Lecture 1: Basic Concepts in Electricity

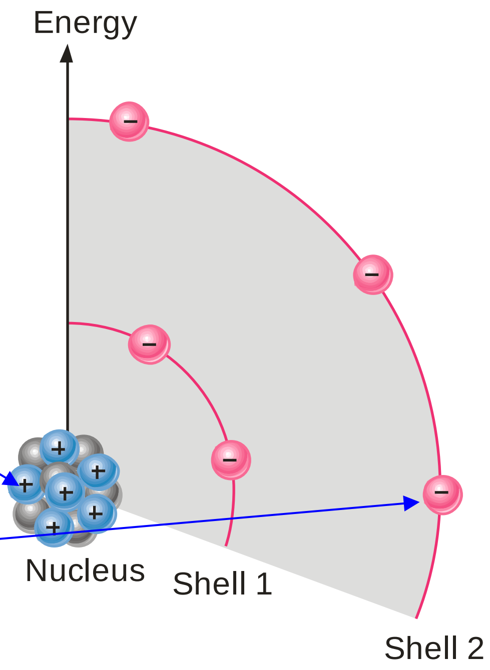
Insulators, conductors, semiconductors, electric force, electric field, electric potential, current, voltage drop

The Bohr Model

The Bohr model of the atom is that electrons can circle the nucleus only in specific orbits, which correspond to discrete energy levels called **shells**.

The **atomic number** is the number of protons in the nucleus.

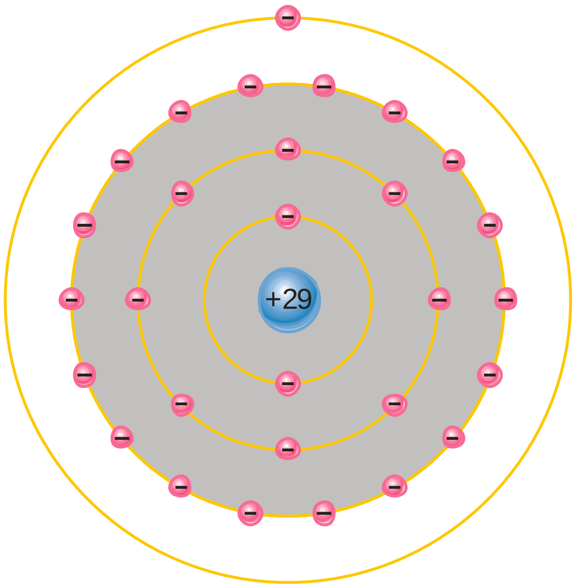
The outermost occupied shell is called the **valence shell** and electrons that occupy this shell are called **valence electrons**.



Conductors

Materials can be classified by their ability to conduct electricity. This ability is related to the valence electrons.

Copper is an example of an excellent **conductor**. It has only one electron in its valence band, which can easily escape to the conduction band, leaving behind a **positive ion** (the core). Like all metals, copper has many free electrons which are loosely held by the attraction of the positive metal ions.



Insulators

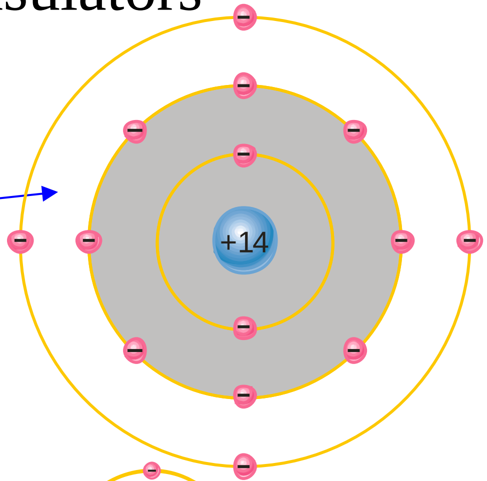
Insulators have tightly bound electrons with few electrons available for conduction.

nonmetals, such as glass, air, paper, and rubber are excellent insulators and widely used in electronics. Even these materials can break down and conduct electricity if the voltage is high enough.

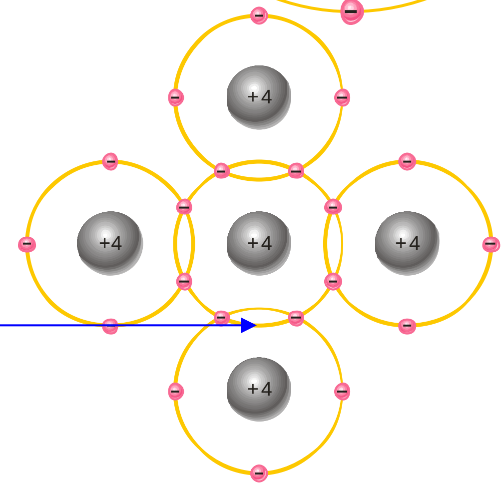
Semiconductors

Semiconductors are between conductors and insulators in their ability to conduct electricity.

Silicon is an example of a single element **semiconductor**. It has four electrons in its valence band.



Unlike metals, silicon forms strong **covalent** bonds (shared electrons) with its neighbors. Intrinsic silicon is a poor conductor because most of the electrons are bound in the crystal and take part in forming the bonds between atoms.



Electric Force

charged particles in atoms: electrons and protons

protons have *positive* charge, and electrons have *negative* charge

electron charge is equal in magnitude to the charge of a proton

electron charge is the smallest <u>indivisible</u> amount of charge

$e \approx -1.602 \times 10^{-19}, \;\; \text{C}$

two electric charges affect one another by force according to Coloumb's law

Electric Force (Cont'd)

Similar charges rebel and different charges attract

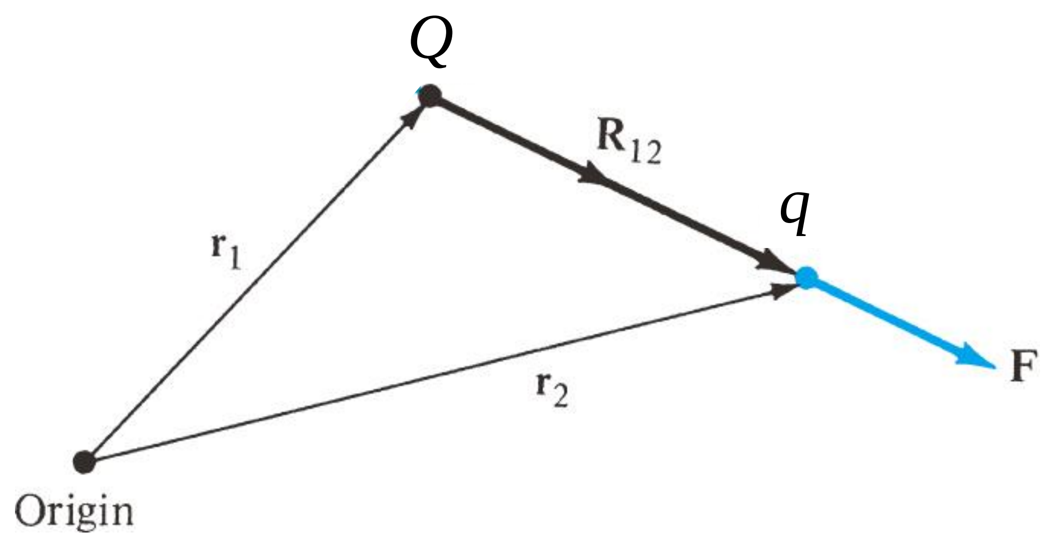
$$\mathbf{F}_{12} = \underbrace{\frac{1}{4\pi\varepsilon}}_{k}\frac{Q_1Q_2}{R_{12}^3}\mathbf{R}_{12} = \underbrace{\frac{1}{4\pi\varepsilon}}_{k}\frac{Q_1Q_2}{\left|\mathbf{r}_2 - \mathbf{r}_1\right|^3}\left(\mathbf{r}_2 - \mathbf{r}_1\right)$$

in vacuum, if the force is measured in *newtons*, the distance in *meters*, and the charge in *ampere-seconds* (coulombs):

$$k \approx 9.0 \times 10^9$$

Example

Electric Field



electric field vector – the force exerted on a unit charge

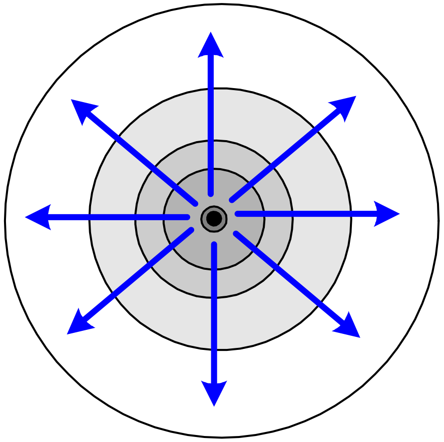
$$\mathbf{E} = \lim_{q \to 0} \frac{\mathbf{F}}{q}, \quad \text{N/C=V/m} \quad \Leftrightarrow \mathbf{F} = q\mathbf{E}, \quad \text{N}$$

q is a *test (probe) charge*, the value and size of which are small enough not to disturb the measured original field of the source.

Electric Field of a Point Charge

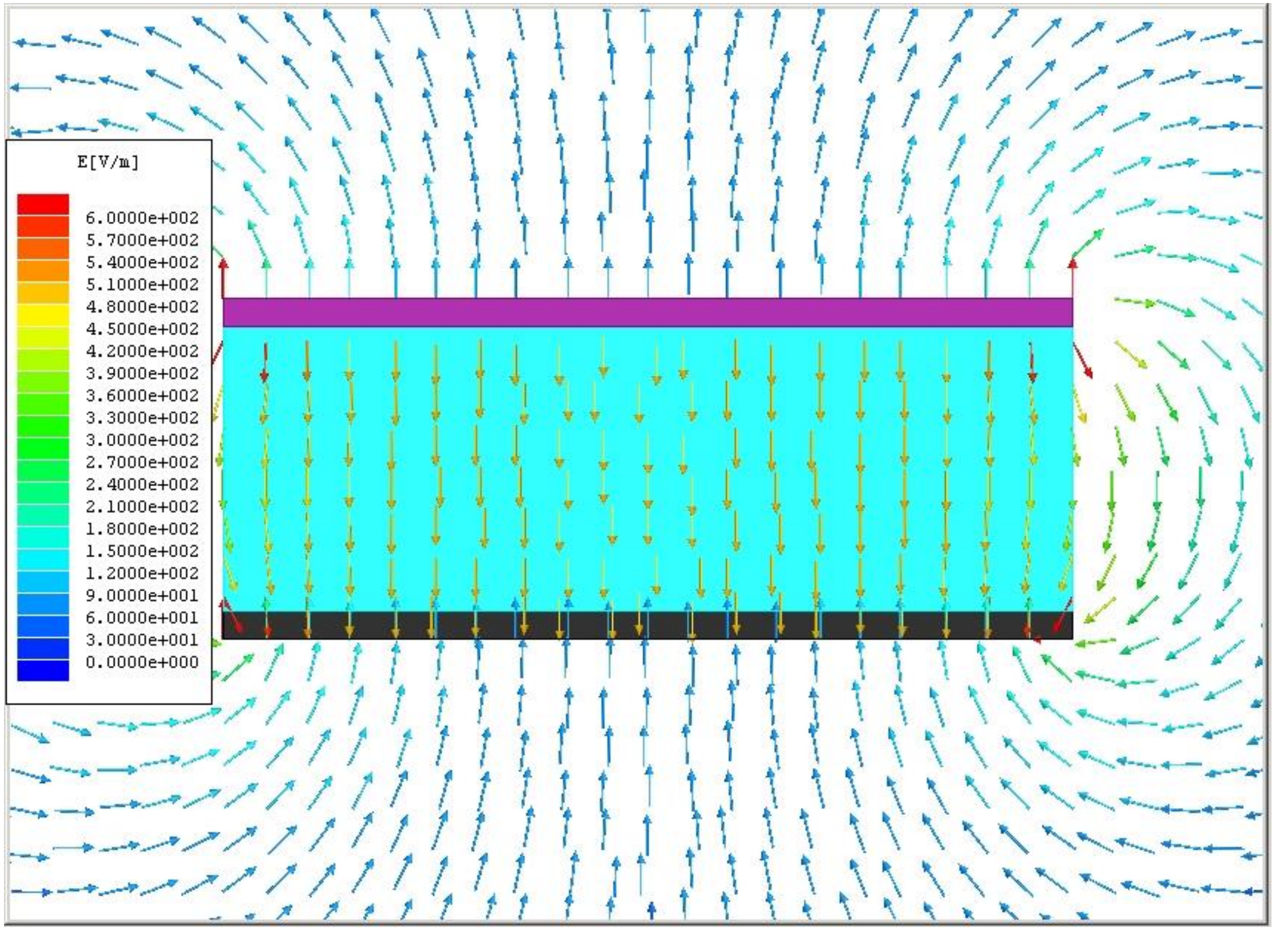
electric field of a positive point charge located at the origin of a spherical coordinate system

$$\mathbf{E} = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}\mathbf{a}_r, \quad \text{V/m}$$



notice that in this expression the charge is at the origin!

Electric Field of a Capacitor



Electric Potential (Voltage Difference)

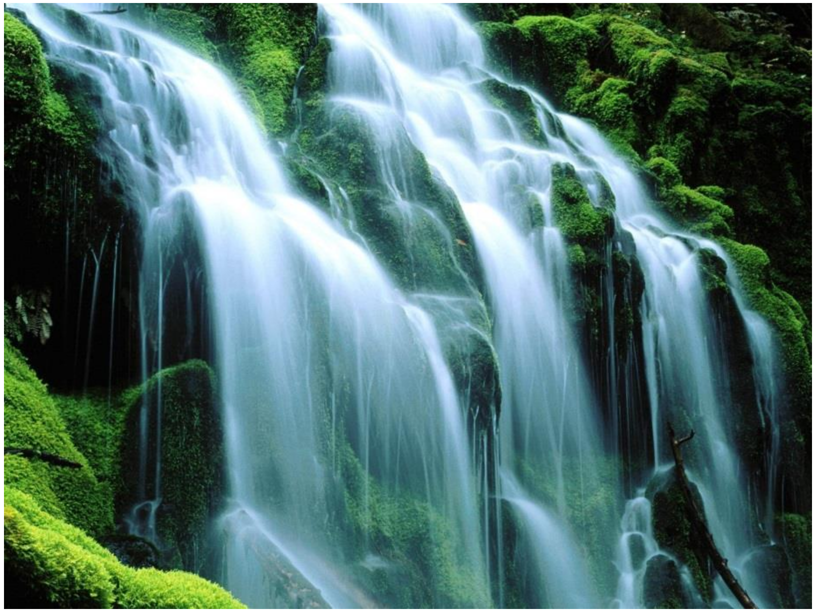
potential difference V_{AB} is the work done by the electric field in moving a unit test charge from point B to point A

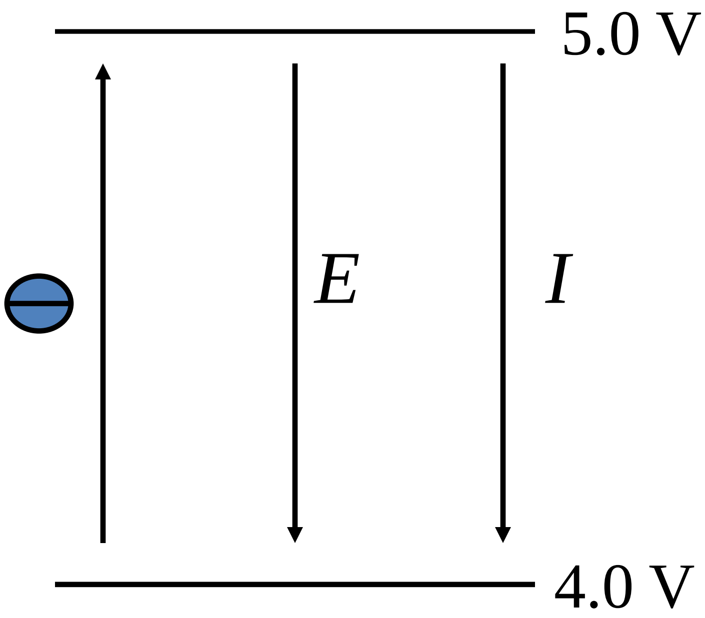
$$V_{AB} = V_B - V_A = \int_B^A \mathbf{E} \cdot d\mathbf{L}, \text{ V}$$

potential difference V_{AB} is the work done by the electric field in moving a unit test charge from point B to point A

Current density is related to the electric field through the conductivity $\mathbf{J}=\sigma\mathbf{E}$ A/m^2

Important Analogy

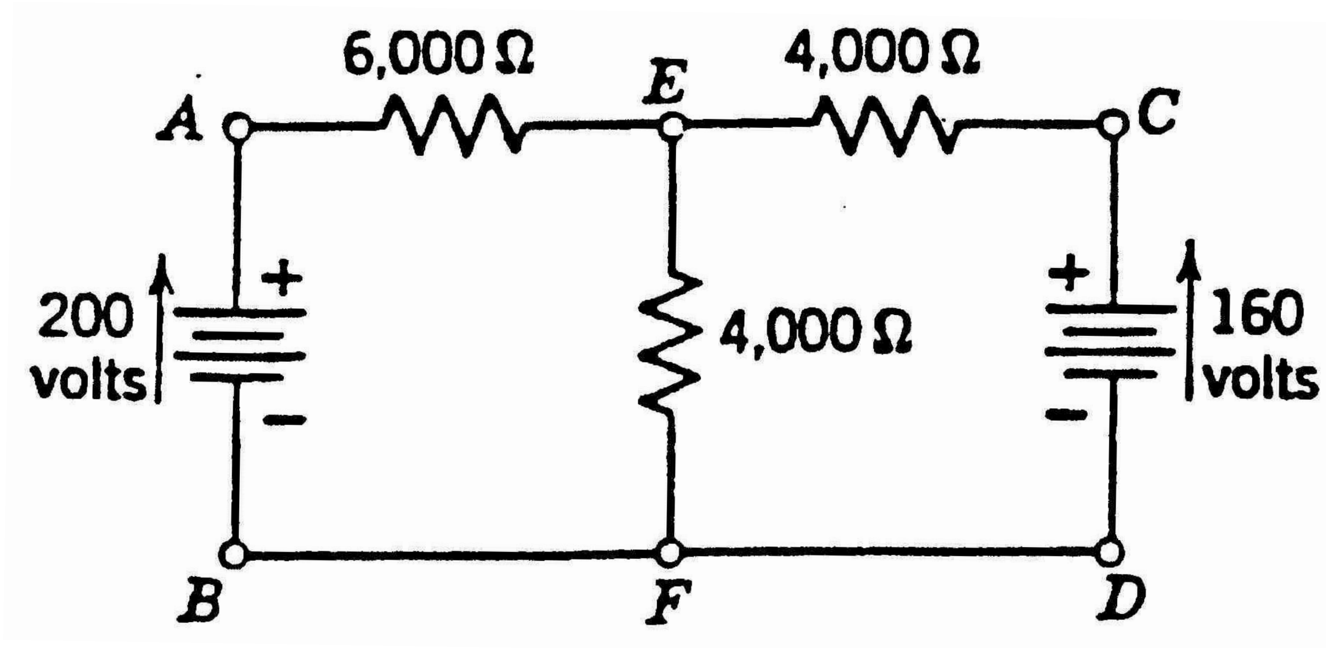




water flows from high elevations to lower elevations and electric field points from higher potential to lower potential!

electric field moves POSITIVE charges in its direction (electric current is the flow of positive charges)

Electric Circuits



Battery creates an electric field everywhere in the circuit

Conductors allow their electrons to drift opposite to the electric field creating a current