E & M Basics

Constants

Unit charge, $e = 1.602 \times 10^{-19}$ Coulomb

Electric permittivity of space, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$

Coulomb's constant, $k = 1/(4\pi\varepsilon_0) = 9 \times 10^9\ Nm^2/C^2$ ← ε_0 is the permittivity of space

Magnetic permittivity of free space, $\mu_0 = 4\pi \times 10^{-7}\ M/A^2 = 1.26 \times 10^{-6}$

Mass of electron, $m_e = 9.11 \times 10^{-31}$ kg

Units

1 Amp = 1 C/s

Electric field: N/C, same as V/m

Basic equations for charges and electric fields

Force and field around a charge

Force between two charges: $\boldsymbol{F} = \dfrac{kqQ}{r^2}$

Field around a point charge: $\boldsymbol{E} = \dfrac{kQ}{r^2}$

Force on a charge in a field: $\boldsymbol{F} = \boldsymbol{E}q$

Electric Potential (Voltage)

The potential at a point is equal to the work done moving a charge from ∞ to that point. It is a scalar, though it does have a sign

$V = \dfrac{kq}{r}$ $\qquad V = \dfrac{U}{q}$ ← U is the potential energy at the point in question

Potential difference between two points

$\Delta V = -E\Delta r$ $\qquad$ Δr = distance between points

$E = -\dfrac{dV}{dr}$ $\qquad$ Just the previous equation rearranged

$V = -\int E\,dr$

Field around a dipole

E field a distance z from a dipole with charges $+q$ and $-q$ that are separated by a distance d is:

$E = \dfrac{p}{4\pi\varepsilon_0 z^3}$ $\qquad$ The dipole moment, $p = qd$

The above assumes $z >> d$

Work and potential energy

Potential Energy between two charges:

$U = \dfrac{kqQ}{r}$

Work, W, in moving a charge a distance d in a constant electic field

$W = Eqd$

In a variable field,

$dW = q\int E(x)dx$ ← Note E is a function of x

Electric flux, Φ

Predicts rate of flow of electric field, *Electric flux*, Φ_E, through a given area. Flux is a scalar value, though it does have a sign.

Uniform E-field: $\Phi_E = \mathbf{E} \cdot \mathbf{A} = EA\cos\theta$

Bold-face quantities are vectors

Non-uniform E-field: $\Phi_E = \oint \mathbf{E} \cdot d\mathbf{A}$

Integrating over the entire surface area.
E is a function of position.

Gauss's Law

Electric flux through a surface enclosing a charge, Q:

$$\Phi_E = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$EA\cos\theta = \frac{Q_{enclosed}}{\varepsilon_0}$$

If E is perpedicular to the surface (parallel to the surface vector): $EA = \dfrac{Q}{\varepsilon_0}$

Miscellaneous

Field Between Two Charged Plates

$$E = -\frac{V}{d}$$

E - Electric field, N/C; V - potential difference, volts; d - distance between plates

Field Above a Charged Infinite Plate

Non-conducting Plate

$$E = \frac{\sigma}{2\varepsilon_0}$$

Conducting Plate

$$E = \frac{\sigma}{\varepsilon_0}$$

E - Electric field, N/C; σ - Charge density, C/m^2

Notes...

- The E field above an infinite plate is uniform and constant.
- The E field within a conducting plate is zero
- The E field above an infinite plate is perpendicular to the surface.