PHY2054 Exam 1 Formula Sheet

Vectors

$\vec{a} = a_x\hat{x} + a_y\hat{y} + a_z\hat{z}$ $\quad \vec{b} = b_x\hat{x} + b_y\hat{y} + b_z\hat{z}$ **Magnitudes:** $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$ $\quad |\vec{b}| = \sqrt{b_x^2 + b_y^2 + b_z^2}$

Scalar Product: $\vec{a}\cdot\vec{b} = a_x b_x + a_y b_y + a_z b_z = |\vec{a}||\vec{b}|\cos\theta$ (θ = angle between $\vec{a}$ and $\vec{b}$)

Electrostatic Force and Electric Field

Electrostatic Force (vector): $\vec{F} = k\dfrac{q_1 q_2}{r^2}\hat{r}$ (r = distance between charge q_1 and charge q_2, units = N)

$k = 1/(4\pi\varepsilon_0) = 8.99\text{x}10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$ $\qquad \varepsilon_0 = 8.85\text{x}10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$

Electric Field (at q_2 due to q_1): $\vec{E} = \vec{F}/q_2 = k\dfrac{q_1}{r^2}\hat{r}$ (units = N/C = V/m)

Electric Flux (through the infinitesimal surface area dA)**:** $d\Phi_E = \vec{E}\cdot d\vec{A}$ (units = Nm^2/C)

Vector Area (directed area): $\vec{A} = A\hat{n}$ (where $\hat{n}$ = normal to the surface)

Gauss' Law (net flux through closed surface **S**)**:** $\Phi_E = \oint_S \vec{E}\cdot d\vec{A} = \dfrac{Q_{enclosed}}{\varepsilon_0}$ (Q_{enclosed} = charge enclosed)

Gauss' Law: Net flux through closed surface **S** = the charge enclosed by surface S divided by ε_0

Electric Potential and Potential Energy

Electric Potential Energy: work done against a constant field E in moving charge q a distance d along straight line path from A to B, $\Delta U = U_B - U_A = -q\vec{E}\cdot\vec{d}$ (units = J)

Electric Potential: Work done per unit charge against a constant field E in moving charge q a distance d along straight line path from A to B, $\Delta V = \Delta U/q = -\vec{E}\cdot\vec{d}$ (units = J/C = V)

Electric Potential (distance r from a point charge q)**:** $V(r) = k\dfrac{q}{r}$ N point charges: $V(r) = \sum_{i=1}^{N} k\dfrac{q_i}{r_i}$

Electric Potential Energy (N point charges): $U = \frac{1}{2}\sum_{i=1}^{N} q_i V_i$, where V_i is the electric potential at q_i due to the other charges

Stored Electric Potential Energy (N conductors with charge Q_i and electric potential V_i)**:** $U = \frac{1}{2}\sum_{i=1}^{N} Q_i V_i$

Capacitance (definition)**: C = Q/V** or **C = Q/ΔV** (units = C/V = F)

Energy Density of the Electric Field: $u = \frac{1}{2}\varepsilon_0 E^2$ (units = J/m^3)

Electric Current and Circuits

Current (through directed area A)**:** $I = \dfrac{dQ}{dt} = \vec{J}\cdot\vec{A} = nq\vec{v}_{drift}\cdot\vec{A}$ (units = C/s = A, n is the number of charged particles q per unit volume, v_{drift} is the average velocity of the charged particles).

Conducting Wire (length L, cross sectional area A)**:** $J = \sigma E$, $I = \sigma EA = EA/\rho$, $|\Delta V| = EL$

Ohm's Law: $|\Delta V| = IR$, $R = \rho L/A$ (Resistance R units = V/A = Ω)

Resistivity (at temperature T in $^{\circ}$C)**:** $\rho(T) = \rho_0(1 + \alpha\Delta T)$, where $\Delta T = T - T_0$

Power (supplied by EMF ε)**:** P = εI **Power** (dissipated in resistor R)**:** $P = I^2R$ (units = J/s = W)

RC Circuits (charging capacitor C through resistor R with EMF ε)**:** $Q(t) = \varepsilon C(1 - e^{-t/\tau})$

RC Circuits (discharging capacitor C with initial charge Q_0 through resistor R)**:** $Q(t) = Q_0 e^{-t/\tau}$

RC Circuits (time constant)**:** τ = RC (units = Ω·F = s)