



Ready For Boards
10th & 12th Exam Prep

CHAPTER 1

Electric Charges and Fields

CBSE Class 12 · Physics · Chapter 1

CBSE · Physics · Class 12

WHAT THIS CHAPTER DOES



State and apply Coulomb's law (scalar + vector form) to multi-charge systems.



Calculate the electric field of point charges, dipoles, lines, planes, and shells.

Boards prep that builds confidence, not anxiety.

TODAY'S MISSION

Today's mission

1

State and apply Coulomb's law (scalar + vector form) to multi-charge systems.

2

Calculate the electric field of point charges, dipoles, lines, planes, and shells.

3

Apply Gauss's law to derive field expressions for symmetric charge distributions.

4

Score 8/10 marks on this chapter's slice of the board paper.

WHY THIS MATTERS

Why this chapter matters

1

8-10 marks every CBSE board paper — highest single-chapter weight in Electrostatics.

2

Every later chapter (Capacitance, Magnetic Field, EM Induction) builds on field + flux ideas seeded here.

3

Nearly identical to JEE Main and NEET syllabus — your board prep doubles as entrance-exam prep.

TOPIC

A

Electric charge — properties & quantisation

TOPIC

Three fundamental properties of charge

QUANTISATION

Electric charge exists only as integer multiples of the elementary charge $e = 1.602 \times 10^{-19}$ C. The relation $q = n \cdot e$ ($n \in \mathbb{Z}$) was first established by Robert Millikan's oil-drop experiment (1909-1913), which earned him the 1923 Nobel Prize. Quantisation arises because charge is a property of fundamental particles — electrons

CONSERVATION

The total electric charge of any isolated system is conserved — it can be neither created nor destroyed, only transferred from one body to another. This is a universal conservation law on par with conservation of energy and momentum, and is a direct consequence of the gauge symmetry of electromagnetism. In

ADDITIVITY

Charge is a scalar with sign — multiple charges add algebraically (not vectorially like forces). A system holding $+5 \mu\text{C}$, $+3 \mu\text{C}$, and $-2 \mu\text{C}$ has net charge $+6 \mu\text{C}$. This additivity underpins the principle of SUPERPOSITION used throughout the chapter: the total electrostatic force or field at a point is the vector sum of contributions from

FRAME-INVARIANCE

The electric charge of a particle has the SAME value in every inertial reference frame — it is a Lorentz invariant. This is empirically verified to extraordinary precision: a neutral atom (equal numbers of protons and electrons) remains neutral even when its constituent particles are in violent thermal motion, demonstrating that the

TOPIC

Conductors vs Insulators · how charging happens

CONDUCTORS

Conductors are materials in which electrons can move freely — metals (the 'sea of electrons' model), molten salts, and electrolyte solutions. Copper has roughly 8.5×10^{28} free electrons per m^3 . When excess charge is placed on a conductor, the free electrons rearrange in microseconds so the net field INSIDE the conductor

INSULATORS

Insulators (dielectrics) have a wide energy gap between filled valence and empty conduction bands, so electrons cannot move freely. Examples include rubber, glass ($K \approx 5$), polythene, dry wood, and air. Charge deposited on an insulator stays localised where it is placed (you can map a charge pattern on it by induction). However,

FRICTION

When two unlike materials are rubbed together, electrons transfer from one to the other in accordance with the triboelectric series — a material's tendency to gain or lose electrons relative to others. Glass rubbed with silk: glass donates electrons (becomes +ve), silk accepts (-ve). Plastic comb rubbed in dry hair: comb takes

INDUCTION

Bring a positively charged rod close to (but NOT touching) an isolated conductor: free electrons inside the conductor migrate toward the near face (negative induced charge there), leaving the far face positive. If you EARTH the far face momentarily — the positive induced charge flows to ground — and then remove

TOPIC

B

Coulomb's law — the law of force

THEOREM · LOAD-BEARING RESULT

Coulomb's Law



The force between two point charges in vacuum is along the line joining them, proportional to the product of their magnitudes and inversely proportional to the square of the distance between them.

STATEMENT

$F = (1 / 4\pi\epsilon_0) \cdot |q_1 q_2| / r^2$; vector form $F_{12} = k q_1 q_2 \hat{r}_{12} / r^2$ where \hat{r}_{12} points from 2 to 1. $k = 9 \times 10^9$ N·m²/C². In a medium of dielectric constant K: $F_{\text{medium}} = F_{\text{vacuum}} / K$.

WHY THIS MATTERS

- Coulomb's law is the inverse-square law for electrostatic interactions, exactly parallel to Newton's universal gravitation
- The inverse-square form is what makes Gauss's law work (flux through closed surface depends only on enclosed charge).

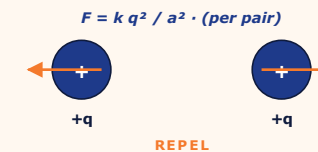
WATCH OUT FOR

NOTE In a medium, the force is REDUCED by factor K, not multiplied. $K > 1$ always. For water $K \approx 80$, so the Coulomb force in water is ~80× weaker than in vacuum.

WORKED EXAMPLE

Force on a vertex charge of an equilateral triangle

- 1 Three charges of $+q$ each sit at vertices A, B, C of an equilateral triangle of side a . Find F on charge at A.
- 2 $F_{AB} = F_{AC} = kq^2/a^2$ each. Angle between them at A = 60° .
- 3 By parallelogram law: $F_{\text{net}} = \sqrt{(F^2 + F^2 + 2F \cdot F \cdot \cos 60^\circ)} = F \cdot \sqrt{3} = \sqrt{3} \cdot kq^2/a^2$.
- 4 Direction: along the perpendicular bisector of BC, AWAY from BC (centroid direction reversed for like charges).



TOPIC

C

Electric field — every point in space

THEOREM · LOAD-BEARING RESULT

Electric Field \vec{E}



The electric field at a point in space is the force per unit positive test charge placed at that point. It is a vector quantity defined at every point, with SI unit N/C (or V/m).

STATEMENT

$\vec{E}(\mathbf{r}) = \lim_{\{q_{\text{test}} \rightarrow 0\}} \vec{F} / q_{\text{test}}$. For a point charge Q at origin: $\vec{E}(\mathbf{r}) = (1 / 4\pi\epsilon_0) \cdot Q / r^2 \cdot \hat{r}$.
Field of multiple charges = vector sum of individual fields (principle of superposition).

WHY THIS MATTERS

- The field concept decouples the source from the test charge
- Once you know \vec{E} at every point, the force on ANY charge q placed there is $\vec{F} = q\vec{E}$ — no need to redo Coulomb's law for each new test charge.

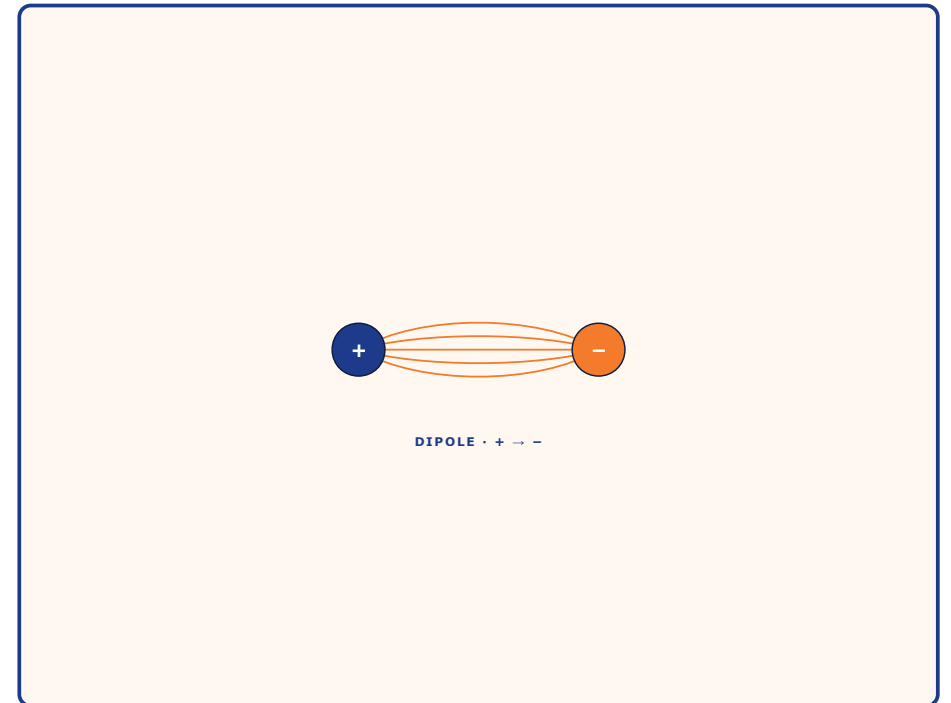
WATCH OUT FOR

NOTE \vec{E} points in the direction of force on a POSITIVE test charge. For a negative test charge placed at the same point, $\vec{F} = q\vec{E}$ flips direction (since q is negative). Confusing E direction with F direction is a perennial 1-mark loss.

WORKED EXAMPLE

Five properties of electric field lines

- 1 Start from +ve charges, end on –ve charges (or at infinity).
- 2 Tangent at every point gives the direction of $E \rightarrow$ there.
- 3 Density (closeness) of lines \propto magnitude of E .
- 4 Lines NEVER cross (else E would have two directions at the crossing point).
- 5 Lines are continuous curves; no sudden breaks except at charges.



TOPIC

D

Electric dipole · dipole field

TOPIC

An electric dipole · setup & moment

DEFINITION

An electric dipole consists of two equal and opposite point charges (+q and -q) separated by a fixed small distance 2a, with the dipole carrying NET charge zero but a NON-ZERO dipole moment. The 'small' separation matters because in the ideal dipole limit ($a \rightarrow 0$, $q \rightarrow \infty$, but $2qa = p$ kept constant) we recover the point-dipole — the basic

DIPOLE MOMENT \vec{p}

The dipole moment \vec{p} is a vector of magnitude $p = q \times 2a$, pointing from the negative charge to the positive charge (NCERT convention; some physics literature uses the reverse, so always check). SI unit is the coulomb-metre (C·m); a more practical molecular unit is the debye (1 D = 3.336×10^{-30} C·m). The water molecule has $p \approx 6.17$

WHY IT MATTERS

Most molecules are electric dipoles — H₂O ($p = 1.85$ D), HCl (1.08 D), NH₃ (1.47 D), CO (0.11 D). The fact that one end of a polar molecule is partly positive and the other partly negative drives a vast portion of chemistry: dipole-dipole forces, hydrogen bonding, solubility rules ('like dissolves like'), surface tension of water, the

LIMIT $R \gg A$

When the observation distance r is much larger than the dipole's half-length a , the dipole's electric field falls off as $1/r^3$ — faster than a point charge's $1/r^2$ because the two opposite charges' fields nearly (but not quite) cancel at distance. On the axial line: $E_{\text{axial}} = 2k \cdot p/r^3$, pointing along \vec{p} . On the equatorial line (perpendicular bisector

WORKED EXAMPLE

E on the axial line of a dipole ($r \gg a$)

- 1 Setup: $+q$ at $+a$, $-q$ at $-a$ (along x-axis). Point P on x-axis at distance r from centre.
- 2 E_{+} at P (along $+x$, away from $+q$) = $kq / (r-a)^2$. E_{-} at P (toward $-q$, $+x$ direction) = $kq / (r+a)^2$.
- 3 Net $E_{\text{axial}} = E_{+} - E_{-} = kq \cdot [(r+a)^2 - (r-a)^2] / [(r^2-a^2)^2] = 4kqra / (r^2-a^2)^2$.
- 4 For $r \gg a$: $E_{\text{axial}} \approx (1 / 4\pi\epsilon_0) \cdot (2p / r^3)$, direction along $p \rightarrow$.

WORKED EXAMPLE

Dipole in a uniform external field

- 1 Place dipole \vec{p} in uniform \vec{E} at angle θ .
- 2 Force on $+q$ is $+q\vec{E}$; on $-q$ is $-q\vec{E}$. Net force = 0 (uniform field).
- 3 But the two forces form a couple \rightarrow produces a torque τ .
- 4 Torque magnitude: $\tau = pE \sin \theta$; vector form $\vec{\tau} = \vec{p} \times \vec{E}$. Direction: into page if rotation tends to align \vec{p} with \vec{E} .

TOPIC

E

Electric flux & Gauss's law

THEOREM · LOAD-BEARING RESULT

Gauss's Law



The total electric flux through ANY closed surface is equal to $(1/\epsilon_0)$ times the total charge enclosed by that surface.

STATEMENT

$\oint \mathbf{E} \cdot d\mathbf{A} = q_{\text{enclosed}} / \epsilon_0$ —
over any closed (Gaussian)
surface, in any electric field.
Charges outside the surface
contribute zero net flux through it.

WHY THIS MATTERS

- Gauss's law is a CONSEQUENCE of Coulomb's inverse-square form
- It is more general than Coulomb's law (works in dynamic situations too) and is one of Maxwell's 4 fundamental equations.

WATCH OUT FOR

NOTE Gauss's law is ALWAYS TRUE. It is only USEFUL for calculating E when symmetry (cylindrical / planar / spherical) lets you pull E out of the integral. Writing 'Gauss only works for symmetric distributions' costs a mark on the statement.

WORKED EXAMPLE

E from an infinite line of charge (λ C/m)

- 1 Symmetry \rightarrow choose a coaxial cylindrical Gaussian surface, radius r , length l .
- 2 \vec{E} is radial on the curved surface (by cylindrical symmetry); parallel to surface on flat ends \Rightarrow flat ends contribute zero flux.
- 3 Flux through curved surface = $E \times 2\pi r l$. Enclosed charge = λl .
- 4 Gauss: $E \times 2\pi r l = \lambda l / \epsilon_0 \Rightarrow E = \lambda / (2\pi\epsilon_0 r)$. Field is radial, falls off as $1/r$ (not $1/r^2$).

WORKED EXAMPLE

E from an infinite plane sheet ($\sigma \text{ C/m}^2$)

- 1 Symmetry \rightarrow choose a Gaussian 'pillbox' cylinder piercing the sheet, with flat ends of area A on either side.
- 2 \vec{E} is perpendicular to the sheet on both sides (by planar symmetry); parallel to the curved side \Rightarrow curved side contributes zero flux.
- 3 Flux through both flat ends = $2 \times E \times A$. Enclosed charge = $\sigma \times A$.
- 4 Gauss: $2EA = \sigma A / \epsilon_0 \Rightarrow E = \sigma / (2\epsilon_0)$. Field is UNIFORM, independent of distance from the sheet.

WORKED EXAMPLE

E from a uniformly charged thin spherical shell (charge Q , radius R)

- 1 Outside ($r > R$): Gaussian sphere of radius r . By symmetry E radial. Flux = $E \times 4\pi r^2$. $q_{\text{enc}} = Q$. So $E = kQ/r^2$ — same as a point charge Q at the centre.
- 2 Inside ($r < R$): Gaussian sphere of radius r encloses NO charge (all charge sits on outer shell). So $E = 0$ everywhere inside.
- 3 At $r = R$: field is discontinuous — jumps from 0 inside to kQ/R^2 just outside. The discontinuity = σ/ϵ_0 (surface charge density).

TOPIC

Electric field direction

TRAP → TRUTH

× **MISTAKE** Electric field points in the direction of force on the charge.

✓ **CORRECT** Electric field at a point is the force PER UNIT POSITIVE charge ($E = F/q$ for a +1 C test charge). On a negative test charge, the FORCE is opposite to E. Confusing F and E direction loses marks every time.

TOPIC

Electric field lines

TRAP → TRUTH

- ✗ **MISTAKE** Electric field lines can cross each other in regions of complex fields.
- ✓ **CORRECT** Field lines NEVER cross. If they did, the tangent at the crossing point would give two different directions for E — impossible (E has one definite direction at every point). They can touch at isolated points (e.g. centre of a dipole's null line) but never cross.

TOPIC

Gauss's law applicability

TRAP → TRUTH

× **MISTAKE** Gauss's law only works for symmetric charge distributions.

✓ **CORRECT** Gauss's law is ALWAYS true ($\oint \mathbf{E} \cdot d\mathbf{A} = q_{\text{enc}}/\epsilon_0$ for any closed surface, any field). It is only USEFUL for calculating E when symmetry makes the integral easy. Stating 'only for symmetric distributions' loses the mark on the statement of the law.

TOPIC

Flux through a cube

TRAP → TRUTH

× **MISTAKE** If the charge sits at the centre of a cube, the flux through one face is q/ϵ_0 .

✓ **CORRECT** Total flux through the closed cube is q/ϵ_0 (Gauss). For a charge at the centre, by symmetry, flux through each of the 6 faces is $q/(6\epsilon_0)$. Confusing 'flux through one face' with 'total flux' is a 2-mark loss.

TOPIC

Charge quantisation in 'macroscopic' problems

TRAP → TRUTH

✗ **MISTAKE** Since charge is quantised ($q = ne$), we should never use non-integer values of e in numerical problems.

✓ **CORRECT** In macroscopic problems (charges in coulombs), the quantisation effect is invisible because n is astronomically large ($1\text{ C} \sim 6 \times 10^{18}$ electrons). Treat charge as continuous in numerical work; mention quantisation only in conceptual questions about 'why' charge can't be $1.5 \times 10^{-19}\text{ C}$.

TOPIC

Coulomb's law in a medium

TRAP → TRUTH

× **MISTAKE** $F_{\text{medium}} = F_{\text{vacuum}} \times K$ (multiplied by dielectric constant).

✓ **CORRECT** $F_{\text{medium}} = F_{\text{vacuum}} / K$. A dielectric REDUCES the force because the medium's molecules align to partially cancel the field. $K > 1$ always (vacuum is $K = 1$). For water, $K \approx 80$, so the force is $\sim 80\times$ weaker than in vacuum.

TOPIC

Dipole moment direction

TRAP → TRUTH

× **MISTAKE** The electric dipole moment p points from $+q$ to $-q$.

✓ **CORRECT** By convention, dipole moment p points FROM $-q$ TO $+q$ (along the axis, with the same direction as the field a positive charge would create). Some textbooks differ; CBSE follows NCERT convention. Drawing p the wrong way costs marks in 'torque on dipole' questions.

TOPPER TEMPLATE · MARK-BY-MARK

5-mark question: 'Using Gauss's law, derive the electric field due to an infinitely long uniformly charged straight wire.'

- 1 STATE GAUSS'S LAW + DIAGRAM**
1 m
Gauss's law: ' $\oint \vec{E} \cdot d\vec{A} = q_{\text{enclosed}} / \epsilon_0$ over any closed surface.' Draw the infinite line of charge with linear charge density λ C/m. Draw a coaxial Gaussian cylinder of radius r and length l .
- 2 SYMMETRY ARGUMENT**
1 m
By cylindrical symmetry, \vec{E} at every point on the curved surface is radial and has the same magnitude. On the two flat ends, \vec{E} is parallel to the surface $\Rightarrow \vec{E} \cdot d\vec{A} = 0$ there. So only the curved surface contributes.
- 3 COMPUTE THE FLUX**
1 m
Total flux through Gaussian cylinder = $E \times (2\pi r l)$ (curved surface area $\times E$, since $E \perp dA$ on curved part).
- 4 ENCLOSED CHARGE**
1 m
Charge enclosed = $\lambda \times l$ (linear density \times length of cylinder).
- 5 SOLVE + FINAL ANSWER**
1 m
Equating: $E \times (2\pi r l) = \lambda l / \epsilon_0 \Rightarrow E = \lambda / (2\pi\epsilon_0 r)$. The field is radial (outward for $\lambda > 0$, inward for $\lambda < 0$) and falls off as $1/r$.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark question: 'Find the electric field at a point on the axial line of an electric dipole, at distance r from the centre.'

- 1 SET UP THE GEOMETRY**
1 m
Dipole: charges $+q$ and $-q$ separated by $2a$, dipole moment $p = q(2a)$, directed from $-q$ to $+q$. Point P is on the axial line, distance r from the centre (so distance $r - a$ from $+q$ and $r + a$ from $-q$).
- 2 APPLY COULOMB / SUPERPOSITION**
1 m
 $E_{+} = kq/(r-a)^2$ (along axis, away from $+q$) ; $E_{-} = kq/(r+a)^2$ (along axis, toward $-q$). Net E at P (along the dipole moment direction) = $E_{+} - E_{-} = kq [1/(r-a)^2 - 1/(r+a)^2]$.
- 3 SIMPLIFY + SMALL-DIPOLE LIMIT**
1 m
Combine fractions: $E = kq \cdot [(r+a)^2 - (r-a)^2] / [(r-a)^2(r+a)^2] = kq \cdot 4ra / (r^2 - a^2)^2$. For $r \gg a$: $E \approx (1 / 4\pi\epsilon_0) \cdot (2p / r^3)$, directed along $p \rightarrow$.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark numerical: 'Three point charges are placed at the vertices of an equilateral triangle of side a . Find the net force

- 1 DRAW + IDENTIFY FORCES**
1 m Draw the triangle. Label the charge under question (say at A). Forces on A due to charges at B and C: F_{AB} and F_{AC} , each = kq^2/a^2 . Each is directed along the line AB or AC.
- 2 RESOLVE + USE PARALLELOGRAM LAW**
1 m Angle between F_{AB} and F_{AC} = 60° (interior angle of equilateral triangle). Net force $F_{net} = \sqrt{F^2 + F^2 + 2F \cdot F \cdot \cos 60^\circ} = \sqrt{3} \cdot F$.
- 3 COMPUTE + DIRECTION**
1 m $F_{net} = \sqrt{3} \cdot kq^2/a^2$, directed along the bisector of angle BAC (i.e. AWAY from the centroid for like charges, TOWARD it for unlike). Substitute numerical values if given.

PYQ PATTERNS







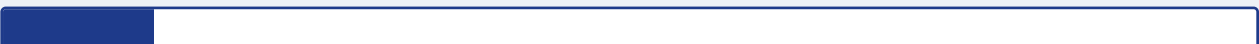
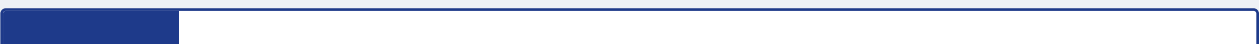

Top PYQ patterns to drill

#1	State Coulomb's law. Use it to find the force on a charge at the vertex of an equilateral triangle with charges at the other two vertices. (3 marks)	2017, 2018, 2019, 2020, 2022, 2023 — annual
#2	Using Gauss's law, derive the electric field due to an infinitely long straight uniformly charged wire / infinite plane sheet of charge. (5 marks)	Annual since 2017
#3	Derive the expression for the electric field at a point on the axial line of an electric dipole. (3 marks)	2018, 2019, 2022, 2024
#4	Define electric flux. Write its SI unit. Find the flux through a closed surface enclosing charge q . (2 marks)	Most years 2017-2024
#5	Two point charges are placed at a distance d . Find the position on the line joining them where the electric field is zero. (3 marks)	2019, 2020, 2023

MARKS DISTRIBUTION

10-year marks distribution

10-YEAR PYQ MARKS DISTRIBUTION

Coulomb's law — numerical (2 or 3 charges in a plane)		48%
Gauss's law — infinite line / infinite plane application		42%
Gauss's law — uniformly charged spherical shell		22%
Electric dipole field on axial line		28%
Electric dipole field on equatorial line		24%
Torque on dipole in uniform field		16%
Properties of electric field lines (conceptual)		12%
Definition: electric flux + units + SI dimensions		14%
Quantisation / additivity / conservation of charge (conceptual)		8%

RECAP · MEMORISE THESE

Recap — 3 things you must walk into the exam with

1 Coulomb — $F = kq_1q_2/r^2$ (vacuum) ; $F = F_{\text{vac}} / K$ (medium). Inverse-square in both r and ϵ_0 .

2 Field — $\vec{E} = \vec{F}/q_{\text{test}}$; superpose vectorially. Field lines $+ \rightarrow -$, never cross.

3 Gauss — $\oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\epsilon_0$. Use it for symmetric charge distributions: line ($1/r$), plane (uniform), shell (0 inside, $1/r^2$ outside).

WHAT'S NEXT

What's next



- Chapter 2 — Electrostatic Potential and Capacitance (builds directly on field + flux).
- Sit the 15-MCQ Quick Drill under 25-minute timer. Target $\geq 12/15$.
- Then the full Board-Pattern Paper — 35 marks, 70 minutes, real CBSE pattern.



Ready For Boards
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Coulomb, Gauss, dipole — now prove it. Take the drill, sit the board paper, beat the chapter.

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