Electrostatics Formulas - Mid

1. **Coulomb's Law:**

$$\vec{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$$

2. **Electric Field Intensity:**

$$\vec{E} = \frac{\vec{F}}{q} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

3. **Electric Potential:**

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

$$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$$

4. **Electric Potential Energy:**

$$U = \frac{1}{4\pi\epsilon_0}\sum_{i>j}\frac{q_i q_j}{r_{ij}} = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_3 q_1}{r_{31}}\right)$$

5. **Potential Difference:**

$$\Delta V = V_B - V_A = -\int_A^B \vec{E} \cdot d\vec{r}$$

6. **Work done to move a charge q from A to B:**

$$W_{A\to B} = q(V_A - V_B) = -q\Delta V$$

(Work is positive if moving against the field, negative if moving with the field)

7. **Gauss's Law:**

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

8. **Electric Flux:**

$$\Phi_E = \vec{E} \cdot \vec{A} = EA\cos\theta$$

$$\Phi_E = \int \vec{E} \cdot d\vec{A} \quad \text{(non-uniform or curved surfaces)}$$

9. **Charge Densities:**

$$\lambda = \frac{q}{L}, \quad \sigma = \frac{q}{A}, \quad \rho = \frac{q}{V}$$

10. **Electric Field from Gauss's Law:**

(a) Spherical Symmetry (outside sphere):

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

(b) Spherical Symmetry - <u>inside</u> a uniformly charged non-conducting sphere (radius R):

$$E = \frac{1}{4\pi\epsilon_0}\frac{qr}{R^3} \quad \text{for } r < R$$

(c) Spherical Symmetry - <u>inside</u> a conducting sphere:

$$E = 0 \quad \text{for } r < R$$

(d) Cylindrical Symmetry (outside line charge):

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

(e) Planar Symmetry (infinite plane):

$$E = \frac{\sigma}{2\epsilon_0}$$

(f) Two Infinite Oppositely Charged Plates:

$$E = \frac{\sigma}{\epsilon_0}$$

11. **Electric Field on Axial Line of Dipole (finite r, d):**

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{qd}{\left(r^2 + \left(\frac{d}{2}\right)^2\right)^{3/2}}$$

Potential (general point):

$$V = \frac{1}{4\pi\epsilon_0} \left[\frac{q}{|\vec{r} - \vec{r}_+|} - \frac{q}{|\vec{r} - \vec{r}_-|} \right]$$

12. **Torque on a Dipole in a Uniform Electric Field:**

$$\vec{\tau} = \vec{p} \times \vec{E} = pE \sin\theta$$

13. **Potential Energy of a Dipole in a Uniform Electric Field:**

$$U = -pE\cos\theta$$

14. **Electric Field of a Finite Line Charge (length L on x-axis, center at origin):**

$$E_x = 0, \quad E_y = \frac{\lambda}{2\pi\epsilon_0 y} \left(\frac{L/2}{\sqrt{(\frac{L}{2})^2 + y^2}} \right)$$

15. **Electric Field of a Circular Arc of Charge (radius R, angle θ_0):**

$$E_x = \frac{\lambda}{4\pi\epsilon_0 R} \int_{-\theta_0/2}^{\theta_0/2} \cos\theta \, d\theta, \quad E_y = \frac{\lambda}{4\pi\epsilon_0 R} \int_{-\theta_0/2}^{\theta_0/2} \sin\theta \, d\theta$$

Symmetric case:

$$E_x = \frac{\lambda}{2\pi\epsilon_0 R} \sin\left(\frac{\theta_0}{2}\right), \quad E_y = 0$$

16. **Electric Field of a Ring of Charge (radius R at point z along the axis):**

$$E_z = \frac{1}{4\pi\epsilon_0} \frac{qz}{(R^2 + z^2)^{3/2}}$$

17. **Electric Field of a Disk of Charge (uniform charge density σ, radius R at point z on axis):**

$$E_z = \frac{\sigma}{2\epsilon_0} \left(1 - \frac{z}{\sqrt{R^2 + z^2}}\right)$$