ELECTRIC FLUX AND GAUSS'S LAW

- The electric flux through a flat surface is given by: $\Phi = \vec{E}\vec{A}$, where the direction of the area is given by the normal vector of the area which is perpendicular to the surface. The magnitude of the flux is then given by $\Phi = EA\cos\theta$, where θ is the angle between the electric field and the normal vector.
- The electric flux Φ through a closed surface (Gaussian surface) is defined as: $\Phi = \oint \vec{E}d\vec{A}$.
- Flux into an enclosed surface is negative and flux out of an enclosed surface is positive.
- Gauss's Law: The net charge enclosed by a closed surface is equal to the flux through this surface times ϵ_0: $q_{enc} = \epsilon_0\Phi$.
- The potential energy of a point charge q in the field of another point charge Q is $U = kqQ/r$.

FIELD OF A CHARGED CONDUCTOR

- The field outside of a charged sphere will be the same as the field of a point charge at the center of the sphere. The field inside of a charged conductor is zero.
- The net charge on an isolated conductor is always on the surface of the conductor. The electric field at the surface of a charged conductor is perpendicular to the surface.
- On irregularly shaped charged conductors, the charges will accumulate more at sharp points.

E-FIELDS OF CONTINUOUS CHARGE DISTRIBUTIONS

The following formulas are valid for infinitely long lines, infinitely large areas, and spheres of radius R of uniformly charged materials:

- Line of charge: $E = \lambda/(2\pi\epsilon_0 r)$
- Surface of an infinitely thick sheet of conductor: $E = \sigma/\epsilon_0$
- Sheet of a non-conductor: $E = \sigma/(2\epsilon_0)$
- Sheet of conductor $E = \sigma_1/\epsilon_0$ (The total charge spreads out over 2 surfaces, σ_1 corresponds to the charge on one surface)
- Field between a positively and negatively charged conductor: $E = 2\sigma_1/\epsilon_0 = \sigma/\epsilon$ (σ now corresponds to the total charge, which is accumulated on the inside of the conductors)
- The field outside ($r > R$) a sphere: $E = kq/r^2$
- The field inside ($r < R$) a conducting sphere: $E = 0$
- The field inside ($r < R$) a nonconducting sphere: $E = kqr/R^3$

ELECTRIC POTENTIAL ENERGY

- The electrostatic potential energy, U is defined as the difference in potential energy of a charge q at two different points i and f: $\Delta U = U_f - U_i$.
- It is equal to the work W done **by** the electrostatic force in transporting this charge from the initial position i to the final position f: $\Delta U = -W$.
- The reference point of $U = 0$ is at $i = \infty$ and thus the electrical potential energy at point f is: $U = -W$.

ELECTROSTATIC POTENTIAL

- Definition: Electrostatic potential difference: $\Delta V = V_f - V_i = \Delta U/q = -W/q$
- With $U_i = U_\infty = 0$ the potential is: $V = -W_\infty/q$.

EQUIPOTENTIAL SURFACE AND RELATION BETWEEN V AND E

- Definition of equipotential surfaces: Surfaces of constant potential.
- The electric field lines are always perpendicular to the equipotential surfaces.
- Metal surfaces are equipotential surfaces.
- From the relation $dW = \vec{F}d\vec{s}$ the potential between two points separated by a distance s can be calculated from the electric field: $V = -\int_i^f \vec{E}d\vec{s}$
- The component of the electric field in a given direction can be calculated from the potential: $E = -\partial V/\partial s$

POTENTIAL OF POINT CHARGES

- The potential of a single point charge is given by: $V = kq/r$. The potential at infinity is assumed to be zero and this equation is valid including the sign when the sign of the charge is also included.
- Again, the superposition principle is valid, the potential of several point charges is equal to the sum of the individual potentials: $V = V_1 + V_2 + V_3 + ... + V_n = \sum_{i=0}^n V_i = k\sum_{i=0}^n (q_i/r_i)$
- A positive charge accelerates from a region of higher potential to a region of lower potential.
- The potential due to a dipol at large distances r is given by: $V = kp\cos\theta/r^2$, where p is the dipole moment and θ is the angle between the dipole axis (pointing from the negative to the positive charge of the dipole) and $\vec{r}$.