ELECTROSTATICS

ELECTRIC CHARGE

- Electric charge is a property of atomic particles, the electron and the proton, which make up atoms (together with neutrons).
- The standard unit of charge is the Coulomb (C).
- Electric charge and mass of particles

Particle	Electric Charge	Mass
Electron	$-e = -1.6 \cdot 10^{-19}$ C	$m_e = 9.11 \cdot 10^{-31}$ kg
Proton	$+e = 1.6 \cdot 10^{-19}$ C	$m_p = 1.672 \cdot 10^{-27}$ kg
Neutron	0	$m_n = 1.674 \cdot 10^{-27}$ kg

- Law of charges: *Like charges repel, and unlike charges attract.*
- An electric charge q is a charge which is an integer multiple of the fundamental charge constant $e = 1.6 \cdot 10^{-19}$ C, $q = n\,e$. Electric charge is quantized.
- The *net charge* of an object is the difference between the number of protons and electrons in it times the elementary charge constant.
- Law of conservation of net charge: *The net charge of an isolated system remains constant.*
- Electric charge transfer is a transfer of electrons.

  Charging positively: Removal of electrons from an object
  Charging negatively: Addition of electrons to an object

ELECTRIC FORCE

- The mutual electrostatic forces on two point charges are equal and opposite, pointing to (away from) the other particle for unlike (like) charges.
- Coulomb's Law
  The electrostatic force between two charges q_1 and q_2 separated by a distance r is:

$$
\begin{aligned}
F &= k\frac{q_1\,q_2}{r^2} \\
k &= 8.99 \cdot 10^9\ \mathrm{N\,m^2/C^2}
\end{aligned}
$$

- Charges interact pairwise via Coulomb force. The superposition principle is valid:

  The net force acting on any charge is the vector sum of the forces due to each of the remaining charges in a given distribution.

ELECTRIC FIELD

- *Test charge* = charge which feels the force of other charges, but exerts no force on them. (mathematical construction)
- *Electric field,* $\vec{E}$ = force per unit test charge: $\vec{E} = \vec{F}/q_0$.
  SI-unit of the $\vec{E}$-field: N/C.
- Electric field of a point charge:
  — Force between two point charges: $F = kQq_0/r^2$.
  — E-field felt by test charge q_0 at r due to the presence of Q is then: $E = F/q_0 = kQ/r^2$.
  — Direction of $\vec{E}$ = direction of $\vec{F}$.
  — Unit positive test charge would be attracted to a negative charge. $\vec{E}$-field points towards a negative point charge and away from a positive point charge.
- Superposition of electric fields: $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...,\quad \vec{E} = \vec{F}/q_0 \quad \rightarrow \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + ...$
- Rules for electrical field lines:
  — The lines are directed pointing away from the positive and towards the negative charges.
  — At any given point in space, the tangent to the line is the direction of the $\vec{E}$-field at that point.
  — The number of lines drawn to or from a charge is proportional to the magnitude of the charge.
- Consequences of these rules:
  — In the immediate vicinity of a point charge, field lines are radially directed.
  — Field lines do not intersect in a charge-free region.
  — Field lines do not begin or end in a charge-free region.
- Density of field lines (number of field lines per unit area) is proportional to the $\vec{E}$-field; and by convention, the total number of field lines is proportional to the charge q.

ELECTRIC DIPOLE

- An arrangement of two equal but opposite charges q separated by a fixed distance d is called a dipole. In a uniform field E, a fixed dipole is subject to a torque: $\tau = qdE sin\theta$. θ is the angle between the dipole direction and the field. $p = qd$ is the dipole moment.
- The field of a dipole along the dipole axis at large distances ($z >> d$) is: $E = 2kp/z^3$
- The field of a dipole along an axis perpendicular to the dipole axis at large distances ($x >> d$) is: $E = kp/x^3$

CONTINUOUS CHARGE DISTRIBUTIONS

- The linear charge density is defined as $\lambda = Q/L$
  The surface charge density is defined as $\sigma = Q/A$
  The volume charge density is defined as $\rho = Q/V$
- The electric field along the z-axis of a charged ring is: $E = kqz/(z^2 + R^2)^{3/2}$
- The electric field along the z-axis of a charged disk is: $E = \sigma/2\epsilon_0(1 - z/\sqrt{z^2 + R^2})$