Electric Charge

Unit: Electric Force, Field & Potential

NGSS Standards/MA Curriculum Frameworks (2016): HS-PS3-5

AP® Physics 2 Learning Objectives/Essential Knowledge (2024): 10.1.A, 10.1.A.1, 10.1.A.1.i, 10.1.A.1.ii, 10.1.A.1.iii, 10.1.A.iv, 10.2.A, 10.2.A.1, 10.2.A.1.i, 10.2.A.1.ii, 10.2.A.1.iii, 10.2.A.2, 10.2.A.2.i, 10.2.A.2.ii, 10.2.A.3

Mastery Objective(s): (Students will be able to…)

- Describe properties of positive and negative electric charges.
- Describe properties of conductors and insulators.

Success Criteria:

- Variables are correctly identified and substituted correctly into the correct part of the correct equation.
- Algebra is correct and rounding to appropriate number of significant figures is reasonable.

Language Objectives:

- Explain why the mass of the pendulum does not affect its period.

Tier 2 Vocabulary: charge

Labs, Activities & Demonstrations:

- charged balloon making hairs repel, attracting water molecules.
- charged balloon sticking to wall (draw on one side of balloon to show that charges do not move)
- charged balloon pulling meter stick
- build & demonstrate electroscope
- Wimshurst machine
- Van de Graaff generator

Notes:

<u>charge:</u>

1. A physical property of matter which causes it to experience a force when near other electrically charged matter. (Sometimes called "electric charge".) Measured in coulombs (C).
2. A single microscopic object (such as a proton or electron) that carries an electric charge. (Sometimes called a "point charge.) Denoted by the variable q.
3. The total amount of electric charge on a macroscopic object (caused by an accumulation of microscopic charged objects). Denoted by the variable Q.

4. (verb) To cause an object to acquire an electric charge.

positive charge: the charge of a proton. Originally defined as the charge left on a piece of glass when rubbed with silk. The glass becomes positively charged because the silk pulls electrons off the glass.

negative charge: the charge of an electron. Originally defined as the charge left on a piece of amber (or rubber) when rubbed with fur (or wool). The amber becomes negatively charged because the amber pulls the electrons off the fur.

static electricity: stationary electric charge, such as the charge left on silk or amber in the above definitions.

elementary charge: the magnitude (amount) of charge on one proton or one electron. One elementary charge equals 1.60×10^{-19} C. Because ordinary matter is made of protons and electrons, the amount of charge carried by any object must be an integer multiple of the elementary charge.

Note however that quarks, which protons and neutrons are made of, carry fractional charges; up-type quarks carry a charge of $+\frac{2}{3}$ of an elementary charge, and down-type quarks carry a charge of $-\frac{1}{3}$ of an elementary charge. A proton is made of two up quarks and one down quark and carries a charge of +1 elementary charge. A neutron is made of one up quark and two down quarks and carries no charge.

electric current (sometimes called electricity): the movement of electrons through a medium (substance) from one location to another. Note, however, that electric current is defined as the direction a *positively* charged particle would move. Thus, electric current "flows" in the opposite direction from the actual electrons.

Some Devices that Produce, Use or Store Charge

capacitor: a device that stores electric charge.

battery: a device that uses chemical reactions to produce an electric current.

generator: a device that converts mechanical energy (motion) into an electric current.

motor: a device that converts an electric current into mechanical energy.

Conductors *vs.* Insulators

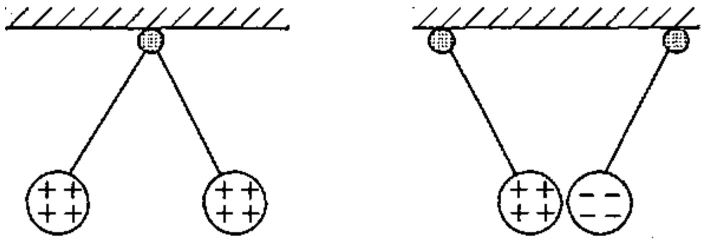
conductor: a material that allows charges to move freely through it. Examples of conductors include metals and liquids with positive and negative ions dissolved in them (such as salt water). When charges are transferred to a conductor, the charges distribute themselves evenly throughout the substance.

insulator: a material that does not allow charges to move freely through it. Examples of insulators include nonmetals and most pure chemical compounds (such as glass or plastic). When charges are transferred to an insulator, they cannot move, and remain where they are placed.

Behavior of Charged Particles

- **Like charges repel.** A pair of the same type of charge (two positive charges or two negative charges) exert a force that pushes the charges away from each other.

- **Opposite charges attract.** A pair of opposite types of charge (a positive charge and a negative charge) exert a force that pulls the charges toward each other.



Note that if you were to place a charge (either positive or negative) on a solid metal sphere, the charges would repel, and the result would be that the charges would be spread equally over the *outside* surface, but not inside the sphere.

Conservation of Charge

Because electric charges are an inherent property of subatomic particles (protons and electrons), and because mass is conserved (as you should have learned in chemistry), charge is therefore also a conserved quantity.

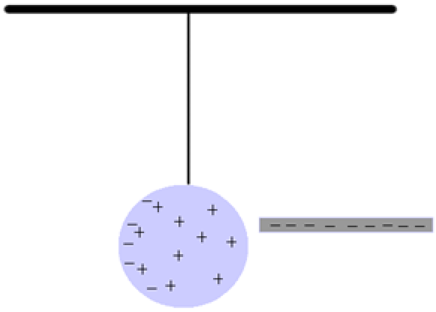
This means that electric charges can be moved from one object to another, but cannot be created or destroyed.

This means that the net charge on a system is constant unless electrons are transferred to or from the surroundings. For example, if you wear shoes with rubber soles and scuff your feet on a carpet, this action transfers electrons from the carpet to your shoes.

Charging by Induction

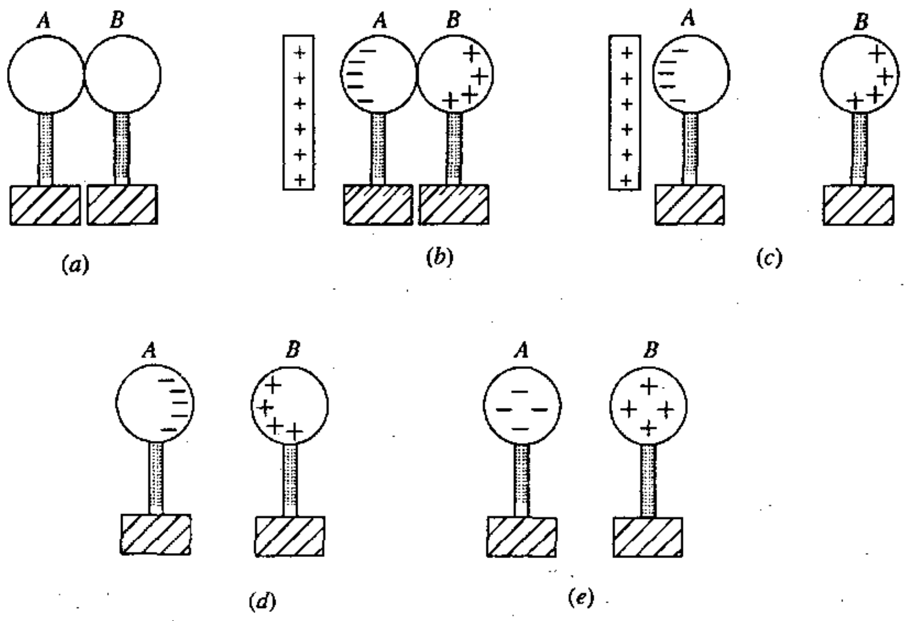
induction: when an electrical charge on one object causes a charge in a second object.

When a charged rod is brought near a neutral object, the charge on the rod attracts opposite charges and repels like charges that are near it. The diagram to the right shows a negatively charged rod repelling negative charges.



If the negatively charged rod were touched to the sphere, some of the charges from the rod would be transferred to the sphere at the point of contact. This would cause the sphere to have an overall negative charge.

A procedure for inducing charges in a pair of metal spheres is shown below:



(a) Metal spheres *A* and *B* are brought into contact.

(b) A positively charged object is placed near (but not in contact with) sphere *A*. This induces a negative charge in sphere *A*, which in turn induces a positive charge in sphere *B*.

(c) Sphere *B* (which is now positively charged) is moved away.

(d) The positively charged object is removed.

(e) The charges distribute themselves throughout the metal spheres.

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Charge Density

The amount of electric charge on a surface is called the charge density. As with density (in the mass/volume sense), the variable used is usually the Greek letter rho with a subscript *q* indicating charge (ρ_q). Charge density can be expressed in terms of length, area, or volume, which means, the units for charge density can be $\frac{\text{C}}{\text{m}}$, $\frac{\text{C}}{\text{m}^2}$, or $\frac{\text{C}}{\text{m}^3}$.

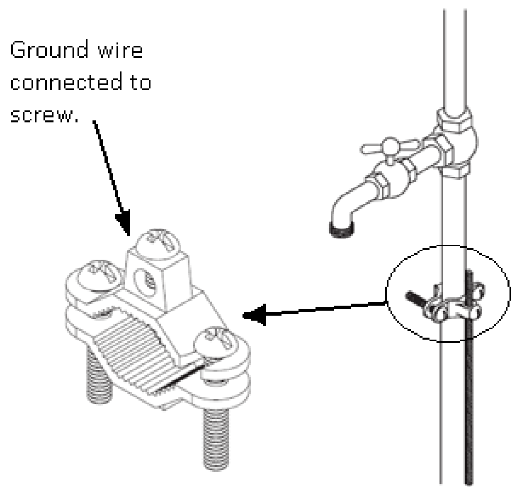
Grounding

For the purposes of our use of electric charges, the ground (Earth) is effectively an endless supply of both positive and negative charges. Under normal circumstances, if a charged object is touched to the ground, electrons will move to neutralize the charge, either by flowing from the object to the ground or from the ground to the object.

Grounding a charged object or circuit means neutralizing the electrical charge on an object or portion of the circuit by connecting it to a much larger and approximately neutral system, such as the Earth.

The charge of any object that is connected to ground is zero, by definition.

The term “grounding” comes from the fact that this is often accomplished by connecting the system via a wire to a metal pipe or stake that is partially or fully buried in the ground.



In buildings, the metal pipes that bring water into the building are often used to ground the electrical circuits. The metal pipe is a good conductor of electricity and carries the unwanted charge out of the building and into the ground outside.