Electricity 101

MSJ Physics Club

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It should be noted that these handouts are concise and do not take the place of a full physics class. A bit of familiarity with calculus notation is assumed.

1 Basic Electricity

Electricity involves the electric force, and the electric potential energy, much like the gravitational force.

1.1 Electric Force on two charged particles

The electric force between two particles of charges Q,q at a distance r is given by Coulomb's law

$$|F| = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$$

where $\epsilon_0 = 8.854187 \times 10^{-12} \frac{\mathrm{s^2C^2}}{\mathrm{kg\cdot m^3}}$ is the electric constant (electric permittivity of free space). Opposite charges attract, similar charges repel.

Note that charge is measured in coulombs (C).

1.2 Electric Field

The electric field at any location is equal to

$$E = \frac{F}{q}$$

where F is the electric force that would be exerted on a charged test particle at that location, and q is the charge of the test particle. Rearranging this equation, we get $F = qE$. Note that the electric field always points away from positive charges and towards negative charges.

1.3 Electric Potential

Since $W = Fd$, we can integrate the electric force over distance to get the electric potential energy:

$$U = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r}$$

(We let Q be a static charge.) We define the *electric potential* to be

$$V = \frac{E}{q}$$

similar to the definition for electric field.

1.4 Electric Flux

The electric flux through a surface is equivalent to the area of the surface multiplied by the component of the electric field *normal to the surface.*

$$\Phi = A \cdot E$$

If the surface is curved or the electric field is not constant, we can just add up the fluxes of a lot of little surfaces

$$\Phi = \sum E \cdot \Delta S = \int E \cdot dS$$

Flux is a very useful tool as we will see in a later section (next week).

1.5 Electric Field and Potential Lines

Sometimes, problems ask you to draw field and potential lines. Electric potential lines are curves such that all points on the curve have the same electric potential. Electric field lines are lines such that the electric field at every point is tangent to the line. Electric field lines are always perpendicular to electric potential lines. (Try drawing some yourself!)

1.6 Conductors and Insulators

Conductors are materials in which electrons can move (relatively) freely. As such, electrons quickly settle to equilibrium, and usually at the lowest possible energy state. In insulators, however, the electrons cannot move around, so the charges remain in place, unless they are rubbed off if they are near the surface of the insulator.