Electric Potential Energy

- Potential energy can be defined as the capacity for doing work which arises from position or configuration
- In the electrical case, a charge will exert a force on any other charge and potential energy arises from any collection of charges

$$U = k\frac{qQ}{r}$$

Work done on a charged particle in a field:

F = EQ

$$\boxed{W = Fs = EQs}$$

- Positive charges will accelerate in the direction of the field, while negative charges will accelerate in a direction opposite to that of the field.

The principle of conservation of energy dictates that the **kinetic energy gained** by the charged particle accelerating in the field is **equal to its loss in potential energy**.

Electric potential (Voltage)

- Voltage is electric potential energy per unit charge
- The unit of potential is the volt (V), measured in joules per coulomb (J/C)

$$V = \frac{W}{Q}$$

Volt

- *"One volt is the potential difference between two points in an electric field such that one joule of work is done in moving one coulomb of charge from one point to another."*

The potential at a point can be defined as the work required to move one coulomb of charge from infinity to that point.

$$W = VQ \qquad W = Fd = EQd$$

$$EQd = VQ \qquad E = \frac{V}{d}$$

Units of the electric field

$$[E] = \frac{N}{C} \qquad [E] = \frac{V}{m}$$

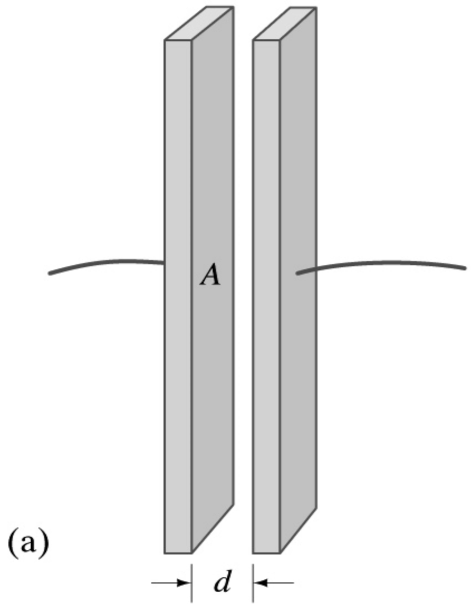
Equipotential lines

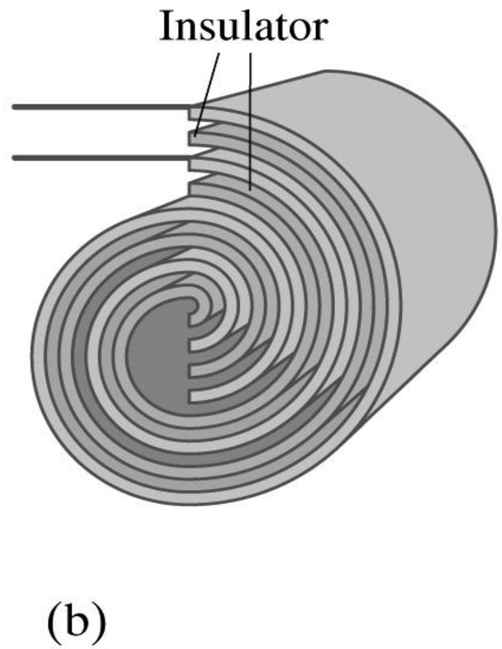
- A line on which the potential is the same everywhere is called an equipotential line.
- Equipotential lines are always perpendicular to the electric field.

Capacitors

- A **capacitor** is a device that stores electric charge.
- A capacitor consists of two conductors separated by an insulator.
- Capacitors have many applications:
  - Computer RAM memory and keyboards.
  - Electronic flashes for cameras.
  - Electric power surge protectors.
  - Radios and electronic circuits.

Types of Capacitors





Parallel-Plate Capacitor

Cylindrical Capacitor

- A cylindrical capacitor is a parallel-plate capacitor that has been rolled up with an insulating layer between the plates.

Capacitors and Capacitance

A capacitor in a simple electric circuit.

Charge *Q* stored: $$Q = CV$$

The stored charge *Q* is proportional to the potential difference *V* between the plates.

$$C = \frac{Q}{V}$$

The capacitance *C* is the constant of proportionality

Units of capacitance $$[F] = \frac{C}{V}$$

$1\ \mu F = 10^{-6} F$

Capacitors in Parallel

$$Q = Q_1 + Q_2 + Q_3 =$$

$$C_1 V + C_2 V + C_3 V =$$

$$(C_1 + C_2 + C_3)V = C_{eq} V$$

$$C_{eq} = C_1 = C_2 + C_3 + \ldots$$

Capacitors in Series

$$V = V_1 + V_2 + V_3 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} =$$

$$Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) = \frac{Q}{C_{eq}}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Dielectrics

- A **dielectric** is an insulating material *(e.g. paper, plastic, glass)*.
- If a dielectric material is inserted between the plates, the microscopic dipole moments of the material will shield the charges on the plates and alter the relation.

- A dielectric placed between the conductors of a capacitor increases its capacitance by a factor κ, called the **dielectric constant**.

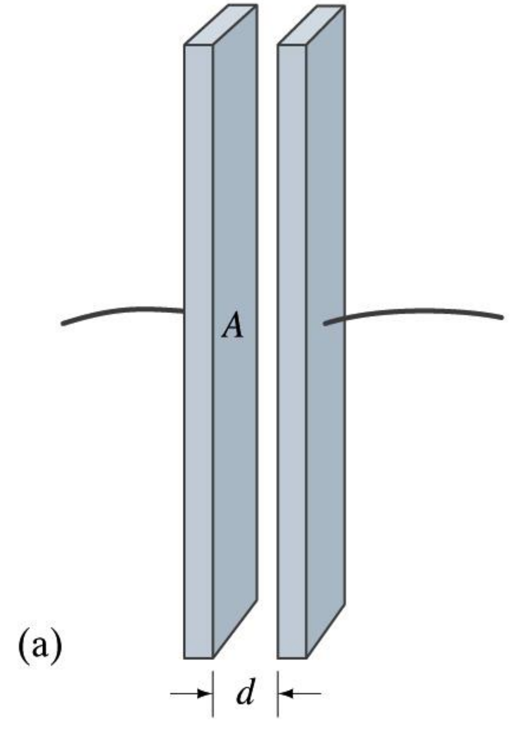
$$C = \kappa C_o$$

(C_o=capacitance without dielectric)

Dielectrics

For a parallel-plate capacitor:

$$C = \kappa \frac{\varepsilon_0 A}{d} = \varepsilon \frac{A}{d}$$



$\varepsilon = \kappa\varepsilon_o$ = **permittivity** of the material

A – the surface area of the plates

d – a distance between plates

Energy Stored in a Capacitor

- A charged capacitor stores energy. The energy stored in charging
  a capacitor from an uncharged condition to
  a charged of (Q) and
  a potential difference (V) can be expressed in three equivalent forms:

$$U = \frac{1}{2}\mathrm{QV} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\mathrm{CV}^2$$