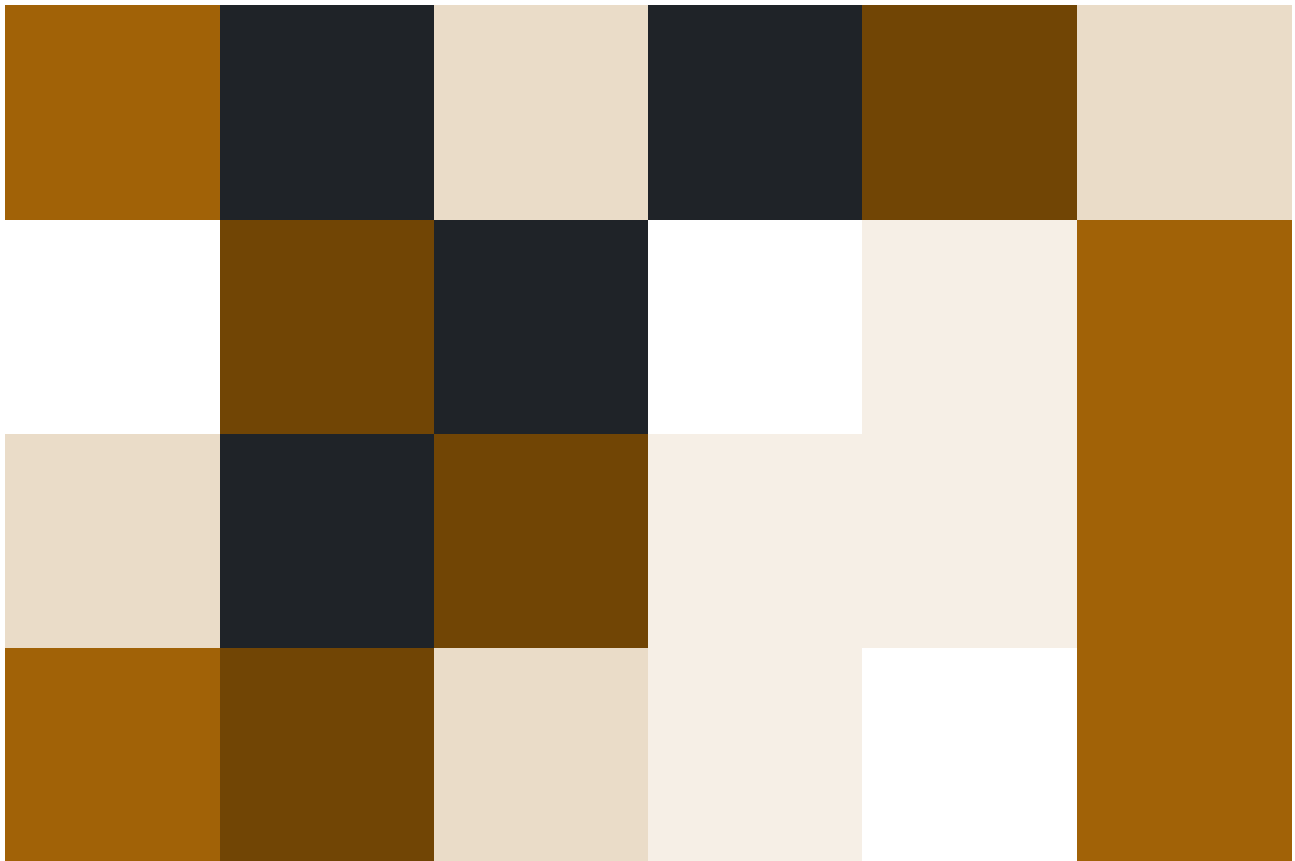




CHAPTER NOTES

Electrostatics

Charges, fields, potential and capacitance

SUBJECT

Physics

CLASS / COURSE

Class 12 • CBSE / JEE foundation

PREPARED BY

Subject Teacher

How to Use These Notes

These notes cover electric charges and fields, electrostatic potential and capacitance. Each chapter starts with a short overview, then lists the key definitions, explains the core concepts with examples, and ends with practice questions. Answers to the multiple-choice questions are at the end.

Study plan

- Read the overview and definitions first
- Work through the solved examples without looking at the answers
- Attempt the practice questions in timed conditions
- Revise using the summary sheet the night before the exam

Contents

Unit 1: Electric Charges and Coulomb's Law.....	4
Key Definitions.....	4
Charging Methods.....	4
Coulomb's Law and Superposition.....	4
Important Formulas.....	4
Solved Examples.....	4
Practice Questions.....	5
Unit 2: Electric Field and Gauss's Law.....	6
Key Definitions.....	6
Properties of Field Lines.....	6
Gauss's Law and Its Uses.....	6
Solved Examples.....	6
Practice Questions.....	7
Unit 3: Potential and Capacitance.....	8
Key Definitions.....	8
Potential and Field.....	8
Capacitors in Circuits.....	8
Important Formulas.....	8
Solved Examples.....	9
Practice Questions.....	9
Quick Revision Sheet.....	10
Answer Key.....	11

Unit 1: Electric Charges and Coulomb's Law

Electric charge is a fundamental property of matter. Like charges repel and unlike charges attract. Charge is quantised, conserved and additive, and the force between two point charges is given by Coulomb's law.

Key Definitions

Term	Meaning
Quantisation	Charge exists only in integral multiples of $e = 1.6 \times 10^{-19} \text{ C}$
Conservation	Total charge of an isolated system remains constant
Conductor	Material that allows charges to move freely
Insulator	Material in which charges cannot move freely
Permittivity (ϵ_0)	$8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ for free space

Charging Methods

Bodies can be charged by friction, conduction and induction. In induction, a charged body brings opposite charge to the near side of a conductor without touching it; earthing the far side leaves the conductor permanently charged.

Coulomb's Law and Superposition

The force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. When several charges act, the net force on any one is the vector sum of the individual forces.

- Force acts along the line joining the charges
- In a medium, the force reduces by the dielectric constant K

Important Formulas

Quantity	Formula	Note
Coulomb force	$F = k q_1 q_2 / r^2$	$k = 1/4\pi\epsilon_0 = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Quantisation	$q = ne$	n is an integer
Force in medium	$F_m = F / K$	K = dielectric constant

Solved Examples

Q1. Two charges of $+2 \mu\text{C}$ and $-3 \mu\text{C}$ are 30 cm apart in air. Find the force.

$$F = 9 \times 10^9 \times (2 \times 10^{-6})(3 \times 10^{-6})/(0.3)^2 = 0.6 \text{ N, attractive.}$$

Q2. How many electrons make up -1 C of charge?

$$n = q/e = 1/(1.6 \times 10^{-19}) = 6.25 \times 10^{18} \text{ electrons.}$$

Exam tip

Always convert μC to C and cm to m before substituting — unit slips cost more marks than physics errors in this chapter.

Practice Questions

A. Multiple choice

- The SI unit of charge is
(a) Ampere (b) Coulomb (c) Volt (d) Farad
- If the distance between two charges is doubled, the force becomes
(a) Double (b) Half (c) One-fourth (d) Four times
- Charge on an electron is
(a) $+1.6 \times 10^{-19}\text{ C}$ (b) $-1.6 \times 10^{-19}\text{ C}$ (c) 1 C (d) -1 C
- Dielectric constant of air is about
(a) 0 (b) 1 (c) 80 (d) ∞

B. Short answer

- State Coulomb's law in vector form.
- What is meant by quantisation of charge?
- Distinguish between conductors and insulators.

C. Long answer

- State and explain Coulomb's law. Define one coulomb.
- Explain the principle of superposition with a suitable example of three charges.

Unit 2: Electric Field and Gauss's Law

An electric field is the region around a charge where another charge experiences a force. Field lines picture the field, and Gauss's law relates the flux through a closed surface to the charge enclosed.

Key Definitions

Term	Meaning
Electric field (E)	Force per unit positive test charge, F/q_0
Field lines	Imaginary curves whose tangent gives the field direction
Electric flux	Number of field lines through a surface, $\Phi = E \cdot A$
Dipole	Two equal and opposite charges separated by a small distance
Gaussian surface	A closed surface chosen to apply Gauss's law

Properties of Field Lines

Field lines start on positive charges and end on negative charges, never cross, and are closer together where the field is stronger.

- Never form closed loops in electrostatics
- Perpendicular to the surface of a conductor

Gauss's Law and Its Uses

The total flux through any closed surface equals the enclosed charge divided by ϵ_0 . With a symmetric Gaussian surface, it gives the field of an infinite line charge, an infinite plane sheet and a charged spherical shell quickly.

- Line charge: $E = \lambda / 2\pi\epsilon_0 r$
- Plane sheet: $E = \sigma / 2\epsilon_0$
- Outside a shell: $E = q / 4\pi\epsilon_0 r^2$; inside: $E = 0$

Solved Examples

Q1. Find the field 10 cm from a 5 μC point charge.

$E = 9 \times 10^9 \times 5 \times 10^{-6} / (0.1)^2 = 4.5 \times 10^6 \text{ N/C}$, directed away from the charge.

Q2. What is the flux through a cube enclosing a charge q at its centre?

$\Phi = q/\epsilon_0$ in total, so $q/6\epsilon_0$ through each face.

Exam tip

For Gauss's law derivations, draw the Gaussian surface clearly and state why the field is constant over

it — that line carries a mark.

Practice Questions

A. Multiple choice

1. SI unit of electric field is
(a) N/C (b) C/N (c) N m (d) V m
2. Field inside a charged conducting shell is
(a) Maximum (b) Zero (c) Infinite (d) Depends on charge
3. Electric flux is a
(a) Vector (b) Scalar (c) Tensor (d) Constant
4. Field due to an infinite sheet depends on distance as
(a) $1/r$ (b) $1/r^2$ (c) Independent of r (d) r

B. Short answer

6. Why do two field lines never intersect?
7. State Gauss's law.
8. Define dipole moment and give its unit.

C. Long answer

9. Using Gauss's law, derive the field due to an infinitely long straight charged wire.
10. Derive the field at a point on the axial line of an electric dipole.

Unit 3: Potential and Capacitance

Electrostatic potential is the work done per unit charge in bringing a charge from infinity to a point. A capacitor stores energy by holding equal and opposite charges on two conductors separated by an insulator.

Key Definitions

Term	Meaning
Potential (V)	Work done per unit positive charge from infinity, W/q
Equipotential surface	Surface on which potential is the same everywhere
Capacitance (C)	Charge stored per unit potential difference, Q/V
Dielectric	Insulating material that increases capacitance
Farad	Capacitance when 1 C raises the potential by 1 V

Potential and Field

The field points in the direction of decreasing potential and equals the negative potential gradient. No work is done in moving a charge along an equipotential surface.

Capacitors in Circuits

The capacitance of a parallel-plate capacitor increases with plate area and dielectric constant and decreases with plate separation. Capacitors in series share the same charge; in parallel they share the same voltage.

- Series: $1/C = 1/C_1 + 1/C_2 + \dots$
- Parallel: $C = C_1 + C_2 + \dots$
- Energy stored: $U = \frac{1}{2}CV^2$

Important Formulas

Quantity	Formula	Note
Potential of point charge	$V = kq / r$	scalar quantity
Field-potential	$E = -dV/dr$	field points to lower V
Parallel plate	$C = K\epsilon_0 A / d$	K = dielectric constant
Energy	$U = \frac{1}{2}CV^2 = Q^2/2C$	stored in the field

Solved Examples

Q1. Find the capacitance of a parallel-plate capacitor with area 0.02 m^2 and separation 1 mm in air.

$$C = \epsilon_0 A/d = 8.85 \times 10^{-12} \times 0.02 / 0.001 = 1.77 \times 10^{-10} \text{ F}.$$

Q2. Two capacitors of $3 \mu\text{F}$ and $6 \mu\text{F}$ are in series across 9 V . Find the charge.

$$C = 2 \mu\text{F}, \text{ so } Q = CV = 18 \mu\text{C} \text{ on each.}$$

Exam tip

Series and parallel rules for capacitors are the reverse of those for resistors — write both side by side in your formula sheet.

Practice Questions

A. Multiple choice

- Unit of capacitance is
(a) Henry (b) Farad (c) Ohm (d) Tesla
- Work done on an equipotential surface is
(a) Maximum (b) Zero (c) Negative (d) Infinite
- Inserting a dielectric slab in a capacitor
(a) Decreases C (b) Increases C (c) Has no effect (d) Makes C zero
- Energy stored in a capacitor is
(a) CV (b) $\frac{1}{2}CV^2$ (c) C^2V (d) V/C

B. Short answer

- Define electrostatic potential and give its SI unit.
- Why is no work done on an equipotential surface?
- Write the expression for energy stored in a capacitor.

C. Long answer

- Derive the expression for the capacitance of a parallel-plate capacitor with a dielectric slab.
- Derive the expression for the energy stored in a capacitor and its energy density.

Quick Revision Sheet

Chapter	Term	Remember
Electric Charges and Coulomb's Law	Quantisation	Charge exists only in integral multiples of $e = 1.6 \times 10^{-19}$ C
Electric Charges and Coulomb's Law	Conservation	Total charge of an isolated system remains constant
Electric Charges and Coulomb's Law	Conductor	Material that allows charges to move freely
Electric Field and Gauss's Law	Electric field (E)	Force per unit positive test charge, F/q_0
Electric Field and Gauss's Law	Field lines	Imaginary curves whose tangent gives the field direction
Electric Field and Gauss's Law	Electric flux	Number of field lines through a surface, $\Phi = E \cdot A$
Potential and Capacitance	Potential (V)	Work done per unit positive charge from infinity, W/q
Potential and Capacitance	Equipotential surface	Surface on which potential is the same everywhere
Potential and Capacitance	Capacitance (C)	Charge stored per unit potential difference, Q/V

Answer Key

Chapter	Question	Answer
1	1	b
1	2	c
1	3	b
1	4	b
2	1	a
2	2	b
2	3	b
2	4	c
3	1	b
3	2	b
3	3	b
3	4	b