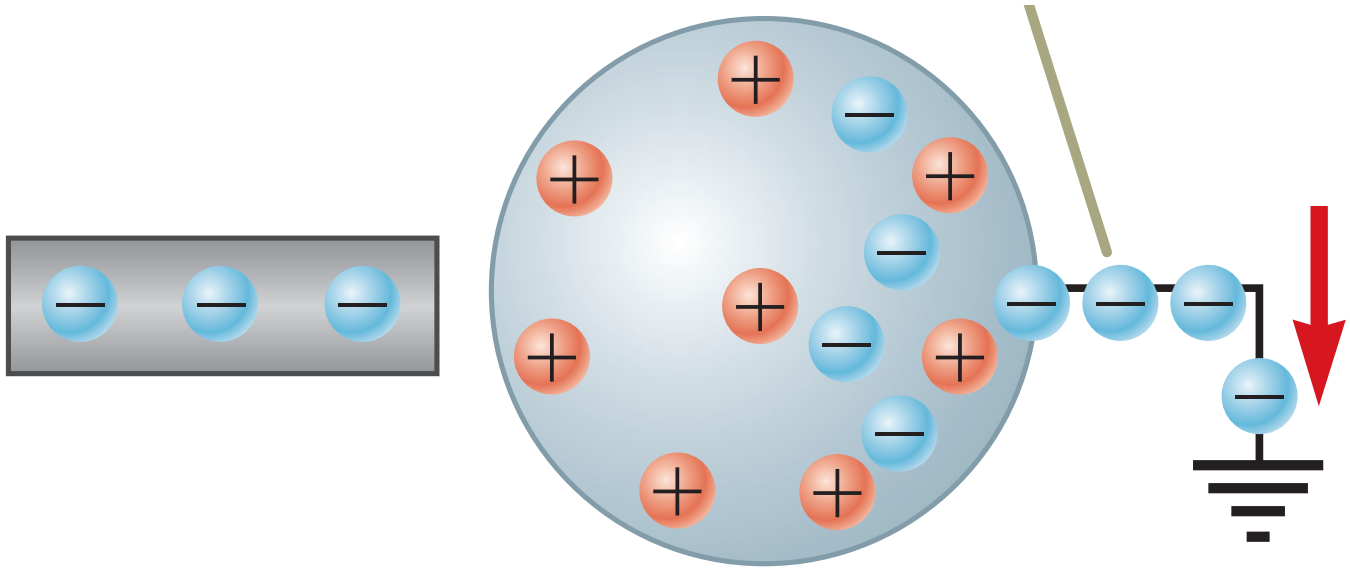
Charging by Induction



Excess (negative) charge on the far side is drawn off the conductor by grounding it.

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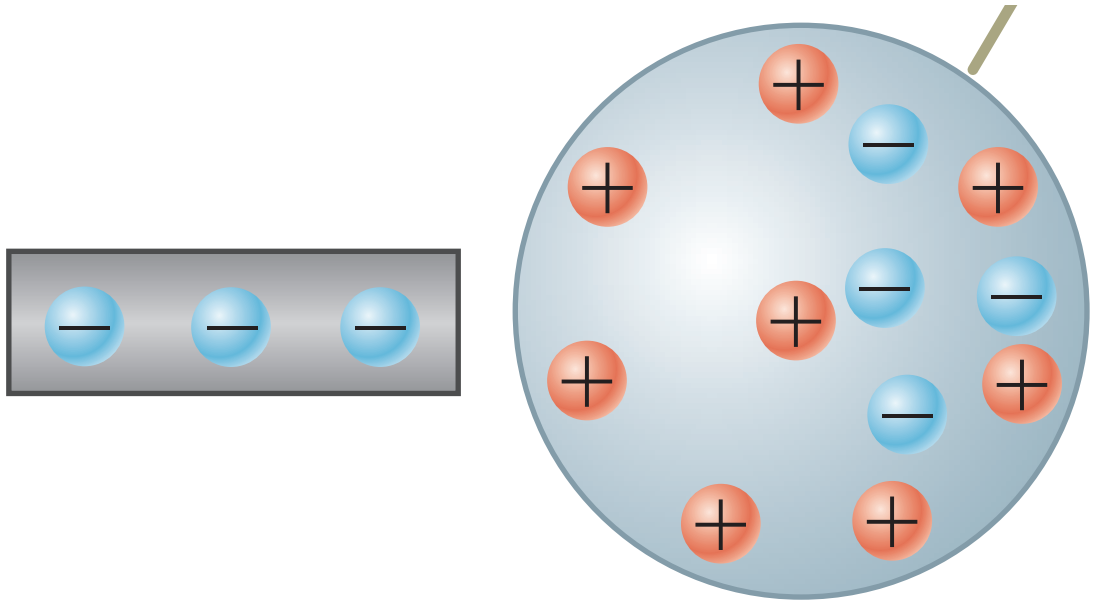
Charging by Induction



The conductor is isolated again.

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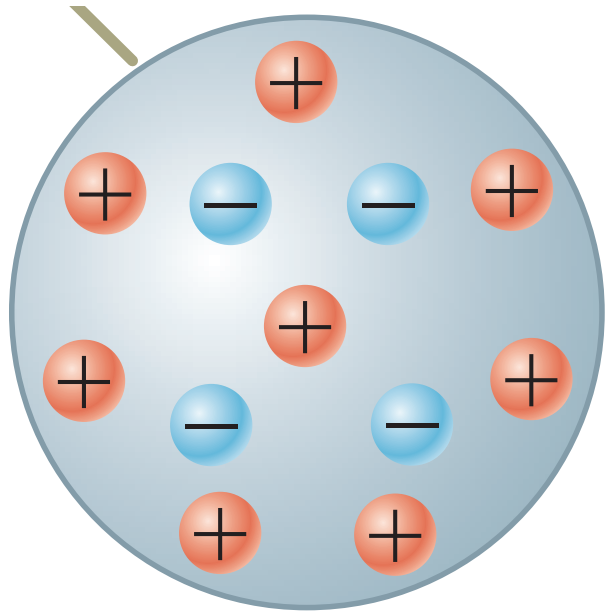
Charging by Induction



The conductor is now (positively) charged.

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Charge is Quantized

quantization

A physical quantity is said to be **quantized** if if can only take discrete values.

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Just like water has a smallest unit, the H_2O molecule, charge has a smallest unit, written e, the *elementary charge.*

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

Any charge must be

$$q = ne\ , \qquad n \in \mathbb{Z}$$

Question

Initially, sphere A has a charge of $-50e$ and sphere B has a charge of $20e$. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?

(A) $-50e$

(B) $-30e$

(C) $-15e$

(D) $20e$

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Conservation of Charge

Charge can move from one body to another but the net charge of an isolated system never changes.

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Noether's Theorem $\Rightarrow$ the corresponding

Conservation of Charge

One interesting phenomenon that shows the conservation of charge is *pair production*.

A gamma ray (very high energy photon) converts into an electron and a positron (anti-electron):

$$\gamma \rightarrow e^- + e^+$$

New mass is created out of light, but charge is still conserved!

Electrostatic Forces

Charged objects interact via the electrostatic force.

The force that one charge exerts on another can be attractive or repulsive, depending on the signs of the charges.

- Charges with the **same** electrical sign **repel** each other.
- Charges with **opposite** electrical signs **attract** each other.

Charge is written with the symbol q or Q.

Electrostatic Forces

For a pair of point-particles with charges q_1 and q_2, the magnitude of the force on each particle is given by **Coulomb's Law**:

$$F_{1,2} = \frac{k_e \, q_1 q_2}{r^2}$$

k_e is the electrostatic constant and r is the distance between the two charged particles.

$k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ N m}^2/\text{C}^2$

Electrostatic Forces: Coulomb's Law

$$F_{1,2} = \frac{k_e\, q_1 q_2}{r^2}$$

Remember however, forces are vectors. The vector version of the law is:

$$\mathbf{F}_{1\to 2} = \frac{k_e\, q_1 q_2}{r^2}\,\hat{\mathbf{r}}_{1\to 2}$$

where $\mathbf{F}_{1\to 2}$ is the force that particle 1 exerts on particle 2, and $\hat{\mathbf{r}}_{1\to 2}$ is a unit vector pointing from particle 1 to particle 2.

Summary

- charge
- conductors and insulators
- induced charge
- quantization of charge
- charge conservation
- Coulomb force

Quiz Friday, start of class.

Homework

- Get the textbook: Physics for Scientists and Engineers, 9th Edition, Serway & Jewett
- Read Ch 23.
- Ch 23, onward from page 716. Objective Qs: 7, 9; Conceptual Qs: 1, 5; Probs: 1, 3, 9, 16, 17