CHAPTERS 21 AND 22 NOTES

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Contents

21 Electric Charge and Electric Field

Electromagnetic interactions involve particles that have electric charge, an attribute that is as fundamental as mass. Just as objects with mass are accelerated by gravitational forces, so electrically charged objects are accelerated by electric forces.

21.1 Electric Charge.

Definition 1. Electric Charge: is the state of having more or less than a natural amount of electrons.*Positive* if less or *Negative* if more.

Remark. Two positive charges or two negative charges repel each other. A positive charge and a negative charge attract each other.

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Definition 2. Electrostatics: the interactions between electric charges that are at rest (or nearly so).

21.1.1 Electric Charge and the Structure of Matter.

Definition 3. Parts of Atom: Positive Protons, negative Electrons and Neutral Neutrons. Protons and Neutrons are held by *Strong Nuclear Force* to form the Nucleus and are themselves comprised of *Quarks*. The Majority of Atom is the *Electron Cloud*

Definition 4. Ionization: Normally positive charge and negative charge cancel out, but through an addition or loss of an electron the atom becomes ionized, becoming either a *positive* or *negative* ion

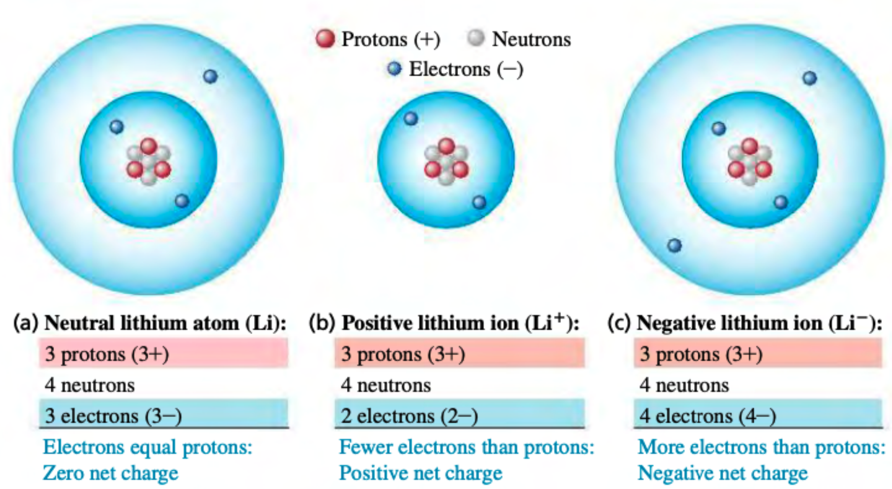

FIGURE 1. Atomic Structure and Ionization

21.1.2 Electric Charge is Conserved.

Theorem 1. Principle of conservation of charge: The algebraic sum of all the electric charges in any closed system is constant. In any charging process, charge is not created or destroyed; it is merely transferred from one body to another.

Theorem 2. Quantized Nature of Charge: The magnitude of charge of the electron or proton is a natural unit of charge.

21.2 Conductors, Insulators, and Induced Charges.

Definition 5. Conductivity and Insulation: *Conductors* are materials that transfer electrons well, such as copper and other metals.

The opposite are *Insulators* which are poor and transfering charge, these are often nonmetals. Some materials called *semiconductors* are intermediate in their properties between good conductors and good insulators.

21.2.1 Charging by Induction.

Definition 6. Induction: a method used to charge an object without actually touching the object to any other charged object. This is done by rearranging electrons already present in object

Definition 7. Polarization: The slight shifting of charge within the molecules of the neutral insulator when placed near a charge object. This is what causes charge by Induction

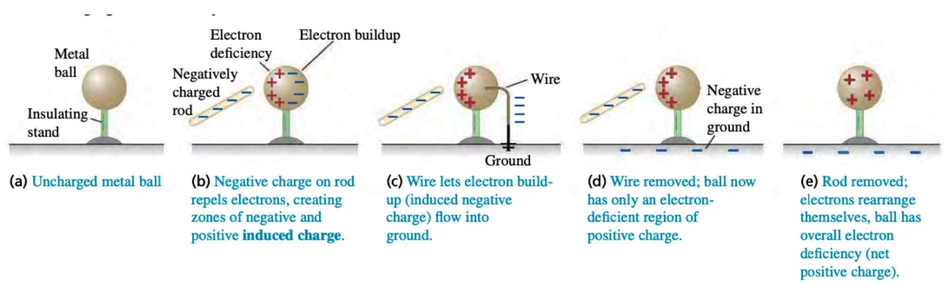

FIGURE 2. Charge by Induction

21.3 Coulomb's Law.

Definition 8. : **Point Charges**: Simple charged bodies whose mass is irrelevant.

Theorem 3. Coulomb's Law: The magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. In mathematical terms shown as

$$F = k\frac{|q_1 * q_2|}{r^2}$$

where the coulomb constant k = $8.987551787 * 10^9 N \cdot m/C^2$ and can also be described in SI units as $\frac{1}{4\pi\epsilon_0}$.

Theorem 4. Principle of Superposition of Forces: To find sum of forces a vector sum must be calculated involving the composite internal forces.

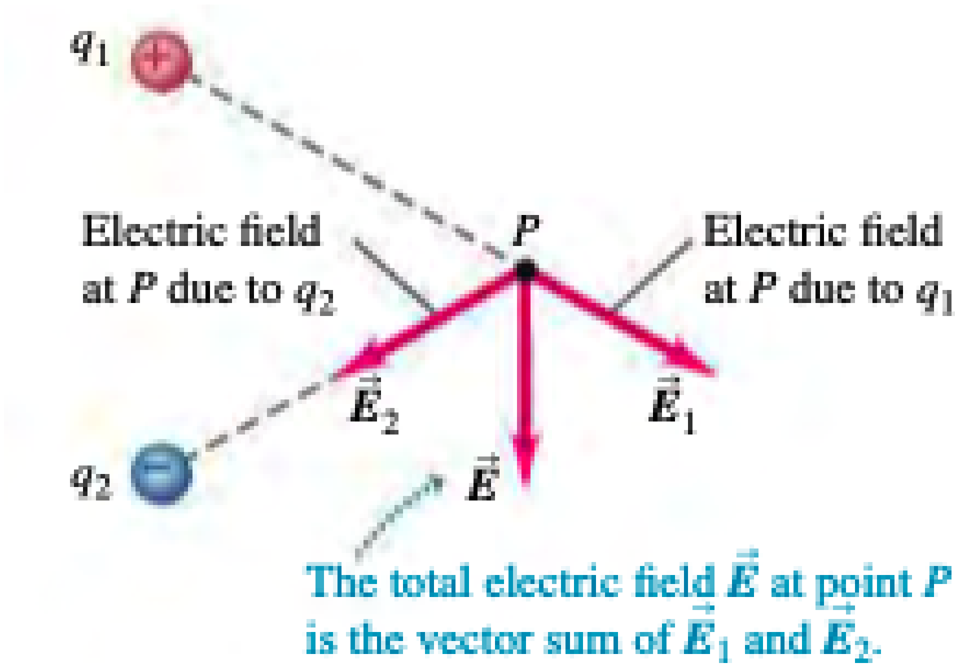

FIGURE 3. Superposition

21.4 Electric Field and Electric Forces.

Definition 9. Electric Field: The intermediary through which charges interact. The equation to find the strength of an electric field is

$$|E| = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

where the sign relates to the direction of the field.

Remark. The electric force on a charged body is exerted by the electric field created by other charged bodies.

21.5 Electric-Field Calculations.

Theorem 5. Principle of Superpositon of Electric Fields:The total electric field at P is the vector sum of the fields at P due to each point charge in the charge distribution.

Definition 10. Types of Charge Density:

(1) Linear Charge Density: Charge per unit length, measured in C/m and written as λ

(2) Surface Charge Density: Charge per unit area, measured in C/m^2 and written as σ
(3) Volume Charge Density: Charge per unit volume, measured in C/m^3 and written as ρ.

21.6 Electric Field Lines.

Definition 11. Electric Field Line: An imaginary line demonstrating direction of electric field —E— vector at point and the density of lines shows magnitude.

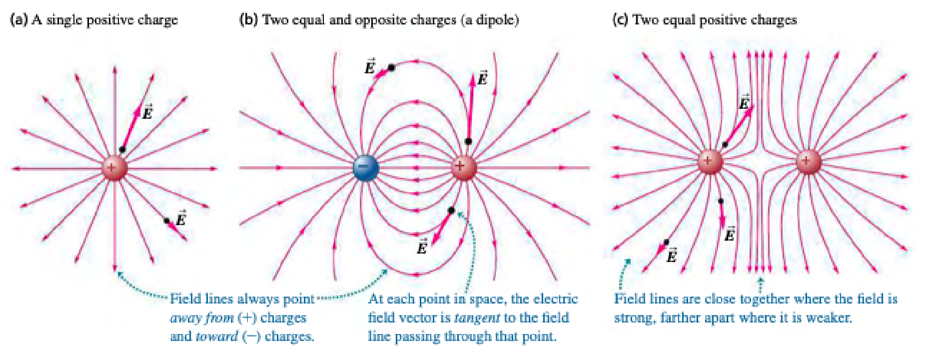

FIGURE 4. Field Lines

21.7 Electric Dipoles.

Definition 12. Electric Dipole: A pair of point charges with equal magnitude and opposite sign (a positive charge q and a negative charge -q) separated by a distance d.

21.7.1 Force and Torque on an Electric Dipole.

Definition 13. Electric Dipole Moment: A measure of the system's overall polarity, can be calculated using

$$p = qd$$

where q is charge and d is seperation. Direction of p is from negative to positive

Definition 14. Torque on an Electric Dipole: Because the point charges may not be parallel, a torque exists and can be found through the equation

$$\tau = pEsin\phi$$

where p is the dipole moment and ϕ is the angle between the dipole moment and E

Definition 15. Potetial Energy of an Electric Dipole: Because there is work being there is a change in potential energy and we can find this through the equation

$$U = -p \cdot E = pEcos\phi$$

22 Gauss's Law

Here's what Gauss's law is all about. Given any general distribution of charge, we surround it with an imaginary surface that encloses the charge. Then we look at the electric field at various points on this imaginary surface. Gauss's law is a relationship between the field at all the points on the surface and the total charge enclosed within the surface.

Definition 16. Closed Surface: An essential part of making a calculation of flux, The shape must entirely enclose a volume to calculate Gauss's Law.

22.1 Charge and Electric Flux.

Definition 17. Electric Flux: the rate of flow of the electric field through a given area. Electric flux is proportional to the number of electric field lines going through a virtual surface. Independent of size.

Remark. Positive charge inside the box goes with an outward electric flux through the box's surface, and negative charge inside goes with an inward electric flux. If there is no charge, neto zero charge, or the same flux in and out there is no electrix flux.

22.2 Calculating Electric Flux.

Definition 18. Flux of Uniform Electric Field: Flux exists as the overlap of the electric field and the surface. Mathematically it is expressed as

$$\Phi_E = EAcos\phi$$

where ϕ is the vertical angle normal to the surfaces.

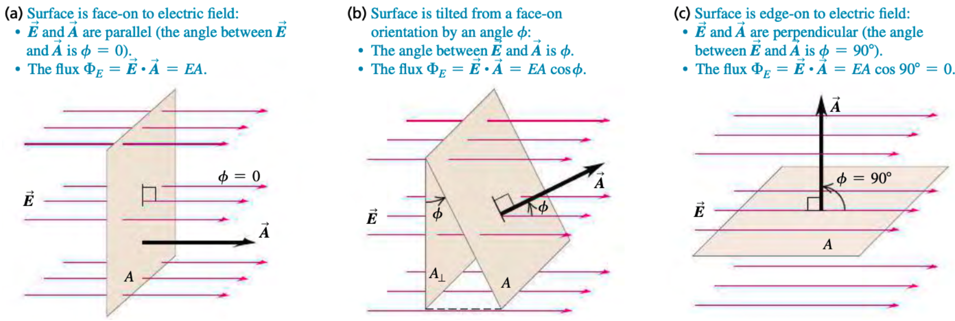

FIGURE 5. Uniform Flux

Definition 19. Flux of Nonuniform Electric Field:' To find the flux of a varying electric field or on a curved survace we must find the surface integral by finding an infintesimal dA.For this case the equation morphs to

$$\Phi_E = \int EAcos\phi dA = \int E \cdot dA$$

where ϕ is again the vertical angle normal to surface and A is surface area.

22.3 Gauss's Law.

Theorem 6. Gauss's Law: An alternative to Coulomb's Law, Gauss's law states the total electric flux through a closed surface is proportional to total net electric charge. The complete relation can be read as

$$\Phi_E = \int EAcos\phi = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2}(4\pi R^2) = \frac{q}{\epsilon_0}$$

for a sphere, noting that flux is independent of Radius, only charge q

Remark. General Form of Gauss's Law can be expressed as The total electric flux through a closed surface is equal to the total (net) electric charge inside the surface, divided by ϵ_0, or in equation form

$$\Phi_E = \frac{Q_encl}{\epsilon_0}$$