Formula Sheet. Electricity and Magnetism,

Coulomb's law

$$\vec{F}_{1,2} = \frac{kq_1q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

The force on charge 1 due to charge 2. The unit vector points from charge 2 to charge 1

Electric Fields

$$\vec{F}(\text{on } q_0) = q_0\vec{E}$$

Field of a point charge $\vec{E} = \frac{kq}{r^2}\hat{r}$

Principle of superposition $\vec{E}_{net} = \sum_{i=1}^{n}\vec{E}_i$

Field from an infinitesimal charge element. $d\vec{E} = \frac{kdq}{r^2}\hat{r}$

Field on either side of an infinite charged plane $|E| = \frac{\sigma}{2\varepsilon_0}$

Discontinuity at the surface of charged plane $|\Delta E| = \frac{\sigma}{\varepsilon_0}$

Gauss's law

Flux: defined: $\phi_{net} = \oint_S \vec{E}\cdot\hat{n}dA = \oint_S E_n dA$

Gauss's Law: $\phi_{net} = 4\pi k q_{enclosed}$

$$= \frac{q_{enclosed}}{\varepsilon_0}$$

Electric potential

$$V(r) = \frac{kq}{r}$$

The potential for a point charge or outside a spherically symmetric charge distribution, with V=0 at infinity.

$$dV = \frac{kdq}{r}$$

potential from an infinitesimal charge element.

Potential calculated from the electric field

$$dV = -\vec{E}\cdot d\vec{\ell} \quad \text{and} \quad -\frac{dV}{d\ell} = E_{\tan}$$

$$\Delta V = V_b - V_{ref} = -\int_{ref}^{b}\vec{E}\cdot d\vec{\ell}$$

Potential Energy

$\Delta U = q_0\Delta V$ for q_0 moving through ΔV

(see next page for conservation of energy)

Constants

$e = 1.602 \times 10^{-19}$ C

$1\text{eV} = 1.602 \times 10^{-19}$ J

$m_e = 9.11 \times 10^{-31}$ kg

$m_p = 1.67 \times 10^{-27}$ kg

$k = 1/(4\pi\varepsilon_o) = 8.99 \times 10^9$ N m^2/C^2

$\varepsilon_o = 8.85 \times 10^{-12}$ F/m (or C^2/N m^2)

$\mu_o = 4\pi \times 10^{-7}$ T m/A

$1\text{ T} = 10^4$ G

$g = 9.8$ m/s^2

Differential area element: dA

dA = (circumference)x(thickness)

ring: $dA = 2\pi r\, dr$

Differential volume elements: dv

dv = (surface area)x(thickness)

thin sheet: $dv = A\, dy$

thin cylindrical shell: $dv = 2\pi rL\, dr$

thin spherical shell: $dv = 4\pi r^2\, dr$

Kinematics & Forces

$$v_x = \frac{dx}{dt} \quad a_x = \frac{dv_x}{dt}$$
$$\bar{v}_x = \frac{\Delta x}{\Delta t} \quad \bar{a}_x = \frac{\Delta v_x}{\Delta t}$$

Constant acceleration
(These equations can be used for any coordinate)

$x(t) = x_o + v_o t + \frac{1}{2} at^2$
$v(t) = v_o + at$
$v_f^2 = v_o^2 + 2a\Delta x$
$\bar{v} = (v_f + v_0)/2$
$x(t) = x_o + vt - \frac{1}{2} at^2$

Projectile motion (special case of constant acceleration)

$v_x(t) = v_{ox}$
$x(t) = x_o + v_{ox}t$
$v_y(t) = v_{oy} + a_y t$
$y(t) = y_o + v_{oy}t + \frac{1}{2}a_y t^2$
(remember that v and a can be positive or negative)

$\Sigma \mathbf{F} = m\mathbf{a}$

Uniform circular motion

$$a_c = \frac{v^2}{r}$$
$$v = \frac{2\pi r}{T} \qquad T = \frac{1}{f}$$

$f_s \leq \mu_s F_n$
$f_k = \mu_k F_n$

$F_{grav} = mg$
$F_{spring} = -kx$

Vector Operations

$$\vec{A} \bullet \vec{B} = AB\cos\theta$$

$$\vec{A} \bullet \vec{B} = A_x B_x + A_y B_y + A_z B_z$$

Energy & Momentum

$$K = \frac{1}{2} mv^2 = \frac{p^2}{2m}$$
$$W = \int F_{\|}\, dx \ (= \int \mathbf{F} \cdot d\mathbf{r})$$

For mechanical energy and friction

$W_{external} = \Delta E_{SYSTEM}$
$\qquad = \Delta E_{Mech} + \Delta E_{Th}$

$\Delta E_{Th} = f_k \Delta s$

For electric fields

$W_{external} = \Delta E_{SYSTEM}$
$\qquad = \Delta K + \Delta U$
where ΔU is as given on the previous page.

$$P_{instantaneous} = \frac{dW}{dt} = \mathbf{F} \cdot \mathbf{v}$$

$\Delta U = -W$ of conservative force
$$F(x) = -\frac{dU(x)}{dx}$$

$$U_{spring}(x) = \frac{1}{2} kx^2$$
$U_g(y) = mgy$ [near the earth's surface]