FREE NOTES · NCERT + JEE/NEET LEVEL

# Electric Charges & Fields

Charge ke gun, Coulomb's law, electric field, field lines, dipole, electric flux aur Gauss's law ke saare applications. Diagrams aur solved numericals ke saath.

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## 01 Electric charge

Matter ka ek basic gun jiski wajah se wo electric force mehsoos karta aur lagata hai. Do type: **positive** aur **negative** (naam Benjamin Franklin ne diye). **Same charges repel, ulte charges attract.**

Kaanch ki rod resham se ragdo: rod +, resham −. Plastic ki rod oon (fur) se ragdo: rod −, oon +. Electrons ek se doosre pe jaate hain; proton nahi hilte.

**CONDUCTOR VS INSULATOR**

**Conductor** (metal, insaani shareer, zameen): charge aasaani se behta, free electrons. **Insulator** (kaanch, plastic, rubber): charge jahan diya wahin rehta. **Earthing**: conductor ko zameen se jodna, extra charge zameen me chala jaata.

## 02 Charge ke gun

| Gun | Matlab |
|---|---|
| Additivity | Total charge = sab charges ka algebraic sum (scalar). +2, −5, +1 ⇒ −2. |
| Conservation | Isolated system ka total charge na banta na mitta, sirf transfer hota. |
| Quantization | $q = n\,e,\ e = 1.6 \times 10^{-19}\ C,\ n$ integer |

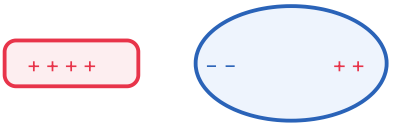
SI unit: coulomb (C). 1 C me ≈ 6.25 × $10^{18}$ electrons. Bade level pe (macroscopic) quantization dikhti nahi kyunki e bahut chhota hai.

## 03 Charging ke tareeke

| Tareeka | Kaise | Charge ka sign |
|---|---|---|
| Friction (ragadna) | Do cheezein ragdo, electrons transfer | Dono pe ulte, barabar |
| Conduction (chhoona) | Charged body se chhoo do | Same sign |
| Induction (bina chhoe) | Charged rod paas lao, door wale sire ko earth karo, earth hatao, phir rod hatao | Ulta sign |

**HALKA KAAGAZ ROD KI TARAF KYUN?**

Charged rod kaagaz me paas wale sire pe ulta charge induce karti hai. Ulta charge paas, same door ⇒ attraction zyada ⇒ kaagaz chipakta. **Charged body neutral body ko bhi kheench sakti hai.**




Induction: paas wale sire pe ulta charge

## 04 Coulomb's law

$$F = k\, q_1\, q_2 / r^2 = q_1 q_2 / (4\pi\varepsilon_0\, r^2)$$

$k = 9 \times 10^9$ N·m²/C², $\varepsilon_0 = 8.854 \times 10^{-12}$ C²/N·m² (permittivity of free space). Force dono charges ko jodne wali line pe. Point charges ke liye.

**MEDIUM ME**

Medium (dielectric constant $K = \varepsilon_r$) me force K guna kam: $F_{medium} = F_{vacuum}/K$. Paani $K \approx 80$, isliye namak paani me ghul jaata ($Na^+$ $Cl^-$ ka attraction 80 guna kam).

**GRAVITY SE COMPARISON**

Do protons ke beech electric force gravity se ~$10^{36}$ guna zyada. Par electric force attract aur repel dono, gravity sirf attract.

## 05 Superposition principle

Kai charges ho toh kisi ek charge pe net force = har doosre charge ke force ka **vector sum**. Har pair ka force doosre charges se affect nahi hota.

$$F_1 = F_{12} + F_{13} + \ldots + F_{1n}\,(\text{vector})$$

**EQUILIBRIUM TRICK**

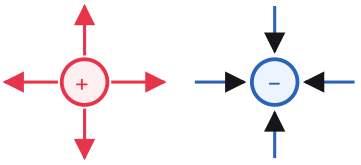
Do same-sign charges ke beech teesra charge kahan rakhein ki net force 0 ho? Kamzor charge ke paas: $x/(d-x) = \sqrt{(q_1/q_2)}$. Ulte sign wale charges me ye point bahar, chhote charge ki taraf hota hai.

## 06 Electric field

Charge apne chaaron taraf ek "asar ka ilaaka" banata hai. Kisi point pe **unit positive test charge** pe lagne wala force = electric field.

$$E = F/q_0,\ E = kq/r^2$$

Unit N/C = V/m. Vector. Positive charge se bahar ki taraf, negative ki taraf andar. Charge q pe force: $F = qE$.




+ se bahar, − ki taraf andar

**Continuous charge:** linear density λ (C/m), surface density σ (C/m²), volume density ρ (C/m³). Chhote hisse dq ka field nikaal ke integrate karo.

## 07 Electric field lines

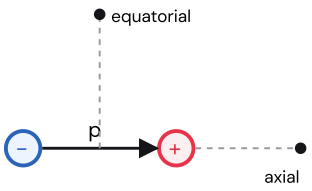
- Positive se shuru, negative pe khatam (akele charge ke liye infinity tak).
- Kisi point pe tangent = field ki direction.
- **Do lines kabhi nahi katati** (warna ek point pe do directions).
- Jahan lines ghani, wahan field tez.
- Closed loop nahi banati (electrostatic field me).
- Conductor ki surface pe ⊥ milti hain; conductor ke andar field 0.

## 08 Electric dipole

Do barabar aur ulte charges (+q, -q) chhoti doori 2a pe. Example: $H_2O$, HCl molecules.

$$p = q \times 2a$$

Dipole moment, vector, **-q se +q ki taraf**. Unit C·m.




Axial line vs equatorial line

| Point | Field ($r \gg a$) | Direction |
|---|---|---|
| Axial line | $E = 2kp/r^3$ | p ki direction |
| Equatorial line | $E = kp/r^3$ | p ke ulta |

**YAAD RAKHO**

Dipole ka field $\propto 1/r^3$ (point charge ka $1/r^2$), jaldi kam hota. $E_{axial} = 2 \times E_{equatorial}$ (same r pe).

## 09 Dipole in a uniform field

Net force $= 0$ (dono pe barabar ulta)

$$\text{Torque } \tau = p \times E, \ |\tau| = pE \sin\theta$$

Potential energy $U = -p \cdot E = -pE\cos\theta$

| θ | Torque | U | Equilibrium |
|---|---|---|---|
| 0° (p ∥ E) | 0 | -pE (min) | Stable |
| 90° | pE (max) | 0 | — |
| 180° | 0 | +pE (max) | Unstable |

$\theta_1$ se $\theta_2$ tak ghumane me work = $pE(\cos\theta_1 - \cos\theta_2)$. Non-uniform field me net force bhi lagta hai.

## 10 Electric flux

Kisi surface se kitni field lines guzar rahi hain, uska naap.

$$\Phi = \mathrm{E} \cdot \mathrm{A} = \mathrm{E}\,\mathrm{A}\cos\theta$$

θ = E aur area vector (surface ke ⊥) ke beech angle. Unit N·m²/C. Scalar. Closed surface me bahar jaati lines +, andar aati −.

## 11 Gauss's law

**STATEMENT**

$\oint \mathrm{E} \cdot d\mathrm{A} = q_{\text{enclosed}} / \varepsilon_0$

Kisi bhi closed surface (Gaussian surface) se total flux = andar band charge / $\varepsilon_0$. Bahar ke charges ka net flux 0 (par field pe asar hai).

- Surface ka shape ya size matter nahi karta, sirf andar ka charge.
- Cube ke centre pe q: har face se flux = $q/(6\varepsilon_0)$. Cube ke corner pe q: total = $q/(8\varepsilon_0)$.
- Gaussian surface aisi chuno jahan E har jagah same ho ya ⊥/∥ ho (symmetry).

## 12 Gauss's law ke applications

| Charge distribution | Field | Kis pe depend |
|---|---|---|
| Infinite line (λ) | $E = \lambda/(2\pi\varepsilon_0 r)$ | $\propto 1/r$ |
| Infinite plane sheet (σ) | $E = \sigma/(2\varepsilon_0)$ | Doori pe nahi |
| Do ulte sheets (+σ, -σ) ke beech | $E = \sigma/\varepsilon_0$ (bahar 0) | Capacitor |
| Conductor ki surface ke paas | $E = \sigma/\varepsilon_0$ | Surface ke ⊥ |
| Spherical shell (R, q): bahar | $E = kq/r^2$ | Point charge jaisa |
| Spherical shell: andar | E = 0 | — |
| Solid sphere (uniform ρ): andar | $E = kqr/R^3$ | $\propto r$ |

**ELECTROSTATIC SHIELDING**

Hollow conductor ke andar field hamesha 0. Isliye bijli girne pe car ke andar baithna safe hai (car ek metal ka dabba = Faraday cage).

## 13 JEE Extra + Tricks

**JEE LEVEL**

- Ring ke axis pe field: $E = kQx/(x^2 + R^2)^{3/2}$; $x = R/\sqrt{2}$ pe max; centre pe zero.
- Dipole: axial $E = 2kp/r^3$, equatorial $E = kp/r^3$ (p ka ulta); torque $\tau = p \times E$; PE $U = -p \cdot E$.
- Flux tricks: cube ke centre pe charge ⇒ har face $q/6\varepsilon_0$; corner pe charge ⇒ door ke teen faces se $q/(24\varepsilon_0)$.
- Infinite line $\lambda/(2\pi\varepsilon_0 r)$; infinite sheet $\sigma/(2\varepsilon_0)$; conductor ke theek bahar $\sigma/\varepsilon_0$.
- Do charges: null point ulte charges me jodi ke bahar (chhote charge ki taraf), same charges me beech me.

## 14 Solved numericals ($k = 9 \times 10^9$)

**Q1. Ek body pe $-3.2 \times 10^{-7}$ C charge. Kitne electrons extra?**
$n = 3.2 \times 10^{-7}/1.6 \times 10^{-19} = 2 \times 10^{12}$. **Ans: $2 \times 10^{12}$ electrons**

**Q2. 2 µC aur 3 µC, 30 cm door. Force?**
$F = 9 \times 10^9 \times 6 \times 10^{-12}/0.09 = 0.6$ N (repulsive). **Ans: 0.6 N**

**Q3. 4 µC aur 9 µC, 1 m door. Teesra charge kahan rakhein ki uspe net force 0?**
$x/(1 - x) = \sqrt{(4/9)} = 2/3$ ⇒ $x = 0.4$ m (4 µC se). **Ans: 4 µC se 40 cm**

**Q4. 5 µC charge se 10 cm door field?**
$E = 9 \times 10^9 \times 5 \times 10^{-6}/0.01 = 4.5 \times 10^6$ N/C. **Ans: $4.5 \times 10^6$ N/C**

**Q5. Dipole ($p = 4 \times 10^{-9}$ C·m) 30° pe $5 \times 10^4$ N/C field me. Torque?**
$\tau = pE \sin 30° = 4 \times 10^{-9} \times 5 \times 10^4 \times 0.5 = 10^{-4}$ N·m. **Ans: $10^{-4}$ N·m**

**Q6. 10 cm side ka cube, centre pe 8.85 µC. Ek face se flux? ($\varepsilon_0 = 8.85 \times 10^{-12}$)**
Total $= q/\varepsilon_0 = 10^6$. Ek face $= 10^6/6 \approx 1.67 \times 10^5$ N·m²/C. **Ans: ≈ $1.67 \times 10^5$ N·m²/C**

**Q7. Infinite line ($\lambda = 2 \times 10^{-7}$ C/m) se 2 cm door field?**
$E = 2k\lambda/r = 2 \times 9 \times 10^9 \times 2 \times 10^{-7}/0.02 = 1.8 \times 10^5$ N/C. **Ans: $1.8 \times 10^5$ N/C**

## 15 Common mistakes

- μC ko $10^{-6}$ me na badalna, cm ko m me na badalna.
- Dipole moment ki direction + se - maan lena (sahi: - se +).
- Flux me bahar ke charge ko gin lena.
- Infinite sheet ka field doori pe depend maan lena.
- Shell ke andar field $kq/r^2$ lagana (andar 0).
- Uniform field me dipole pe net force maan lena (sirf torque).

## 16 Formula sheet

| | |
|---|---|
| Quantization | $q = ne,\ e = 1.6 \times 10^{-19}\ C$ |
| Coulomb's law | $F = kq_1q_2/r^2,\ k = 1/4\pi\varepsilon_0 = 9 \times 10^9$ |
| In medium | $F/K$ |
| Field | $E = F/q = kq/r^2$ |
| Dipole moment | $p = q(2a)$ |
| Dipole field | axial $2kp/r^3$, equatorial $kp/r^3$ |
| Torque, PE | $\tau = pE \sin\theta,\ U = -pE\cos\theta$ |
| Flux | $\Phi = EA\cos\theta$ |
| Gauss | $\oint E\cdot dA = q/\varepsilon_0$ |
| Line, sheet, conductor | $\lambda/2\pi\varepsilon_0 r,\ \sigma/2\varepsilon_0,\ \sigma/\varepsilon_0$ |
| Shell | $kq/r^2$ outside, 0 inside |

## 17 Practice questions

1. Do charges ke beech doori aadhi aur dono charges 2 guna. Force?
2. Same force paani (K = 80) me kitna hoga?
3. Dipole ko uniform field me 0° se 180° ghumane ka work?
4. Closed surface ke andar +3 μC aur −5 μC. Net flux?
5. Do sheets +σ aur −σ. Unke beech aur bahar field?

**ANSWERS**

1) 4 × 4 = 16 guna · 2) F/80 · 3) 2pE · 4) −2 μC/$\varepsilon_0$ (andar ki taraf) · 5) Beech me $\sigma/\varepsilon_0$, bahar 0

## 18 Quick revision: exam se pehle 5 minute

**CHARGE & FORCE**

- q = ne; conserved; additive.
- F = $kq_1q_2/r^2$; medium me /K.
- Induction: ulta charge.

**FIELD**

- E = $kq/r^2$, F = qE.
- Lines: + se −, kabhi nahi katati.
- Conductor andar E = 0.

**DIPOLE**

- p = q·2a, − se +.
- Axial $2kp/r^3$, equatorial $kp/r^3$.
- $\tau = pE \sin\theta$, $U = -pE\cos\theta$.

**GAUSS**

- $\Phi = q_{in}/\varepsilon_o$.
- Line $\lambda/2\pi\varepsilon_o r$; sheet $\sigma/2\varepsilon_o$.
- Shell andar 0.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.