CLASS 12 PHYSICS

CHAPTER 1 — ELECTRIC CHARGES AND FIELDS

COMPLETE BOARD NOTES • DERIVATIONS • CONCEPTS • PYQ-STYLE PRACTICE
CBSE SESSION 2026–27 • BOARD EXAMINATION 2027

Expanded version: derivations are written step-by-step, with no intentional blank pages.

SYLLABUS CHECK

The official CBSE 2026–27 syllabus for Chapter 1 lists electric charges, conservation, Coulomb’s law, multiple charges/superposition, continuous charge distribution, electric field and field lines, electric dipole and its field, torque on a dipole, electric flux, Gauss’s theorem and applications to an infinite straight wire, uniformly charged infinite plane sheet, and uniformly charged thin spherical shell (inside and outside). citeturn0search4

Note: This is a study-notes PDF, not an official CBSE publication. It is designed to cover the syllabus and board-style derivations; always cross-check the final official CBSE syllabus/sample paper before the exam.

MASTER CONTENTS

1. ELECTRIC CHARGE

Definition: Electric charge is a fundamental property of matter responsible for electrical interaction. SI unit = coulomb (C).

Types: Positive and negative. Like charges repel; unlike charges attract.

Conservation: In an isolated system, total charge remains constant. Charge can be transferred but cannot be created or destroyed in ordinary charging processes.

Quantisation: $q = ne$, where n is an integer and $e = 1.6 \times 10^{-19}$ C.

Additivity: Total charge is the algebraic sum: $Q = q_1 + q_2 + \dots$.

2. COULOMB'S LAW

For two point charges q_1 and q_2 separated by r in vacuum, $F = k|q_1 q_2|/r^2$, where $k = 1/(4\pi\epsilon_0) = 9 \times 10^9$ N m² C^{-2}.

The force acts along the line joining the charges. In a medium with relative permittivity K, $F_{medium} = F_{vacuum}/K$.

Vector form: $\vec{F}_{12} = (1/4\pi\epsilon_0)\,(q_1 q_2/r^2)\,\hat{r}_{12}$.

Board point: Coulomb's law is an inverse-square law, so changing r strongly changes F.

3. SUPERPOSITION PRINCIPLE

The force due to several point charges is the vector sum of individual forces.

$\vec{F} = \Sigma \vec{F}_i$.

Always calculate each force separately, mark its direction, then resolve into x/y components where geometry requires.

4. ELECTRIC FIELD AND POINT CHARGE

Electric field at a point is force per unit positive test charge: $\vec{E} = \vec{F}/q_0$.

Derivation — field due to point charge:
Take source charge q and test charge q_0 at distance r. By Coulomb's law, $F = (1/4\pi\epsilon_0)qq_0/r^2$ in magnitude. Divide by q_0: $E = F/q_0 = (1/4\pi\epsilon_0)q/r^2$. Therefore $\vec{E} = (1/4\pi\epsilon_0)(q/r^2)\hat{r}$.

Direction: away from +q and towards −q. SI unit N C^{-1}.

5. ELECTRIC FIELD LINES

Field lines are imaginary curves whose tangent gives the direction of E at a point.

Properties: start on positive and end on negative/infinity; never intersect; density indicates relative strength; normal to conductor surface in electrostatic equilibrium; no closed loops in electrostatics.

6. ELECTRIC DIPOLE

Two equal and opposite charges +q and −q separated by 2a form an electric dipole.

Dipole moment: $p = q(2a)$. Direction is from −q to +q. Unit = C m.

Important: The dipole field expressions below are for the usual far-field/ideal-dipole result ($r \gg a$).

7. AXIAL FIELD OF A DIPOLE — FULL DERIVATION

Let +q and −q be separated by 2a. Let P be on the axial line at distance r from the centre O, on the +q side.

Distance from +q to P = r − a; distance from −q to P = r + a.

Field due to +q at P: $E_+ = kq/(r-a)^2$, directed away from +q.

Field due to −q at P: $E_- = kq/(r+a)^2$, directed towards −q. These fields are opposite along the axial line.

Therefore, $E = kq[1/(r-a)^2 - 1/(r+a)^2]$.

Taking LCM: $E = kq[(r+a)^2 - (r-a)^2]/[(r^2-a^2)^2]$.

$(r+a)^2 - (r-a)^2 = 4ar$. Hence $E = kq(4ar)/(r^2-a^2)^2$.

Since $p = 2aq$, $E = (1/4\pi\epsilon_0)\,(2pr)/(r^2-a^2)^2$.

For $r \gg a$, $(r^2-a^2)^2 \approx r^4$, so $E_{axial} \approx (1/4\pi\epsilon_0)\,2p/r^3$.

Direction on the +q side is along p.

8. EQUATORIAL FIELD OF A DIPOLE — FULL DERIVATION

Let P be on the perpendicular bisector (equatorial line), at distance r from centre O. Distance from P to each charge is $R = \sqrt{(r^2+a^2)}$.

Field magnitude due to each charge is $E_0 = kq/R^2$. By symmetry, components perpendicular to the dipole axis cancel, while components along the dipole axis add.

The component of each field along the dipole direction has magnitude $E_0(a/R)$. Thus $E = 2(kq/R^2)(a/R)$.

So $E = 2kqa/R^3$. Since $p = 2aq$, $E = kp/R^3$.

Therefore, $E_{equatorial} = (1/4\pi\epsilon_0)\,p/(r^2+a^2)^{3/2}$.

For $r \gg a$, $R \approx r$, giving $E_{equatorial} \approx (1/4\pi\epsilon_0)p/r^3$.

Direction is opposite to p.

9. TORQUE ON AN ELECTRIC DIPOLE — FULL DERIVATION

Place dipole p in a uniform electric field E at angle θ.

Force on +q = qE along E. Force on −q = qE opposite E. Net force is therefore zero.

The two forces form a couple. Perpendicular distance between their lines of action = $2a\sin\theta$.

Torque τ = force × perpendicular distance = $qE(2a\sin\theta)$.

Since $p = 2aq$, $\tau = pE\sin\theta$.

Vector form: $\vec{\tau} = \vec{p} \times \vec{E}$.

At $\theta = 90°$, τ is maximum = pE. At $\theta = 0°$ or $180°$, $\tau = 0$.

10. CONTINUOUS CHARGE DISTRIBUTION

When charge is distributed continuously, define: $\lambda = dq/dl$ (linear), $\sigma = dq/dA$ (surface), $\rho = dq/dV$ (volume).

Thus $dq = \lambda dl$, $dq = \sigma dA$, or $dq = \rho dV$.

The field of each small element is found and integrated vectorially over the complete distribution.

11. ELECTRIC FLUX

Electric flux through a plane surface in a uniform field is $\Phi = EA\cos\theta$, where θ is the angle between E and area vector A.

For a general surface, $d\Phi = \vec{E}\cdot d\vec{A}$.

SI unit: $N\,m^2\,C^{-1}$. For a closed surface, use outward area vectors.

12. GAUSS’S THEOREM

Statement: Total electric flux through any closed surface equals the net charge enclosed divided by ϵ_0.

$\oint \vec{E}\cdot d\vec{A} = Q_{enc}/\epsilon_0$.

The theorem is especially useful when symmetry makes the magnitude of E constant over the chosen Gaussian surface.

13. INFINITE STRAIGHT WIRE — FULL DERIVATION

Consider an infinitely long straight wire with uniform linear charge density λ.

Choose a cylindrical Gaussian surface of radius r and length l, coaxial with the wire.

By cylindrical symmetry, E has the same magnitude everywhere on the curved surface and is radial. Flux through the two flat ends is zero because E is parallel to those faces.

Curved-surface area = $2\pi rl$. Hence total flux $\Phi = E(2\pi rl)$.

Charge enclosed = λl.

By Gauss's law: $E(2\pi rl) = \lambda l/\epsilon_0$.

Cancel l: $E = \lambda/(2\pi\epsilon_0 r)$.

Direction is radially outward for positive λ and inward for negative λ.

14. INFINITE PLANE SHEET — FULL DERIVATION

Consider an infinite uniformly charged plane sheet with surface charge density σ.

Choose a cylindrical pillbox Gaussian surface with its flat faces parallel to the sheet and one face on each side.

By symmetry, field is perpendicular to the sheet and has equal magnitude on both sides.

Flux through curved surface is zero because E is parallel to it. Flux through two flat faces = EA + EA = 2EA.

Charge enclosed = σA.

Gauss's law: $2EA = \sigma A/\epsilon_0$.

Cancel A: $E = \sigma/(2\epsilon_0)$.

Important: for an ideal infinite sheet, field is independent of distance from the sheet.

15. UNIFORMLY CHARGED THIN SPHERICAL SHELL — FULL DERIVATION

Outside ($r > R$): Choose a concentric Gaussian sphere of radius r. By spherical symmetry, E is constant on the surface and radial.

Flux = $E(4\pi r^2)$. Enclosed charge = Q.

Gauss's law: $E(4\pi r^2) = Q/\epsilon_0$.

Therefore $E = (1/4\pi\epsilon_0)Q/r^2$. It is the same as the field of a point charge Q at the centre.

Inside ($r < R$): A Gaussian sphere inside the shell encloses zero charge.

Therefore $E(4\pi r^2) = 0$, giving $E = 0$.

At the surface just outside: $E = (1/4\pi\epsilon_0)Q/R^2$.

16. COMPLETE FORMULA BANK

$q = ne$; $e = 1.6 \times 10^{-19}$ C
$F = (1/4\pi\epsilon_0)\lvert q_1 q_2\rvert/r^2$
$E = F/q_0$
E(point charge) = $(1/4\pi\epsilon_0)q/r^2$
$p = q(2a)$
Eaxial (far field) = $(1/4\pi\epsilon_0)(2p/r^3)$
Eequatorial (far field) = $(1/4\pi\epsilon_0)(p/r^3)$, opposite to p
$\tau = pE \sin\theta$
$\Phi = EA \cos\theta$; $d\Phi = E\cdot d\vec{A}$
$\oint E\cdot d\vec{A} = Q_{enc}/\epsilon_0$
Long wire: $E = \lambda/(2\pi\epsilon_0 r)$
Infinite sheet: $E = \sigma/(2\epsilon_0)$
Spherical shell: $E_{out} = (1/4\pi\epsilon_0)Q/r^2$; $E_{in} = 0$

BOARD ANSWER WRITING CHECKLIST

• Write the law/formula first.

• Draw or mentally identify the correct geometry.

• Mention the Gaussian surface and symmetry in Gauss-law derivations.

• Do not skip cancellation/algebra steps in 3–5 mark derivations.

• Write SI units in numericals.

• Box the final expression and state direction where relevant.

17. BOARD / PYQ-STYLE PRACTICE WITH ANSWER POINTS

Q. State Coulomb's law. How does the force change if distance becomes 3 times?

Ans. $F \propto 1/r^2$, so the new force is F/9.

Q. A test charge is doubled. Does the electric field due to a fixed source charge change?

Ans. No. E is a property of the source configuration: $E = F/q_0$; the test charge changes force proportionally, not E.

Q. Why can two electric field lines not intersect?

Ans. At one point the electric field has a unique direction. Intersection would imply two directions at the same point.

Q. Write the exact axial dipole field and its far-field result.

Ans. $E = (1/4\pi\epsilon_0)\, 2pr/(r^2-a^2)^2$; for $r \gg a$, $E \approx (1/4\pi\epsilon_0)2p/r^3$.

Q. Write the exact equatorial dipole field and its far-field result.

Ans. $E = (1/4\pi\epsilon_0)p/(r^2+a^2)^{(3/2)}$; for $r \gg a$, $E \approx (1/4\pi\epsilon_0)p/r^3$, opposite to p.

Q. Why is net force on a dipole in a uniform field zero?

Ans. Forces qE and qE act in opposite directions with equal magnitudes.

Q. Why can the dipole still rotate in a uniform field?

Ans. The equal opposite forces act along different lines, forming a couple and hence torque.

Q. Why is Gauss's law easiest for symmetric distributions?

Ans. Symmetry can make E constant on a Gaussian surface and simplify the surface integral.

Q. Why is field inside a uniformly charged spherical shell zero?

Ans. A Gaussian surface inside encloses no charge; spherical symmetry gives E = 0.

Q. What is the field of an infinite plane sheet dependent on?

Ans. For an ideal infinite sheet, $E = \sigma/(2\epsilon_0)$, so it depends on σ and ϵ_0, not distance.

Q. What is the direction of dipole moment?

Ans. From negative charge to positive charge.

Q. What is the unit of electric flux?

Ans. $N\ m^2\ C^{-1}$.

FINAL 100%-PREP CHECK

☐ All Chapter 1 concepts understood

☐ All 5 major derivation blocks practiced

☐ Formula sheet memorised

☐ NCERT examples/exercises solved

☐ Numericals on superposition and dipole solved

☐ Gauss-law diagrams practised

☐ Previous-year questions practised

☐ Official CBSE sample paper attempted under time