

# NEET PHYSICS

## ELECTROSTATICS — Complete Formula Sheet

★ Exam-Oriented | All Charge Distributions | Last-Day Revision

★ NEET Important

▶ Common Mistake

• Formula | ◦ Symbol | ✓ Note

### 1. ELECTRIC CHARGE & PROPERTIES

#### Quantisation of Charge

$$q = ne, \quad n = 0, \pm 1, \pm 2, \dots, \quad e = 1.6 \times 10^{-19} \text{ C}$$

✓ Charge is always an integral multiple of  $e$ .

	Type	Formula	Unit
Charge Density	Linear $\lambda$	$\lambda = Q/L$	$\text{C m}^{-1}$
	Surface $\sigma$	$\sigma = Q/A$	$\text{C m}^{-2}$
	Volume $\rho$	$\rho = Q/V$	$\text{C m}^{-3}$

### 2. COULOMB'S LAW

$$F = k \frac{|q_1 q_2|}{r^2}, \quad k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{C}^{-2}$$

$$\text{Vector form: } \vec{F}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{N}^{-1} \text{m}^{-2}$$

$$\text{In medium: } F_{\text{med}} = F_{\text{vac}}/K \quad (K = \text{dielectric constant})$$

✓ Valid for point charges at rest. Force reduces  $K$  times in medium.▶ Forces add as **vectors**, not scalars (superposition).

### 3. ELECTRIC FIELD — POINT CHARGE

$$\vec{E} = \frac{\vec{F}}{q_0}, \quad E = \frac{kq}{r^2} = \frac{q}{4\pi\epsilon_0 r^2}$$

$$\text{Unit: } \text{N C}^{-1} = \text{V m}^{-1} \quad (\text{vector quantity})$$

✓ Direction: away from  $+q$ , toward  $-q$ .

### 4. E AND V DUE TO CHARGE DISTRIBUTIONS

#### 4.1 Uniformly Charged Ring (on axis)

$$E_{\text{axis}} = \frac{kQx}{(R^2 + x^2)^{3/2}}$$

$$V_{\text{axis}} = \frac{kQ}{\sqrt{R^2 + x^2}}$$

 $R$  = radius,  $x$  = distance along axis from centreAt centre ( $x = 0$ ):  $E = 0$ ,  $V = kQ/R$ 

$$E \text{ is maximum at } x = R/\sqrt{2}: \quad E_{\text{max}} = \frac{kQ}{3\sqrt{3} R^2/2}$$

✓  $V$  is maximum at centre;  $E$  is zero at centre.

#### 4.2 Uniformly Charged Disc (on axis)

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

$$V = \frac{\sigma}{2\epsilon_0} \left( \sqrt{R^2 + x^2} - x \right)$$

 $\sigma$  = surface charge density,  $R$  = disc radius,  $x$  = axial distanceAs  $R \rightarrow \infty$  (infinite sheet):  $E = \sigma/2\epsilon_0$ 

#### 4.3 Infinite Plane Sheet

$$E = \frac{\sigma}{2\epsilon_0} \quad (\text{each side, uniform})$$

 $V$  decreases linearly away from sheet;  $E$  is independent of distance.✓ Between two oppositely charged parallel plates:  $E = \sigma/\epsilon_0$ .▶  $E = \sigma/2\epsilon_0$  for one sheet. Between plates of a capacitor  $E = \sigma/\epsilon_0$ .

#### 4.4 Infinite Long Wire

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

 $\lambda$  = linear charge density ( $\text{C m}^{-1}$ ),  $r$  = perpendicular distance✓  $E \propto 1/r$  for wire (vs  $1/r^2$  for point charge).  $V$  is not absolute here.

#### 4.5 Uniformly Charged Spherical Shell

$$\text{Outside } (r > R): \quad E = \frac{kQ}{r^2}, \quad V = \frac{kQ}{r}$$

$$\text{On surface } (r = R): \quad E = \frac{kQ}{R^2}, \quad V = \frac{kQ}{R}$$

$$\text{Inside } (r < R): \quad E = 0, \quad V = \frac{kQ}{R} \quad (\text{constant})$$

✓  $V$  inside = surface  $V$  (constant).  $E$  inside = 0 — charge resides on surface.▶  $E = 0$  inside shell, but  $V \neq 0$  inside — most common NEET trap!

### 4.6 Uniformly Charged Solid Sphere

**Outside** ( $r > R$ ):  $E = \frac{kQ}{r^2}, V = \frac{kQ}{r}$   
**On surface** ( $r = R$ ):  $E = \frac{kQ}{R^2}, V = \frac{kQ}{R}$   
**Inside** ( $r < R$ ):  $E = \frac{kQr}{R^3}, V = \frac{kQ}{2R} \left( 3 - \frac{r^2}{R^2} \right)$

$E \propto r$  inside (linear);  $V$  is parabolic inside.

$$V_{\text{centre}} = \frac{3}{2} \cdot \frac{kQ}{R} = \frac{3}{2} V_{\text{surface}}$$

✓ *Maximum E is at the surface for a solid sphere.*

▶ Shell:  $E = 0$  inside. Solid sphere:  $E \neq 0$  inside ( $E \propto r$ ). Do NOT confuse the two!

### 4.7 Electric Dipole

**Axial** ( $\theta = 0^\circ, r \gg a$ ):  $E_{\text{ax}} = \frac{2kp}{r^3}, V_{\text{ax}} = \frac{kp}{r^2}$   
**Equatorial** ( $\theta = 90^\circ, r \gg a$ ):  $E_{\text{eq}} = \frac{kp}{r^3}, V_{\text{eq}} = 0$   
**General point:**  $V = \frac{kp \cos \theta}{r^2}$   
 $E = \frac{kp}{r^3} \sqrt{3 \cos^2 \theta + 1}$

$p = q \cdot 2a$  (dipole moment, C m), direction:  $-q \rightarrow +q$

✓  $E_{\text{ax}} = 2E_{\text{eq}}$  at same  $r \gg a$  — directly asked in NEET!

### 4.8 Summary Table: E and V

Distribution	E (field)	V (potential)
Point charge	$kq/r^2$	$kq/r$
Shell (outside)	$kQ/r^2$	$kQ/r$
Shell (inside)	0	$kQ/R$ (const.)
Solid sphere (out)	$kQ/r^2$	$kQ/r$
Solid sphere (in)	$kQr/R^3$	$\frac{kQ}{2R} (3 - r^2/R^2)$
Infinite wire	$\lambda/2\pi\epsilon_0 r$	$\propto -\ln r$
Infinite sheet	$\sigma/2\epsilon_0$	decreases linearly
Ring (centre)	0	$kQ/R$
Ring (axis)	$kQx/(R^2 + x^2)^{3/2}$	$kQ/\sqrt{R^2 + x^2}$
Dipole (axial)	$2kp/r^3$	$kp/r^2$
Dipole (equat.)	$kp/r^3$	0

## 5. GAUSS'S LAW

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

Flux  $\Phi = EA \cos \theta$  (Unit:  $\text{N m}^2 \text{C}^{-1} = \text{V m}$ )

✓ *Charges outside Gaussian surface give zero net flux.*

## 6. ELECTRIC POTENTIAL

$$V = \frac{W}{q_0} = \frac{kq}{r}, \quad V_{AB} = V_A - V_B = \frac{W_{AB}}{q}$$

$$E = -\frac{dV}{dr}, \quad E_x = -\frac{\partial V}{\partial x}$$

System of charges:  $V = k \sum_i \frac{q_i}{r_i}$  (algebraic sum)

✓  $E$  points from high  $V$  to low  $V$ . If  $V = \text{const}$ ,  $E = 0$ .

▶  $E = 0 \not\Rightarrow V = 0$ . ▶  $V = 0 \not\Rightarrow E = 0$ .

## 7. POTENTIAL ENERGY

Two charges:  $U = kq_1q_2/r$   
 Three charges:  $U = k \left( \frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_3}{r_{13}} \right)$   
 Work done:  $W = q(V_A - V_B)$

✓ *Count each pair once only in multi-charge systems.*

## 8. DIPOLE IN UNIFORM FIELD

Torque:  $\tau = pE \sin \theta$  ( $\vec{\tau} = \vec{p} \times \vec{E}$ )  
 PE:  $U = -pE \cos \theta = -\vec{p} \cdot \vec{E}$

✓ *Stable eq.:  $\theta = 0^\circ$ ; Unstable eq.:  $\theta = 180^\circ$ ;  $\tau_{\text{max}}$  at  $\theta = 90^\circ$ .*

## 9. CAPACITORS

$C = Q/V$  ( $F = \text{C V}^{-1}$ )  
 Parallel plate:  $C_0 = \epsilon_0 A/d$ ; With dielectric:  $C = K\epsilon_0 A/d$   
 Energy:  $U = \frac{1}{2} CV^2 = \frac{1}{2} QV = Q^2/2C$   
 Energy density:  $u = \frac{1}{2} \epsilon_0 E^2$  ( $\text{J m}^{-3}$ )

	Quantity	Series	Parallel
Series & Parallel	$C_{\text{eq}}$	$\frac{1}{C} = \sum \frac{1}{C_i}$	$C = \sum C_i$
	Charge $Q$	same on each	$Q = \sum Q_i$
	Voltage $V$	$V = \sum V_i$	same across

	Battery ON ( $V = \text{const}$ )	Battery OFF	
Dielectric Effect Table	$C$	$KC_0 \uparrow$	$KC_0 \uparrow$
	$Q$	$KQ_0 \uparrow$	$Q_0$ (same)
	$V$	$V_0$ (same)	$V_0/K \downarrow$
	$E$	$E_0$ (same)	$E_0/K \downarrow$
	$U$	$KU_0 \uparrow$	$U_0/K \downarrow$

▶  $C_{\text{series}} < \text{smallest } C$ ;  $C_{\text{parallel}} > \text{largest } C$ .  
 ▶  $U$  decreases when dielectric inserted with battery off.

## ★★ TOP 10 MUST-REMEMBER FORMULAS FOR NEET ★★

#	Formula	Key Note
1	Coulomb: $F = kq_1q_2/r^2$	Foundation of electrostatics; $k = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$ .
2	Point charge field: $E = kq/r^2$	Superpose as vectors for multiple charges.
3	Gauss: $\oint \vec{E} \cdot d\vec{A} = Q_{\text{enc}}/\epsilon_0$	Net flux depends only on enclosed charge.
4	Shell — inside: $E = 0, V = kQ/R$	$E = 0$ but $V \neq 0$ — NEET's favourite trap!
5	Solid sphere inside: $E = kQr/R^3$ ; $V_c = \frac{3}{2}(kQ/R)$	$E \propto r$ inside; $V$ is parabolic inside.
6	Dipole ratio: $E_{\text{ax}} = 2E_{\text{eq}} = 2kp/r^3$	At equal distance $r \gg a$ ; ratio 2:1 directly asked.
7	$E = -dV/dr$ ; $E = 0 \not\Rightarrow V = 0$	$E$ points from high $V$ to low $V$ .
8	Infinite sheet: $E = \sigma/2\epsilon_0$ ; Between plates: $E = \sigma/\epsilon_0$	Single sheet vs capacitor — do NOT confuse.
9	Capacitor energy: $U = \frac{1}{2}CV^2 = Q^2/2C$	All three forms are NEET-tested; use what's given.
10	Ring axis: $E_{\text{max}}$ at $x = R/\sqrt{2}$ ; $V_{\text{max}}$ at centre	$E = 0$ at centre of ring; $V$ is maximum there.