# Chapter 22

### 22.1

- $\mu = 10^{-6}$
- $\epsilon_0 = 8.85 * 10^{-12} \frac{C^2}{Nm^2}$
- $M_e = 9.109 * 10^{-31} kg$
- $M_p = 1.672 * 10^{-27} kg$
- $F_g = 6.67 * 10^{-11} \frac{Nm^2}{kg^2}$
- When you connect a $Q^+$ to the ground i becomes neutralized.
- SI unit of electric charge: **Coulombs (C)**
- Charge of electron/proton: $\pm 1.60 X 10^{-19} C$
- **Ions:** Atoms with a missing/extra electron.

### 22.2 - Coulomb's Law

- $q'$ exerts the force on $q$.
- **Coulomb's Law** is use to find electric force (F) that a particle of charge $q'$ exerts on a particle of charge $q$ at distance $r$.
- $|\mathbf{F}| = \frac{1}{4\pi\epsilon_0} \frac{q'q}{r^2}$ where $\frac{1}{4\pi\epsilon_0} = 8.99 X 10^9 N * m^2/C^2$
- Repulsive force if $F > 0$, attractive if $F < 0$.
- Coulomb's law applies to particles (electrons and protons) and small charged bodies, that is, where the distance between them is much great than the charge. These are called point charges.

### 22.3 - The Superposition of Electric Forces

- The electric force is a vector.
- Superposition Principle of Electric Forces: $\mathbf{F} = \mathbf{F_1} + \mathbf{F_2} + ...$
- Look for symmetry to make calculations easier. Symmetry generally leads to force components canceling thus easier vector sums. (Figure 22.8/Example 22.6)
- *Note:* The $y$ component of $\mathbf{F}_1$ is $-F_1 \cos\theta$. Not always true. **How is this determined??!!??**

### 22.4 - Charge Quantization and Conservation

- Antiparticles have opposite charges.
- All charge is discrete (quantized). ie., some multiple of the fundamental charge $e$. For ease we treat large bodies as continuos.

### 22.5 - Conductors and Insulators; Charging by Friction or by Induction

- **Conductor:** a material that permits the motion of electric charges through its volume. Charges immediately spread out and reach an equilibrium.
- **Insulator:** is a material that does not readily permit the motion of electric charges. Charges to not move when they come in contact with an insulator.
- A body will acquire a net positive charge if electrons are removed and a net negative charge if electrons are added.
- **Electrolytes:** Liquid conductors with an abundance of ions.

# Chapter 23 - The Electric Field

### 23.1 - The Electric Field of Point Charges

- **Electric Field:** Charges exert forces on one another by means of disturbances that they generate in the space surrounding them via disturbances known as electric fields.
- Electric force cannot move faster than the speed of light.
- Electric field of a point charge: $E = \frac{1}{4\pi\epsilon_0} \frac{q'}{r^2}$
- The force that the electric field exerts on q is $\mathbf{F} = q\mathbf{E} = M\mathbf{a}$
- The electric field & electric force: $\mathbf{E} = \frac{\mathbf{F}}{q} N/C$
- SI unit for $\mathbf{E}$ is $\frac{Newtons}{Coulimb} = \frac{Volts}{Meter}$
- The net electric field generated by any distribution of point charges can be calculated by forming the vector sum of the individual electric fields due to the point charges.
- If $-\mathbf{E}$ that means acceleration is in opposite direction of the field.

### 23.2 The Electric Field of Continuos Charge Distributions

- Magnitude of electric field contribution:
  $dE = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2}$ where $dq$ is a small region within a continuos body that contributes a field of magnitude $dE$. Assuming the region is small enough it is treated as a point charge.
- x component of electric field contribution: $dE_x = \frac{1}{4\pi\epsilon_0} \frac{\cos\theta}{r^2} dq$
- Ugh...should probably re-read this section...
- $E = \frac{1}{2\pi\epsilon_0} \frac{\lambda}{r}$ - Used for finding charge on extremely long rods..;). $\lambda$ is the charge per unit length.
- Electric field of a flat sheet: $E_x = \frac{\rho}{2\epsilon_o}$. Used for finding charge on extremely long disks.

### 23.3 Lines of Electric Field

- The density of the field lines represents the strength of the electric field.
- Two times as many field lines originate from a $2q$ charge than a $q$ charge.
- Field lines never intersect. Thus fields can have only one direction.
- At distance $r$ from the point charge these lines are uniformly distributed over the area $A = 4\pi r^2$

### 23.4 Motion in a Uniform Electric Field

- Velocity for x and y components:
  $v_x = v_{0x} + a_x t$ and $v_y = v_{0y} + a_y t$ where $v_{0x}$ and $v_{0y}$ are initial velocity components. $a_x = \frac{F_x}{m} = \frac{qE_x}{m}$ and $a_y = \frac{F_y}{m} = \frac{qE_y}{m}$.
- Position eq: $x = x_0 + v_{0x}t + \frac{1}{2} a_x t^2$

### 23.5 Electric Dipole in an Electric Field

- **External Force:** The electric field that acts on a body.
- **Self-field:** The field generated by the body itself. This field exerts internal forces within the body and does not contribute to the net force acting on the body from outside.
- A body may experience a torque in a uniform external electric field.
- Torque on electric dipole: $\tau = -pE \sin\theta$, where $p = lQ$. $p$ is known as the **dipole moment** of the body.
- Work done to rotate the dipole to some other angle $\theta$: $W = pE \cos\theta$.
- The potential is the negative of the work done: $U = -W = -pE \cos\theta$
- Stopped at equation 23.20.

# Chapter 24 Gauss' Law

### 24.1 Electric Flux

- **Electric flux:** $\Phi_E$ through the surface is defined as the product of the area A and the normal component of the electric field.
- $\Phi_E = EA \cos\theta = E_\perp A$, where $E_\perp$ is the perpendicular component.
- SI unit for electric flux is $N * m^2/C$
- $E_\perp$ can be expressed as $E \cos\theta$ where $\theta$ is the angle between $\mathbf{E}$ and $\perp$ to the surface.
- If $\theta = 0°$ (ie. the surface is $\perp$ to the electric field thus intercepting maximum field lines) then $\Phi_E = EA$.
- If $\theta = 90°$ (ie. the surface is $||$ to the electric field thus intercepting no field lines) then $\Phi_E = 0$.
- The normal component $E_\perp$ is reckoned as positive if the direction of the electric field $\mathbf{E}$ is outward from the surface, and negative if $\mathbf{E}$ is inwards, into the surface.
- $\Phi = \mathbf{E} \bullet \mathbf{A}$
- To find charge density of faces/surfaces: $\rho = E\epsilon_0$
- Total charge of plates: $Q = A\rho$

### 24.2 Gauss' Law

- **Gauss' Law:** If an arbitrary closed surface has a net electric charge $Q_{inside}$ within it, then the electric flux through the surface is $\frac{Q_{inside}}{\epsilon_0}$.
- Gauss' Law: $\Phi_E = \oint E_\perp dA = \frac{Q_{inside}}{\epsilon_0}$

### 24.3 Applications of Gauss' Law

- Line: $q = \lambda L$, where $\lambda$ is the charge per unit length in coulombs per meter $C/m$.
- Surface: $q = \sigma A$, where $\sigma$ is the charge per unit area in coulombs per square meter, $C/m^2$.
- Volume: $q = \rho V$, where $\rho$ is the charge per unit volume is coulombs per cubic meter, $C/m^3$

## Chapter 25 Electrostatic Potential and Energy

### 25.1 The Electrostatic Potential

- Work $= U_1 - U_2 = \frac{qq'}{4\pi\epsilon_0}(\frac{1}{r_1} - \frac{1}{r_2})$
- Work done depends only on radial distance.
- $K + U = \frac{1}{2}mv^2 - qE_0y$
- **Electric Potential Energy:** $U = \frac{1}{4\pi\epsilon_0}\frac{qq'}{r}$
- **Electrostatic Potential:** $V = \frac{U}{q}$
- SI Unit: 1 volt = 1 $\frac{joule}{coulomb}$
- For two charges of equal signs, the electric potential energy is positive and it decreases in inverse proportion to the distance.
- For opposite signs, its negative and decreases in the same manor.
- **Coulomb potential:** $V = \frac{1}{4\pi\epsilon_0}\frac{q'}{r}$. Used to find the electrostatic potential of a point charge.
- Avogadros Number: $-N_A = 6.02 * 10^{23}$
- $\Delta V = \frac{Work}{Q}$

### 25.2 Calculation of the Potential from the Field

- Electrostatic potential from field: $V = -\int_{P_0}^{P} E\, cos\,\theta\, ds + V_0$

### 25.3 Potential in Conductors

- All points within a conducting body are at the same electrostatic potential.
- Potential of the Earth's surface is $V = 0$, zero.
- Outside a sphere the potential is the same as a point charge,
  $V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$ $(r \geq R)$
- Inside the conductor, the potential is the same everywhere, thus $V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$ $(r \leq R)$

### 25.4 Calculation of the Field from the Potential

- Electric field from potential: $E = \frac{dV}{ds}$, where $V - V_0 = dV$ and $ds$ is a small displacement in the direction of the electric field.
- Components of the electric field: $E_x = -\frac{\partial V}{\partial x}$, etc.

### 25.5 Energy of Systems of Charges

- Potential energy of a system of point charges:
  $U = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r_{12}} + \frac{1}{4\pi\epsilon_0}\frac{q_2q_3}{r_{23}} + \frac{1}{4\pi\epsilon_0}\frac{q_1q_3}{r_{13}}$
- Potential energy of a Conductor: $U = \frac{1}{2}QV$
- For a system of conductors, just sum the various potentials.
- Electric potential energy for two charged plates separated by distance $d$: $U = \frac{1}{2}\frac{Q^2d}{\epsilon_0 A} = \frac{1}{2}\epsilon_0(\frac{Q}{\epsilon_0 A})^2 Ad = \frac{1}{2}\epsilon_0 E^2 * Ad$
- For a volume: $U = \frac{1}{2}\epsilon_0 E^2 * [volume]$
- Energy density in electric field: $u = \frac{1}{2}\epsilon_0 E^2$

## Chapter 26 Capacitors and Dielectrics

- Known: Potential difference and charge density. Want distance of plates of parallel capacitor: $\frac{Q}{A} = \sigma = \frac{\epsilon_0(\Delta V)}{d}$
- Known: Capacitors farads and voltage. Want potential difference is connected in series: $V_n = \frac{Q_n}{C_n} = \frac{C_1C_2V}{C_n(C_1+C_2)}$. If connected it series its just the voltage since all have the same potential.
- "Over a certain region in space, $V =$ some equation. Find the electric field in this region." Simply take the partial derivatives of each component of the equation with respect to x, y, and z. Resulting vector is answer.

### 26.1 Capacitance

- If the amount of charge placed on a sphere is $Q$ then the potential of the sphere will be $V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$
- Capacitance of a single conductor: $Q = CV$, where $C$ is the constant of proportionality (the capacitance of the conductor).
- SI unit is farad (F). $1F = 1\frac{Coulomb}{Volt}$
- Capacitance of a pair of conductors: $Q = C\,\Delta V$.
- Capacitance of parallel-plate capacitor: $C = \frac{\epsilon_0 A}{d}$

### 26.2 Capacitors in Combination

- Circuit components connected in parallel have the same voltage across each component.
- Capacitors in parallel: $C = C_1 + C_2 + ...$
- Capacitors in series have the same magnitude of charge on each plate.
- Capacitors in series: $\frac{1}{C} = \frac{1}{C_1} + ...$

### 26.3 Dielectrics

- The dielectric reduces the strength of the electric field.
- Electric field in dielectric: $E = \frac{1}{\kappa}E_{free}$, where $\kappa > 1$ and $E_{free} = \frac{Q}{\epsilon_0 A}$
- Capacitance of capacitor filled with dielectric: $C = \kappa C_0$, where $C_0 = Q/\Delta V_0$ is the capacitance in the absence of dielectric.
- Gauss' Law in dielectrics: $\oint \kappa E_\perp dA = \frac{Q_{free,inside}}{\epsilon_0}$
- Capacitance per unit length of cylindrical capacitor: $\frac{C_0}{l} = 2\pi\epsilon_0\frac{1}{ln(b/a)}$ where b and a are radii of the outer and inner conductors.

### 26.4 Energy in Capacitors

- Potential energy in capacitor: $U = \frac{1}{2}C(\Delta V)^2 = \frac{1}{2}\frac{Q^2}{C}$
- Energy density in dielectric: $u = \frac{U}{Ad} = \frac{1}{2}\kappa\epsilon_0 E^2$
- Good luck. Remember, its only 10%. If you are pissed off, remember that – and start studying earlier and doing your homework so we can pass this class and not re-take it. Woo! You can do it! (Maybe not right now...but in the long run...you'll get out of this class if you want to.)