CBSE XII 2025

Chapter and Topic-Wise

Solved Papers

2011-2024

PCME

Physics | Chemistry | Mathematics | English Core

(All Sets : Delhi & All India)

Career Launcher

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Physics

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English

PREFACE

At Career Launcher, our goal is not only to help you maximize your scores in Class XII Board Exams, but also to lay a strong foundation in the core subjects to help you get ahead in your college and professional career. Over the last decade, we all have seen how the question paper pattern of Class XII boards has kept changing. Bearing in mind this unpredictable nature of board papers, we've come up with Chapter-wise Solved Papers for Physics, Chemistry, Mathematics and English for Class XII - to help you prepare better and face Boards with confidence.

Exclusively designed for the students of CBSE Class XII by highly experienced teachers, the book provides solutions to all actual questions of Board Exams conducted from 2011 to 2024, in both Delhi and at the All India level. The solutions have been prepared exactly in coherence with the latest marking pattern; after a careful evaluation of previous year trends of the questions asked in Class XII Boards and actual solutions provided by CBSE.

The book follows a three-pronged approach to make your study more focused. The questions are arranged Chapter-wise so that you can begin your preparation with the areas that demand more attention. These are further segmented topic-wise and eventually the break-down is as per the marking pattern. This division will equip you with the ability to gauge which questions require more emphasis and answer accordingly.

We hope the book provides the right exposure to Class XII students so that you not only ace your Boards but mold a better future for yourself. And as always, Career Launcher's school team is behind you with its experienced gurus to help your career take wings.

Let's face the Boards with more confidence!

Wishing you all the best,

Team CL

Blueprint & Marks Distribution

Physics

Class 12th Physics 2024-25 Analysis Unit Wise

Time : 3 hrs. Max Marks : 70

		No. of Periods	Marks
Unit–I	**Electrostatics**		
	Chapter–1: Electric Charges and Fields	26	16
	Chapter–2: Electrostatic Potential and Capacitance		
Unit-II	**Current Electricity**		
	Chapter–3: Current Electricity	18	
Unit-III	**Magnetic Effects of Current and Magnetism**		
	Chapter–4: Moving Charges and Magnetism	25	
	Chapter–5: Magnetism and Matter		17
Unit-IV	**Electromagnetic Induction and Alternating Currents**		
	Chapter–6: Electromagnetic Induction	24	
	Chapter–7: Alternating Current		
Unit–V	**Electromagnetic Waves**		
	Chapter–8: Electromagnetic Waves	04	
Unit–VI	**Optics**		18
	Chapter–9: Ray Optics and Optical Instruments	30	
	Chapter–10: Wave Optics		
Unit–VII	**Dual Nature of Radiation and Matter**		
	Chapter–11: Dual Nature of Radiation and Matter	08	
Unit–VIII	**Atoms and Nuclei**		12
	Chapter–12: Atoms	15	
	Chapter–13: Nuclei		
Unit–IX	**Electronic Devices**		
	Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits	10	7
Total		**160**	**70**

Chemistry

Class 12th Chemistry 2024-25 Analysis Unit Wise

Time : 3 Hours **70 Marks**

S.No.	Title	No. of Periods	Marks
1	Solutions	10	7
2	Electrochemistry	12	9
3	Chemical Kinetics	10	7
4	d -and f -Block Elements	12	7
5	Coordination Compounds	12	7
6	Haloalkanes and Haloarenes	10	6
7	Alcohols, Phenols and Ethers	10	6
8	Aldehydes, Ketones and Carboxylic Acids	10	8
9	Amines	10	6
10	Biomolecules	12	7
	Total	**108**	**70**

Mathematics

Class 12th Mathematics 2024-25 Analysis Unit Wise

Units	Name of Units	No. of Periods	Marks Distribution
Unit-1	Relations and Functions	30	08
Unit-2	Algebra	50	10
Unit-3	Calculus	80	35
Unit-4	Vectors and Three-Dimensional Geometry	30	14
Unit-5	Linear Programming	20	05
Unit-6	Probability	30	08
	Total	**240**	**80**
	Internal Assessment		**20**

English

Class 12th English 2024-25 Question Paper Design

Section	Competencies	Total marks
Reading Skills	Conceptual understanding, decoding, Analyzing, inferring, interpreting,appreciating, literary, conventions and vocabulary, summarizing and using appropriate format/s.	22
Creative Writing Skills	Conceptual Understanding, application ofrules, Analysis, Reasoning, appropriacy of style and tone, using appropriate format and fluency, inference, analysis, evaluation and creativity.	18
Literature Text Books and Supplementary Reading Texts	Recalling, reasoning, critical thinking, appreciating literary convention, inference, analysis, creativity with fluency.	40
	TOTAL	**80**
Internal Assessment		**20**
	Assessment of Listening and Speaking Skills • Listening • Speaking	 5 5
	Project Work	10
	GRAND TOTAL	**100**

Physics

UNIT I: ELECTROSTATICS — 26 Periods

Chapter-1: Electric Charges and Fields

Electric Charges; Conservation of charge, Coulomb's law-force between two point charges, forces between multiple charges; superposition principle and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Chapter-2: Electrostatic Potential and Capacitance

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarisation, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor.

UNIT II: CURRENT ELECTRICITY — 18 Periods

Chapter-3: Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors; temperature dependence of resistance.

Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's laws and simple applications, Wheatstone bridge.

UNIT III: MAGNETIC EFFECTS OF CURRENT AND MAGNETISM — 25 Periods

Chapter-4: Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment.

Biot - Savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire. Straight and toroidal solenoids (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields.

Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

Chapter-5: Magnetism and Matter

Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis, torque on a magnetic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, magnetic field lines; earth's magnetic field and magnetic elements.

Para-, dia- and ferro - magnetic substances, with examples. Electromagnets and factors affecting their strengths, permanent magnets.

UNIT IV: ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENTS 24 Periods

Chapter-6: Electromagnetic Induction

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Eddy currents. Self and mutual induction.

Chapter-7: Alternating Current

Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits, power factor, wattless current.

AC generator and transformer.

UNIT V: ELECTROMAGNETIC WAVES 4 Periods

Chapter-8: Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

UNIT VI: OPTICS 30 Periods

Chapter-9: Ray Optics and Optical Instruments

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and its applications, optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lensmaker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction and dispersion of light through a prism.

Optical Instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

Chapter-10: Wave Optics

Wave Optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light, diffraction due to a single slit, width of central maximum.

UNIT VII: DUAL NATURE OF RADIATION AND MATTER 8 Periods

Chapter-11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light.

Matter waves-wave nature of particles, de-Broglie relation.

UNIT VIII: ATOMS AND NUCLEI 15 Periods

Chapter-12: Atoms

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra (qualitative treatment only).

Chapter-13: Nuclei

Composition and size of nucleus, nuclear force

Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

UNIT IX: ELECTRONIC DEVICES 10 Periods

Chapter-14: Semiconductor Electronics: Materials, Devices and Simple Circuits

Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction

Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode-diode as a rectifier.

Chemistry

UNIT I: SOLUTIONS **10 PERIODS**

Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties, abnormal molecular mass, Van't Hoff factor.

UNIT II: ELECTROCHEMISTRY **12 PERIODS**

Redox reactions, EMF of a cell, standard electrode potential, Nernst equation and its application to chemical cells, Relation between Gibbs energy change and EMF of a cell, conductance in electrolytic solutions, specific and molar conductivity, variations of conductivity with concentration, Kohlrausch's Law, electrolysis and law of electrolysis (elementary idea), dry cell-electrolytic cells and Galvanic cells, lead accumulator, fuel cells, corrosion.

UNIT III: CHEMICAL KINETICS **10 PERIODS**

Rate of a reaction (Average and instantaneous), factors affecting rate of reaction: concentration, temperature, catalyst; order and molecularity of a reaction, rate law and specific rate constant, integrated rate equations and half-life (only for zero and first order reactions), concept of collision theory (elementary idea, no mathematical treatment), activation energy, Arrhenius equation.

UNIT IV: D AND F BLOCK ELEMENTS **12 PERIODS**

General introduction, electronic configuration, occurrence and characteristics of transition metals, general trends in properties of the first-row transition metals - metallic character, ionization enthalpy, oxidation states, ionic radii, colour, catalytic property, magnetic properties, interstitial compounds, alloy formation, preparation and properties of K2Cr2O7 and $KMnO_4$.

Lanthanoids - Electronic configuration, oxidation states, chemical reactivity and lanthanoid contraction and its consequences.

Actinoids - Electronic configuration, oxidation states and comparison with lanthanoids.

UNIT V: COORDINATION COMPOUNDS **12 PERIODS**

Coordination compounds - Introduction, ligands, coordination number, colour, magnetic properties and shapes, IUPAC nomenclature of mononuclear coordination compounds. Bonding, Werner's theory, VBT, and CFT; structure and stereoisomerism, the importance of coordination compounds (in qualitative analysis, extraction of metals and biological system).

UNIT VI: HALOALKANES AND HALOARENES. **10 PERIODS**

Haloalkanes: Nomenclature, nature of C-X bond, physical and chemical properties, optical rotation mechanism of substitution reactions.

Haloarenes: Nature of C-X bond, substitution reactions (Directive influence of halogen in monosubstituted compounds only). Uses and environmental effects of - dichloromethane, trichloromethane, tetrachloromethane, iodoform, freons, DDT.

UNIT VII: ALCOHOLS, PHENOLS AND ETHERS 10 PERIODS

Alcohols: Nomenclature, methods of preparation, physical and chemical properties (of primary alcohols only), identification of primary, secondary and tertiary alcohols, mechanism of dehydration, uses with special reference to methanol and ethanol.

Phenols: Nomenclature, methods of preparation, physical and chemical properties, acidic nature of phenol, electrophilic substitution reactions, uses of phenols.

Ethers: Nomenclature, methods of preparation, physical and chemical properties, uses.

UNIT VIII: ALDEHYDES, KETONES AND CARBOXYLIC ACIDS 10 PERIODS

Aldehydes and Ketones: Nomenclature, nature of carbonyl group, methods of preparation, physical and chemical properties, mechanism of nucleophilic addition, reactivity of alpha hydrogen in aldehydes, uses.

Carboxylic Acids: Nomenclature, acidic nature, methods of preparation, physical and chemical properties; uses.

UNIT IX: AMINES 10 PERIODS

Amines: Nomenclature, classification, structure, methods of preparation, physical and chemical properties, uses, identification of primary, secondary and tertiary amines.

Diazonium salts: Preparation, chemical reactions and importance in synthetic organic chemistry.

UNIT X: BIOMOLECULES 12 PERIODS

Carbohydrates - Classification (aldoses and ketoses), monosaccharides (glucose and fructose), D-L configuration oligosaccharides (sucrose, lactose, maltose), polysaccharides (starch, cellulose, glycogen); Importance of carbohydrates.

Proteins - Elementary idea of - amino acids, peptide bond, polypeptides, proteins, structure of proteins - primary, secondary, tertiary structure and quaternary structures (qualitative idea only), denaturation of proteins; enzymes. Hormones - Elementary idea excluding structure.

Vitamins - Classification and functions.

Nucleic Acids: DNA and RNA.

Mathematics

UNIT I: RELATIONS AND FUNCTIONS — 30 Periods

Chapter 1. Relations and Functions

Types of relations: reflexive, symmetric, transitive and equivalence relations. One to one and onto functions.

Chapter 2. Inverse Trigonometric Functions

Definition, range, domain, principal value branch. Graphs of inverse trigonometric functions.

UNIT II: ALGEBRA — 50 Periods

Chapter 3. Matrices

Concept, notation, order, equality, types of matrices, zero and identity matrix, transpose of a matrix, symmetric and skew-symmetric matrices. Operation on matrices: Addition and multiplication and Multiplication with a scalar. Simple properties of addition, multiplication and scalar multiplication. Noncommutativity of multiplication of matrices and existence of non-zero matrices whose product is the zero matrix (restrict to square matrices of order 2). Concept of elementary row and column operations. Invertible matrices and proof of the uniqueness of inverse, if it exists; (Here all matrices will have real entries).

Chapter 4. Determinants

Determinant of a square matrix (up to 3 x 3 matrices), properties of determinants, minors, co-factors and applications of determinants in finding the area of a triangle. Adjoint and inverse of a square matrix. Consistency, inconsistency and number of solutions of system of linear equations by examples, solving system of linear equations in two or three variables (having unique solution) using inverse of a matrix.

UNIT III: CALCULUS — 80 Periods

Chapter 5. Continuity and Differentiability

Continuity and differentiability, derivative of composite functions, chain rule, derivatives of inverse trigonometric functions, derivative of implicit functions. Concept of exponential and logarithmic functions.

Derivatives of logarithmic and exponential functions. Logarithmic differentiation, derivative of functions expressed in parametric forms. Second order derivatives.

Chapter 6. Applications of Derivatives

Applications of derivatives: rate of change of bodies, increasing/decreasing functions, tangents and normals, use of derivatives in approximation, maxima and minima (first derivative test motivated geometrically and second derivative test given as a provable tool). Simple problems (that illustrate basic principles and understanding of the subject as well as real-life situations).

Chapter 7. Integrals

Integration as inverse process of differentiation.Integration of a variety of functions by substitution, by partial fractions and by parts, Evaluation of simple integrals of the following types and problems based on them.

$$\int \frac{dx}{x^2 \pm a^2}, \int \frac{dx}{\sqrt{x^2 \pm a^2}}, \int \frac{dx}{\sqrt{a^2 - x^2}}, \int \frac{dx}{ax^2 + bx + c}, \int \frac{dx}{\sqrt{ax^2 + bx + c}}$$

$$\int \frac{px + q}{ax^2 + bx + c} dx, \int \frac{px + q}{\sqrt{ax^2 + bx + c}}, \int \sqrt{a^2 \pm x^2} dx, \int \sqrt{x^2 - a^2} dx,$$

$$\int \sqrt{ax^2 + bx + c}\ dx, \int (px + q)\sqrt{ax^2 + bx + c}\ dx.$$

Definite integrals as a limit of a sum, Fundamental Theorem of Calculus (without proof). Basic properties of definite integrals and evaluation of definite integrals.

Chapter 8. Applications of the Integrals

Applications in finding the area under simple curves, especially lines, circles/parabolas/ellipses (in standard form only).

Chapter 9. Differential Equations

Definition, order and degree, general and particular solutions of a differential equation. Formation of differential equation whose general solution is given. Solution of differential equations by method of separation of variables solutions of homogeneous differential equations of first order and first degree. Solutions of linear differential equation of the type:

$\frac{dy}{dx} + py = q$, where p and q are functions of x or constants.

$\frac{dx}{dy} + px = q$, where p and q are functions of y or constants.

UNIT IV: VECTOR ALGEBRA AND THREE-DIMENSIONAL GEOMETRY 30 Periods

Chapter 10. Vector Algebra

Vectors and scalars, magnitude and direction of a vector. Direction cosines and direction ratios of a vector. Types of vectors (equal, unit, zero, parallel and collinear vectors), position vector of a point, negative of a vector, components of a vector, addition of vectors, multiplication of a vector by a scalar, position vector of a point dividing a line segment in a given ratio. Definition, Geometrical Interpretation, properties and application of scalar (dot) product of vectors, vector (cross) product of vectors, scalar triple product of vectors.

Chapter 11. Three - dimensional Geometry

Direction cosines and direction ratios of a line joining two points. Cartesian equation and vector equation of a line, coplanar and skew lines, shortest distance between two lines.Cartesian and vector equation of a plane. Angle between two lines

UNIT V: LINEAR PROGRAMMING 20 Periods

Chapter 12. Linear Programming

Introduction, related terminology such as constraints, objective function, optimization, different types of linear programming (L.P.) problems, mathematical formulation of L.P. problems, graphical method of solution for problems in two variables, feasible and infeasible regions (bounded and unbounded), feasible and infeasible solutions, optimal feasible solutions (up to three non-trivial constraints).

Unit VI: PROBABILITY 30 Periods

Chapter 13. Probability

Conditional probability, multiplication theorem on probability. independent events, total probability, Baye’s theorem, Random variable and its probability distribution, mean and variance of random variable.

English

SECTION A

Reading Skills

Reading Comprehension through Unseen Passage **22 Marks**

I. One unseen passage to assess comprehension, interpretation and inference. Vocabulary and inference of meaning will also be assessed. The passage may be factual, descriptive or literary. **(12x1=12 Marks)**

II. One unseen case-based passage with verbal/visual inputs like statistical data, charts etc. **(10x1=10 Marks)**

Note: The combined word limit for both the passages will be 700-750 words.

Multiple Choice Questions / Objective Type Questions will be asked.

SECTION B

III. Creative Writing Skills **18 Marks**

The section has Short and Long writing tasks.

i. Notice up to 50 words. One out of the two given questions to be answered. (4 Marks: Format : 1 / Organisation of Ideas: 1/Content : 2 / Accuracy of Spelling and Grammar : 1).

ii. Formal/Informal Invitation and Reply up to 50 words. One out of the two given questions to be answered. (4 Marks: Format : 1 / Organisation of Ideas: 1/Content : 2 / Accuracy of Spelling and Grammar :1).

iii. Letters based on verbal/visual input, to be answered in approximately 120-150 words. Letter types include application for a job with bio data or resume. Letters to the editor (giving suggestions or opinion on issues of public interest) . One out of the two given questions to be answered . (5 Marks: Format : 1 / Organisation of Ideas: 1/Content : 2 / Accuracy of Spelling and Grammar :1).

iv. Article/ Report Writing, descriptive and analytical in nature, based on verbal inputs, to be answered in 120-150 words. One out of the two given questions to be. (5 Marks: Format : 1 / Organisation of Ideas: 1/Content : 2 / Accuracy of Spelling and Grammar :1).

SECTION C

Literature Text Book and Supplementary Reading Text

This section will have variety of assessment items including Multiple Choice Questions, Objective Type Questions, Short Answer Type Questions and Long Answer Type Questions to assess comprehension, analysis, interpretation and extrapolation beyond the text.

IV. Reference to the Context **40 Marks**

i. One Poetry extract out of two from the book Flamingo to assess comprehension, interpretation, analysis and appreciation. **(6x1=6 Marks)**

ii. One Prose extract out of two from the book Vistas to assess comprehension, interpretation, analysis and appreciation. **(4x1=4 Marks)**

iii. One prose extract out of two from the book Flamingo to assess comprehension, interpretation and analysis. **(6x1=6Marks)**

iv. Short answer type question (from Prose and Poetry from the book Flamingo), to be answered in 40-50 words. Questions should elicit inferential responses through critical thinking. Five questions out of the six given are to be answered. **(5x2=10 Marks)**

v. Short answer type question, from Prose (Vistas), to be answered in 40 - 50 words. Questions should elicit inferential responses through critical thinking. Any 2 out of 3 questions to be done. **(2x2=4 Marks)**

vi. One Long answer type question, from Prose/Poetry (Flamingo), to be answered in 120-150 words. Questions can be based on incident / theme / passage / extract / event as reference points to assess extrapolation beyond and across the text. The question will elicit analytical and evaluative response from student. Any 1 out of 2 questions to be done. **(1x5=5 Marks)**

vii. One Long answer type question, based on the chapters from the book Vistas, to be answered in 120-150 words to assess global comprehension and extrapolation beyond the text. Questions to provide evaluative and analytical responses using incidents, events, themes as reference points. Any 1 out of 2 questions to be done.

(1x5=5 Marks)

Prescribed Books

1. **Flamingo:** English Reader published by National Council of Education Research and Training, New Delhi

(Prose)

- The Last Lesson
- Lost Spring
- Deep Water
- The Rattrap
- Indigo
- Poets and Pancakes
- The Interview
- Going Places

(Poetry)

- My Mother at Sixty-Six
- Keeping Quiet
- A Thing of Beauty
- A Roadside Stand
- Aunt Jennifer's Tigers

2. **Vistas:** Supplementary Reader published by National Council of Education Research and Training, New Delhi
   - The Third Level
   - The Tiger King
   - Journey to the end of the Earth
   - The Enemy
   - On the Face of It
   - Memories of Childhood
     - › The Cutting of My Long Hair
     - › We Too are Human Beings

INTERNAL ASSESSMENT

Assessment of Listening Skills - 5 Marks
Assessment of Speaking Skills - 5 Marks
Project Work - 10 Marks

Physics

CHAPTER 1

Electric Charges and Fields

[Topic 1] Coulomb's law, electrostatic field and electric dipole

Summary

Electric Charge

- Electrostatic charge is a fundamental property of matter due to which it produces and experiences electrical and magnetic effects.
- Properties of atoms, molecules and bulk matter are determined by electric and magnetic forces.
- It can be inferred from simple experiments based on frictional electricity that there are two type of charges in nature: negative and positive; and like charges repel and unlike charges attract.
- By convention, the charge on electron is considered as negative and the charge on proton is considered as positive and the charge present is equal. The S.I. unit of electric charge is coulomb. Its C.G.S unit is stat coulomb.
- The nature and amount of electric charge present in a charged body is detected by Gold-leaf electroscope.
- Total charge on a body is expressed as $q = \pm ne$.

Conductors and Insulators

- Objects that allow charges to flow through them are called Conductors (metals) and objects that do not allow charges to flow through are called Insulators (rubber, wood, and plastic).
- Objects that behave as an intermediate between conductors and insulators are called semi-conductors, for example- silicon.
- The process of sharing charges with the earth, when we bring a charged body in contact with the earth is called grounding or earthing.

Charging by Induction

- Charging by induction means charging without contact.
- If a plastic comb is rubbed with wool, it becomes negatively charged.

Three basic properties of electric charge

- **Quantization:** When the total charge of a body is an integral multiple of a basic quantum of charge, this is known as quantization of electric charge. i.e., $q = ne$ where

  $n = \pm 1, \pm 2, \pm 3, ...$
- **Additivity:** It means that the total charge of a system is the algebraic sum (adding taking into account negative and positive signs both) of all the charges in the system.
- **Conservation of charge:** Conservation of electric charges means that there will be no change in the total charge of the isolated system with time. There is transfer of the electric charge from one body to another, but no charge will be created or destroyed.

Coulomb's law

The force between two point charges q_1 and q_2 is directly proportional to the product of the two charges(q_1q_2) and inversely proportional to the square of the distance between them(r^2)and it acts along the straight line joining the two charges.

F_{12} = force on q_2 due to q_1 $= \frac{k\left(q_1q_2\right)}{r^2_{21}}\hat{r}_{21}$

where $k = \frac{1}{4\pi\varepsilon_0}$

The experimental value of the constant ε_0 is

$8.854 \times 10^{-12} C^2N^{-1}m^{-2}$

Therefore, the approximate value of k is

$9 \times 10^9 Nm^2C^{-2}$

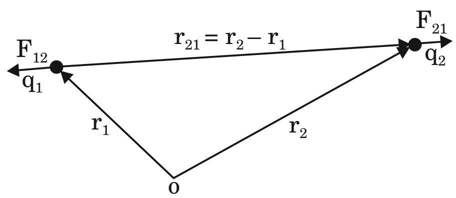


Fig. Depiction of Coulomb's law

Facts about Coulomb's law:

- Coulomb's law is not valid for charges in motion; it should only be used for point charges in vacuum at rest.
- The electrostatic force obeys Newton's third law of motion and acts along the line joining the two charges.
- Presence of other charges in the neighborhood does not affect Coulomb's force.
- The ratio of electric force and gravitational force between a proton and an electron is represented by $\frac{k\,e^2}{G\,m_e m_p} \cong 2.4 \times 10^{39}$

Superposition Principle

The presence of an (or more) additional charge does not affect the forces with which two charges attract or repel each other. Superposition principle states that the net force on any charge due to n number of charges at rest is the vector sum of all the forces on that charges, taken one at a time.

i.e. $\vec{F}_0 = \vec{F}_{01} + \vec{F}_{02} + \vec{F}_{03} + ..\vec{F}_{0n}$

- The force on a small positive test charge q placed at the point divided by the magnitude of the charge is the electric field E at a point due to charge configuration.

Electric Field

- The space around a charge up to which its force can be experienced is called electric field.
- Electric field due to a point charge q has a magnitude $E(r) = \frac{q}{4\pi\varepsilon_0 r^2}\hat{r}$
  - ➢ It is radially outwards if q is positive.
  - ➢ It is radially inwards if q is negative.
- Electric field satisfies the superposition principle.
  - ➢ The unit of electric field is N/C.
  - ➢ Electric field inside the cavity of a charged conductor is zero.

Electric Field lines

- The tangent at each point on the curve of electric field line, gives the direction of electric field at that point.
- The relative strength of electric field at different points is indicated by the relative closeness of field lines.
  - ➢ In regions of strong electric field, they crowd near each other.
  - ➢ In regions of weak electric field, they are far apart.
  - ➢ In regions of constant electric field, the field lines formed are uniformly spaced parallel straight lines.
- Field lines are continuous curves. There will be no breaks.

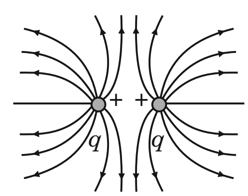


Fig. Electric field lines

- Field lines are not intersecting. They cannot cross each other.
- Electrostatic field lines begin at positive charges and terminate at negative charges.
- No closed loop can be formed by them.

Electric Dipole

- A pair of equal and opposite charges q and –q separated by small distance 2a is known as electric dipole. The magnitude of its dipole moment vector is 2qa and is in the direction of the dipole axis from –q to q.

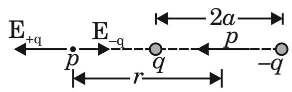


Fig. Electric dipole

- Field of an electric dipole in its equatorial plane at a distance r from the center:

$$E = \frac{-p}{4\pi\varepsilon_o} \frac{1}{\left(a^2 + r^2\right)^{3/2}}$$

$$\cong \frac{-p}{4\pi\varepsilon_o r^3} \quad \text{for } r >> a$$

- Dipole electric field on the axis at a distance r from the center:

$$E = \frac{2pr}{4\pi\varepsilon_o\left(r^2 - a^2\right)^2}$$

$$\cong \frac{2p}{4\pi\varepsilon_o r^3} \quad \text{for } r >> a$$

The $1/r^3$ dependence of dipole electric fields should be noted in contrast to the $1/r^2$ dependence of electric field due to a point charges.

- In a uniform electric field E, a dipole experiences a torque τ given by

$\tau = p \times E$

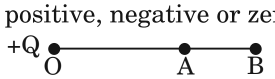
But no net force will be experienced by it.

PREVIOUS YEARS' EXAMINATION QUESTIONS

TOPIC 1

1 Mark Questions

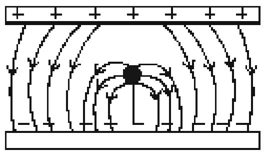
1. What is the geometrical shape of equipotential surface due to a single isolated charge? **[DELHI 2014]**
2. Why do the electric field lines never cross each other? **[ALL INDIA 2014]**
3. A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero?

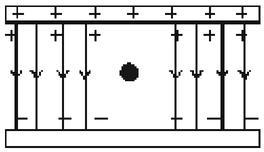


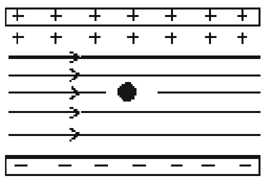
[DELHI 2016]

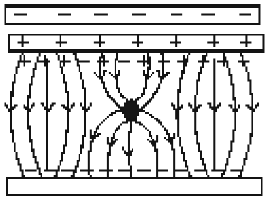
4. In which orientation, a dipole placed in a uniform electric field is in (i) stable, (ii) unstable equilibrium? **[DELHI 2018]**
5. Draw a graph to show the variation of E with perpendicular distance r from the line of charge. **[DELHI 2018]**
6. Draw the pattern of electric field lines, when a point charge - Q is kept near an uncharged conducting plate. **[DELHI 2019]**
7. How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant? **[DELHI 2019]**
8. A point charge is situtated at an axial point of a small electric dipole at a large distance from it. The charge experiences a force F. If the distance of the charge is doubled, the force acting on the charge will become
   (a) 2 F (b) F/2
   (c) F/4 (d) F/8 **[DELHI 2020]**
9. A negatively charged object X is repelled by another charged object Y. However an object Z is attracted to object Y. Which of the following is the most possibility for the object Z?
   (*a*) Positively charged only
   (*b*) negatively charged only
   (*c*) neutral or positively charged
   (*c*) neutral or negatively charged
   [DELHI TERM I, 2022]
10. In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3e, +5e and –3e respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres?
    (*a*) +5e, –4e, +5e
    (*b*) +6e, +6e, –7e
    (*c*) –4e, +3.5e, + 5.5e
    (*d*) +5e, –8e, +7e **[DELHI TERM I, 2022]**
11. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes–
    (*a*) – 0.80 C (*b*) + 0.80 C
    (*c*) + 1.80 C (*d*) + 0.20 C
    [DELHI TERM I, 2022]
12. Two parallel conductors carrying current of 4.0 A and 10.0 A are placed 2.5 cm apart in vacuum. The force per unit length between them is –
    (*a*) 6.4×10^{-5} N/m
    (*b*) 6.4×10^{-2} N/m
    (*c*) 4.6×10^{-4} N/m
    (*d*) 3.2×10^{-4} N/m
    [DELHI TERM I, 2022]

13. Which of the diagrams correctly represents the electric field between two charged plates if a neutral conductor is placed in between the plates?

(*a*)


(*b*)


(*c*)


(*d*)


[DELHI TERM I, 2022]

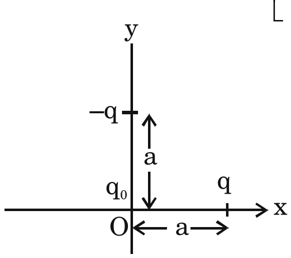
14. The magnitude of electric field due to a point charge 2q, at distance r is E. Then the magnitude of electric field due to a uniformly charged thin spherical shell of radius R with total charge q at a distance $\frac{r}{2}(r >> R)$ will be

(a) $\frac{E}{4}$ (b) 0

(*c*) 2E (*d*) 4E

[DELHI TERM I, 2022]

15. Three charges q, –q and q_0 are placed as shown in figure. The magnitude of the net force on the charge q_0 at point O is $\left[k = \frac{1}{(4\pi \in_0)}\right]$



(a) 0 (b) $\frac{2kqq_0}{a^2}$

(c) $\frac{\sqrt{2}kqq_0}{a^2}$ (d) $\frac{1}{\sqrt{2}}\frac{kqq_0}{a^2}$

[DELHI TERM I, 2022]

16. A + 3.0 nC charge Q is initially at rest at a distance of r_1 = 10 cm from a +5.0 nC charge q fixed at the origin. The charge Q is moved away from q to a new position at r_2 = 15 cm. In this process work done by the field is

(*a*) 1.29×10^{-5} J (*b*) 3.6×10^{5} J

(*c*) -4.5×10^{-7} J (*d*) 4.5×10^{-7} J

[DELHI TERM I, 2022]

17. Given below are the two statements labelled as **Assertion (A)** and **Reason (R).** Select the most appropriate answer from the options given below as:

Assertion (A): A negative charge in an electric field moves along the direction of the electric field.

Reason (R): On a negative charge a force acts in the direction of the electric field.

(a) Both (A) & (R) are true and (R) is correct explanation of (A).

(b) Both (A) & (R) are true, and (R) is not correct explanation of (A)

(c) (A) is true, but (R) is flase.

(d) (A) is false and (R) is also false.

[DELHI TERM I, 2022]

18. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3} Nm, the magnitude of either charge of the dipole is

(*a*) 4 μC (*b*) 7 μC

(*c*) 8 mC (*d*) 2mC **[DELHI, 2023]**

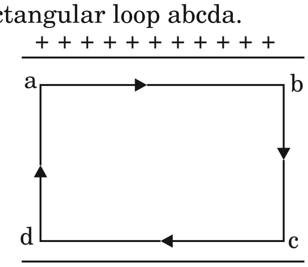
2 Marks Question

19. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has charge ± 8 nC. **[DELHI 2014]**

3 Marks Questions

20. (*a*) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

(*b*) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop abcda.



OR

(*a*) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.

(*b*) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charge q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii. **[DELHI 2014]**

21. A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge. **[DELHI 2016]**

22. (*a*) Draw the equipotential surfaces corresponding to a uniform electric field in the z-direction.

(*b*) Derive an expression for the electric potential at any point along the axial line of an electric dipole. **[DELHI 2019]**

5 Marks Question

23. (*a*) Derive an expression for the electric field E due to a dipole of length "2a' at a point distant r from the centre of the dipole on the axial line.

(*b*) Draw a graph of E versus r for r >> a.

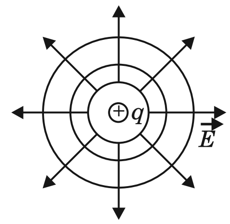
(*c*) If this dipole were kept in a uniform external electric field E_0,diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. **[ALL INDIA 2017]**

24. (*a*) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

(*b*) Two identical point charges, q each are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q. **[DELHI 2019]**

Solutions

1. The equipotential surfaces of an isolated charge are concentric spherical shells(co-centric shells) and potential will be inversely proportional to distance. [½]

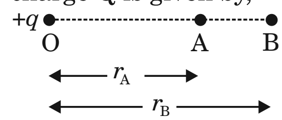


[½]

Fig. Equipotential surfaces of an isolated charge

2. If two electric fields cross each other then there would be two different values of electric field with individual directions at that location which is impossible, hence electric field lines never cross each other. **[1]**

3. Potential at a distance r from a given point charge Q is given by,



[½]

$$V = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r}$$

$$V_A = \frac{Q}{4\pi\varepsilon_o r_A}$$

$$V_B = \frac{Q}{4\pi\varepsilon_o r_B}$$

Since, $r_A < r_B \Rightarrow V_A > V_B$

Hence, $V_A - V_B$ is positive. [½]

4. A dipole placed in a uniform electric field is in:

(*i*) Stable Equilibrium: When the electric field is directed along the direction of the dipole i.e. when $\vec{E}$ is parallel to $\vec{p}$. [½]

(*ii*) Unstable Equilibrium: When the electric field is directed at an angle of 180° with the direction of the dipole i.e. when $\vec{E}$ is anti-parallel to $\vec{p}$. [½]

5.

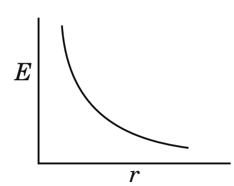
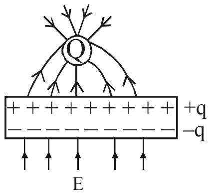


Fig: graph to show the variation of E with perpendicular distance r from the line of charge. **[1]**

6. Equal charge of opposite nature induces in the surface of conductor nearer to the source charge



[1]

Electric lines of forces should fall / normally 90° away on / from the conducting plate.

7. If the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor, mobility of electron remains unchanged because mobility (μ) is independent of applied potential difference. [1]

8. (d) As electric field on axial line varies as,

$$E \propto \frac{1}{r^3} \text{ OR } \frac{F}{Q} \propto \frac{1}{r^3} \text{ OR } F \propto \frac{1}{r^3}$$ [1]

So, when distance is doubled, force reduce to F/8.

9. (c) (neutral or positively charged)

Since we know that like charges repel and unlike charges attract each other. If we suppose Y is having negative charge and X is repelled to it, then X is also having negative charge. Also Y having negative charge, can get attracted towards positive charge, since Z is attracted to Y, so we can suppose Z having positive charge. And among the options, option C satisfies being Neutral/Positive Charge. [1]

10. (b) +6e, +6e, –7e

Given, the charges +3e, +5e and –3e before being sprayed together in the container. After keeping them in the container and making them in contact, the charges get distributed equally, hence the total charge after cancelling the opposite charges of +3e becomes +5e. So net charge over each electron becomes +5e. Now, calculating the sum of charges for each option shows -

Charges			TOTAL SUM
+5e	-4e	+5e	+6e
+6e	+6e	-7e	**+5e**
-4e	+3.5e	+5.5e	+13e
+5e	–8e	+7e	+4e

Hence, correct option is (b) +6e, +6e, –7e [1]

11. (d) +0.20 C

Given, Number of electrons, $n = 5.0 \times 10^{18}$

Charge supplied, Q_{net} = charge of 1 electron x number of electrons

We know that, charge of 1 electron

$= -1.6 \times 10^{-19}$C

$Q_{net} = (-1.6 \times 10^{-19}\text{C}) \times (5.0 \times 10^{18})$

$= -8 \times 10^{-1} = -0.8$ C

$Q_{finally} = Q_{net}$ + Initial charge

$= -0.8 + 1 = +0.20$ C [1]

12. (d) 3.2×10^{-4} N/m

We know $F = \dfrac{\mu_o i_1 i_2}{2\pi r}$

$$= \frac{4\pi \times 10^{-7} \times 4 \times 10}{2\pi \times 2.5 \times 10^{-2}} = 3.2 \times 10^{-4} \text{ N/m}$$ [1]

13. (d) Upper side of the neutral conductor will be negatively charged. Lower side of the neutral conductor will be positively charged. Then the field lines will be from negative to positive, as represented by figure. [1]

14. (c) We know, the Electric Field due to a point charge = $E = \dfrac{k \times 2q}{r^2}$

Electric field due to a spherical shell

$$= E' = \frac{k \times 2q}{\left(\frac{r}{2}\right)^2} = 2F$$ [1]

15. (c) $\dfrac{\sqrt{2}kqq_o}{a^2}$

Positions of q_o, –q and q are shown.

Both q and – q is equidistant from q_o.

So, the magnitude of both the forces on q_o will be equal. The angle between the forces will be 90o° as in figure.

Hence the resultant force

$$= \sqrt{F^2 + F^2 + 2F \times F \times \cos 90°}$$

$$= \sqrt{2}F = \frac{\sqrt{2kqq_o}}{a^2} = \sqrt{2} \times \left(\frac{1}{4\pi\varepsilon_o}\right) \times \frac{qq_o}{a^2}$$

16. (d) 4.5 X 10^{-7} J

We know that, Work Done

$$\int_{r_1}^{r_2} F\,dr = \int_{r_1}^{r_2} \frac{kqQ}{r^2}$$

$$= kqQ\left[\frac{1}{r^1} - \frac{1}{r^2}\right] = (8.99 \times 10^9) \times (5 \times 10^{-9})$$

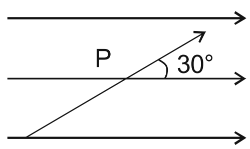
$$\times (3 \times 10^{-9}) \times \left[\frac{1}{0.1} - \frac{1}{0.15}\right]$$

$= 4.5 \times 10^4$ C [1]

17. (d) Assertion is wrong since electron moves in opposite direction of the electric field.

Reason is also false since on negative charge force acts in the opposite direction of the electric field. [1]

18. (a) 2l = 2 cm



$\vec{\tau} = \vec{P} \times \vec{E} = PE\sin\theta$

$\Rightarrow 8 \times 10^{-3} = q \times (2l) \times 2 \times 10^5 \times \sin 30°$

$\Rightarrow 8 \times 10^{-3} = q \times 2 \times 10^{-2} \times 2 \times 10^5 \times \frac{1}{2}$

$\Rightarrow q = \frac{8 \times 10^{-3} \times 2}{4 \times 10^3} = 4\ \mu C$ **[1]**

19. As $\tau = pE \sin\theta$

$\therefore 4\sqrt{3} = pE\sin\theta$ **[1]**

$\Rightarrow pE \times \frac{\sqrt{3}}{2} = 4\sqrt{3}$

$\Rightarrow pE = 8$

Potential energy of dipole,

$U = -pE\cos\theta$ **[1]**

$U = -pE\cos 60°$

$U = -4$ J

20. (*a*) Let us consider a parallel-plate capacitor of plate area A. If separation between plates is d metre (meter), capacitance C in given by

$C = \frac{\varepsilon_o A}{d} F$ **[1]**

We know that the magnitude of the electric field between the charged plates of the capacitor in

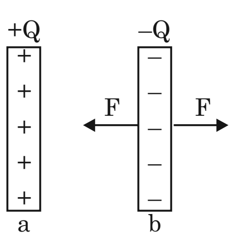
$E = \frac{\sigma}{\varepsilon_o}$

Where, σ is the surface density of either plate. Therefore, the plate charge in is $Q = \sigma A = \varepsilon_0 EA$ Now, the energy stored in the capacitor in $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(\varepsilon_o EA)^2}{\varepsilon_o A/d}$

$U = \frac{1}{2}\varepsilon_o E^2 (Ad) J$ **[½]**

The volume between the plates is Ad metre³. Therefore, the energy per unit volume is given by,

$$\boldsymbol{U = \frac{U}{Ad} = \frac{1}{2}\varepsilon_o E^2 J/m^3}$$



[½]

Fig.: Parallel plate capacitor

(*b*) Work done, $\boldsymbol{W = F.d}$

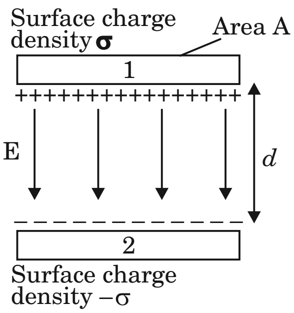
Here, F is the exerted on the charge (q) due to electric field (E) and is given by, $F = qE$

Net displacement, d = 0 **[1]**

Hence, W = 0

OR

(*a*) Derivation for the capacitance of parallel plate capacitor:



[½]

Fig. Capacitance of a parallel plate capacitor

A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance d. The two plates have charges q and -1 and distance between them is d.

Plate 1 has charge density $\sigma = \frac{q}{A}$

Plate 2 has charge density $\sigma = -\frac{q}{A}$

In the inner region between the plates 1 and 2, the electric fields due to the two charged plates add up

$E = \frac{q}{2\varepsilon_o} + \frac{q}{2\varepsilon_o} = \frac{q}{\varepsilon_o} = \frac{q}{A\varepsilon_o}$ **[½]**

For this electric field, potential difference between the plates in given by,

$V = Ed = \frac{1}{\varepsilon_o}\frac{qd}{A}$

The capacitance C of the parallel plate capacitor is then, $C = \frac{Q}{V} = \frac{\varepsilon_o A}{d}$ **[½]**

(*b*) The surface charge density for a spherical conductor of radius R_1 is given by:

$\sigma = \frac{q_1}{4\pi R_1^2}$

Similarly, for spherical conductor R_2, the surface charge density is given by:

$\sigma_2 = \frac{q_2}{4\pi R_2^2}$ **[½]**

$\frac{\sigma_1}{\sigma_2} = \frac{q_1 R_2^2}{q_2 R_1^2}$ (1)

As the spheres are connected so the charges will flow between the spherical conductors till their potential become equal.

$$\frac{kq_1}{R_1} = \frac{kq_2}{R_2}$$ [½]

$$\frac{q_1}{R_1} = \frac{q_2}{R_2} \quad (2)$$

Using (2) in (1) We have,

$$\frac{\sigma_1}{\sigma_2} = \frac{R_1}{R_2} \cdot \frac{R_2^2}{R_1^2} \Rightarrow \frac{R_2}{R_1}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$ [½]

21. Suppose we have a ring of radius a that carries a uniformly distributed positive charge q.

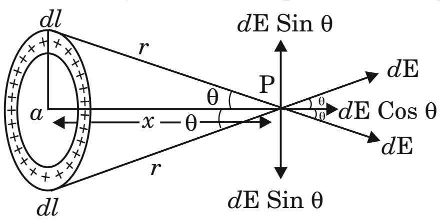


Fig. Uniform distribution of a charge over a ring [½]

As the total charge q is uniformly distributed, the charge dq on the element dl is

$$dq = \frac{q}{2\pi a} \cdot dl$$

∴ The magnitude of the electric field produced by the element dl at the axial point P is

$$dE = k \cdot \frac{dq}{r^2} = \frac{kq}{2\pi a} \cdot \frac{dl}{r^2}$$

(*i*) The axial components dEcosθ and

(*ii*) The perpendicular component dEsinθ. [½]

Since the perpendicular component of any two diametrically opposite elements are equal and opposite, they cancel out in pairs. Only the axial components will add up to produce the resultant field.

E at point P is given by, $E = \int_0^{2\pi a} dE \cos\theta$ [½]

(∵ Only the axial components contribute towards E)

$$E = \int_0^{2\pi a} \frac{kq}{2\pi a} \cdot \frac{dl}{r^2} \cdot \frac{x}{r}$$

$$E = \frac{kqx}{2\pi a} \cdot \frac{1}{r^3} \int_0^{2\pi a} dl \qquad \left(\because \cos\theta = \frac{x}{r}\right)$$

$$E = \frac{kqx}{2\pi a} \cdot \frac{1}{r^3} (l)_o^{2\pi a}$$

$$E = \frac{kqx}{2\pi a} \cdot \frac{1}{\left(x^2 + a^2\right)^{3/2}} \cdot 2\pi a$$ [½]

$$\because r^2 = x^2 + a^2$$

$$E = \frac{kqx}{\left(x^2 + a^2\right)^{3/2}}$$ [½]

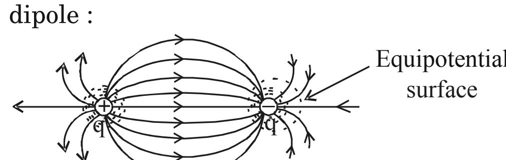
If x > > a, then $x^2 + a^2 \approx x^2$

$$E = \frac{1}{4\pi\varepsilon_o} \frac{qx}{\left(x^2\right)^{3/2}}$$

$$E = \frac{1}{4\pi\varepsilon_o} \frac{q}{x^2}$$ [½]

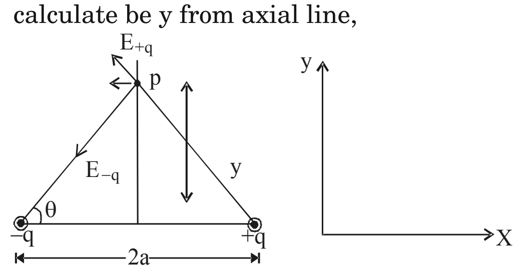
This expression is similar to electric field due to point charge.

22. (*a*) Equipotential surfaces due to an electric dipole :



[1]

(*b*) Let distance of point p where field has to be calculate be y from axial line,



$$\left|\vec{E}_{-q}\right| = \frac{1}{4\pi\varepsilon_o} \frac{q}{\left(y^2 + a^2\right)}$$

and $\left|\vec{E}_{+q}\right| = \frac{1}{4\pi\varepsilon_o} \frac{q}{\left(y^2 + a^2\right)}$ [1]

$$\therefore \vec{E} = \vec{E}_{-q} + \vec{E}_{+q}$$

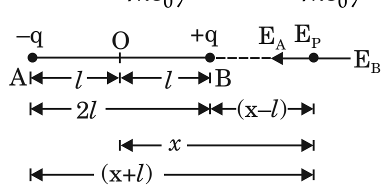
Due to symmetry electric field in y direction will cancel out.

$$\vec{E} = 2\left|\vec{E}_{-q}\right|\cos\theta(-\hat{i}) = \frac{2qa\left(-\hat{i}\right)}{4\pi\varepsilon_0\left(a^2 + y^2\right)^{3/2}}$$

for y >>a

$$\therefore \vec{E} = \frac{2qa}{4\pi\varepsilon_0 y^3}\left(-\hat{i}\right) = -\frac{\vec{p}}{4\pi\varepsilon_0 y^3}$$ [1]

23.



[½]

Electric field intensity due to as electric dipole

(*a*) Dipole at a point on the axial wire: we have to a calculate the field intensity (E) at a point P on the axial line of the dipole and dt a distance OP = π from the centre O of the dipole. Resultant electric field intensity at the point P, $E_P = E_A + E_B$ The vectors E_A and E_B are collinear at opposite.

$\therefore E_P = E_A - E_B$

Here, $E_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x-l)^2}$ and $E_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x+l)^2}$ **[½]**

Thus,

$$E_p = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(x-l)^2} - \frac{q}{(x+l)^2}\right] = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4qlx}{\left(x^2-l^2\right)^2}$$

Hence, $E_p = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4px}{\left(x^2-l^2\right)^2}\left[\because p = q\times 2l\right]$ **[½]**

In vector form, $E_p = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4px}{\left(x^2-l^2\right)^2}$

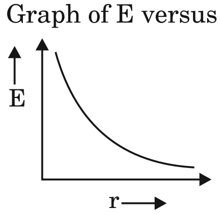
If the dipole is short,i.e. , 2l << x, then **[½]**

$$E_p = \frac{2}{4\pi\varepsilon_0}\cdot\frac{|P|}{x^3} \quad \text{...... (i)}$$

The direction of E_P is long BP produced clearly,

$$E_P \propto \frac{1}{x^3}$$ **[½]**

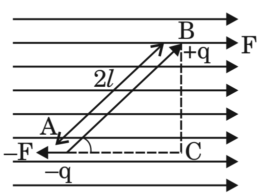
(*b*) Graph of E versus r for r >> a



[1]

Fig.: E versus r

(*c*) Torque on an electric dipole in uniform electric field :-



[½]

Consider an electric dipole considering of two changes –q and +q placed is a uniform external electric field of intensity E. The dipole moment P makes an angle θ with the direction of the electric field. The net force is zero. Since, the two forces are equal in magnitude and opposite in direction and act at different points therefore they constitute a couple. A net torque τ acts on the dipole about an axis passing through the mid-point of the couple. Now τ = force × perpendicular distance BC between the parallel force qE (2l sin θ)

τ = (θ × 2l) E sin θ or τ = pE sin θ **[½]**

In vector notation, τ = p × E

SI unit of torque is newton-meter (N-m) and its dimensional formula is $[ML^2T^2]$

Case-I: If θ = 0° then τ = 0,

The dipole is in stable equilibrium

Case-II: If θ = 90°, thenτ = PE (maximum value)

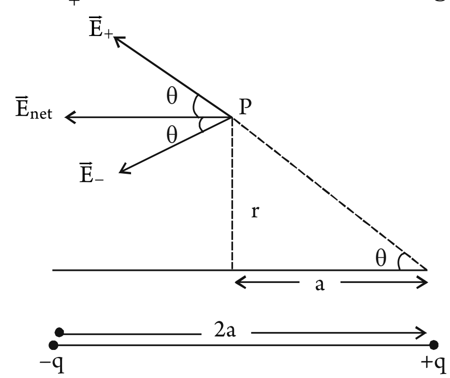
The torque acting on dipole will be maximum.

Case-III: If θ = 180° then τ = 0 **[½]**

The dipole is in unstable equilibrium

24. (*a*) Let P be an equatorial point for a dipole consisting of charges –q and + q with a separation 2a, then

$\vec{E}_+$ = electric field due to the charge + q



[1]

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\times\frac{q}{a^2+r^2} \quad \text{... (i)}$$

Again,

$\vec{E}$ = electric field due to the charge – q

$$= \frac{1}{4\pi\varepsilon_0}\times\frac{q}{a^2+r^2} \quad \text{... (ii)}$$

By superposition principle,

$$\vec{E}_{net} = \vec{E}_+ + \vec{E}_-$$

$$\therefore \left|\vec{E}_{net}\right| = 2E_+\cos\theta = \frac{2}{4\pi\varepsilon_0}\times\frac{q}{\left(a^2+r^2\right)}\times\frac{a}{\sqrt{a^2+r^2}}$$ **[1]**

$$= \frac{1}{4\pi\varepsilon_0}\times\frac{2aq}{\left(a^2+r^2\right)^{3/2}}$$

In vector form,

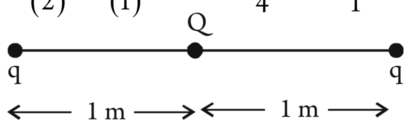
$$\vec{E}_{net} = \frac{1}{4\pi\varepsilon_0}\times\frac{-\vec{p}}{\left(a^2+r^2\right)^{3/2}}$$

For short dipole, r >> a, then

$$\boxed{\vec{E}_{net} = \frac{1}{4\pi\varepsilon_0}\left(\frac{-\vec{p}}{r^3}\right)}$$ **[1]**

(*b*) To overcome the electrostatic repulsion between the point charges q each, Q must be at the centre of the line segment joining the two. The sign of Q must be opposite to that of q.

$$\therefore \frac{kq^2}{(2)^2} + \frac{kqQ}{(1)^2} = 0 \Rightarrow \frac{kq^2}{4} = -\frac{kqQ}{1}$$ **[1]**



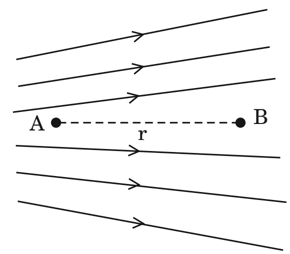
$$\Rightarrow \frac{q}{4} = -Q$$

$$\therefore Q = -\frac{q}{4}$$

Hence, Q must be at a distance of 1 m from each charge q. **[1]**

MULTIPLE CHOICE QUESTIONS

1. When the distance between the charged particles is halved, the force between them becomes.
   (*a*) One-fourth (*b*) Half
   (*c*) Double (*d*) Four times
2. A charge q_1 exerts some force on a second charge q_2. If third charge q_3 is brought near, the force of q_1 exerted on q_2.
   (*a*) Decreases
   (*b*) Increases
   (*c*) Remains unchanged
   (*d*) Increases if q_3 is of the same signs as q_1 and decreases if q_3 is of opposite sign
3. The minimum charge on an object is
   (*a*) 1 coulomb
   (*b*) 1 stat coulomb
   (*c*) 1.6×10^{-19} coulomb
   (*d*) 3.2×10^{-19} coulomb
4. Three charges 4q, Q and q are in a straight line in the position of 0, l/2 and l respectively. The resultant force on q will be zero, if Q =
   (*a*) –q (*b*) –2q
   (*c*) $-\frac{q}{2}$ (*d*) 4q
5. The number of electrons in 1.6 C charge will be
   (*a*) 10^{19} (*b*) 10^{20}
   (*c*) 1.1×10^{19} (*d*) 1.1×10^{2}
6. The electric charge in uniform motion produces
   (*a*) An electric field only
   (*b*) A magnetic field only
   (*c*) Both electric and magnetic field
   (*d*) Neither electric nor magnetic field
7. Figure shows the electric lines of force emerging from a charged body. If the electric field at A and B are E_A and E_B respectively and if the displacement between A and B is r, then



   (*a*) $E_A > E_B$ (*b*) $E_A < E_B$
   (*c*) $E_A = \frac{E_B}{r}$ (*d*) $E_A = \frac{E_B}{r^2}$
8. The electric field near a conducting surface having a uniform surface charge density σ is given by
   (*a*) $\frac{\sigma}{\varepsilon_0}$ and is parallel to the surface
   (*b*) $\frac{2\sigma}{\varepsilon_0}$ and is parallel to the surface
   (*c*) $\frac{\sigma}{\varepsilon_0}$ and is normal to the surface
   (*d*) $\frac{2\sigma}{\varepsilon_0}$ and is normal to the surface
9. Deutron and α-particle are put 1 Å apart in air. Magnitude of intensity of electric field due to deutron at α-particle is
   (*a*) zero (*b*) 2.88×10^{11} N/C
   (*c*) 1.44×10^{11} N/C (*d*) 5.76×10^{11} N/C
10. An electric dipole when placed in a uniform electric field E will have minimum potential energy, if the positive direction of dipole moment makes the following angle with E
    (*a*) π (*b*) $\frac{\pi}{2}$
    (*d*) zero (*d*) $\frac{3\pi}{2}$
11. The electric potential at a point on the axis of an electric dipole depends on the distance r of the point from the dipole as
    (*a*) $\propto \frac{1}{r}$ (*b*) $\propto \frac{1}{r^2}$
    (*c*) $\propto r$ (*d*) $\propto \frac{1}{r^3}$

12. An electric dipole is kept in non-uniform electric field. It experiences

(*a*) A force and a torque

(*b*) A force but not a torque

(*c*) A torque but not a force

(*d*) Neither a force nor a torque

13. The distance between the two charges +q and –q of a dipole is r. On the axial line at a distance d from the centre of dipole, the intensity is proportional to

(*a*) $\frac{q}{d^2}$ (*b*) $\frac{qr}{d^2}$

(*c*) $\frac{q}{d^3}$ (*d*) $\frac{qr}{d^3}$

14. The electric field due to an electric dipole at a distance r from its centre in axial position is E. If the dipole is rotated through an angle of 90° about its perpendicular axis, the electric field at the same point will be

(*a*) E (*b*) $\frac{E}{4}$

(*c*) $\frac{E}{2}$ (*d*) 2E

15. An electric dipole of moment $\vec{p}$ placed in a uniform electric field $\vec{E}$ has minimum potential energy when the angle between $\vec{p}$ and $\vec{E}$ is

(*a*) Zero (*b*) $\frac{\pi}{2}$

(*c*) π (*d*) $\frac{3\pi}{2}$

Answer Keys

1. (*d*)	**2.** (*c*)	**3.** (*c*)	**4.** (*a*)	**5.** (*a*)
6. (*c*)	**7.** (*a*)	**8.** (*c*)	**9.** (*c*)	**10.** (*c*)
11. (*d*)	**12.** (*a*)	**13.** (*d*)	**14.** (*c*)	**15.** (*a*)

Solutions

1. $\because f \propto \frac{1}{r^2}$

$\therefore$ when r is halved the force becomes four times. **[1]**

2. The force will still remain unchanged.

$\therefore F = \frac{q_1 q_2}{4\pi\,\varepsilon_0 r^2}$ **[1]**

3. All other charges are its integral multiple.

$\therefore$ Minimum charge on an object = 1.6×10^{-19} coulomb **[1]**

4. The force between 4q and q.

$$F_1 = \frac{1}{4\pi\,\varepsilon_0}.\frac{4q \times q}{l^2}$$

The force between Q and q

$$F_2 = \frac{1}{4\pi\,\varepsilon_0}.\frac{Q \times q}{\left(\frac{l}{2}\right)^2}$$

$\therefore F_1 + F_2 = 0$ or $\frac{4q^2}{l^2} = -\frac{4Qq}{l^2} \Rightarrow Q = -q$ **[1]**

5. $n = \frac{q}{e} = \frac{1.6}{1.6 \times 10^{-19}} = 10^{19}$ **[1]**

6. A movable charge produces electric field and magnetic field both. **[1]**

7. In non-uniform electric field. Intensity is more, where the lines are more denser. **[1]**

8. Electric field near the conductor surface is given by $\frac{\sigma}{\varepsilon_0}$ and it is perpendicular to surface. **[1]**

9. Due to deutron, intensity of electric field at 1 Å distance

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{e}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19}}{10^{-20}}$$

$= 1.44 \times 10^{11}$ N/C **[1]**

10. Potential energy = $-pE \cos\theta$.

when $\theta = 0$,

Potential energy = $-pE$ (minimum) **[1]**

11. Electric potential due to dipole in it's general position is given by $v = \frac{k.p\cos\theta}{r^2} \Rightarrow v \propto \frac{1}{r^2}$ **[1]**

12. As the dipole will feel two forces which are although opposite but not equal.

$\therefore$ A net force will be there and as these forces act at different points of a body. A torque is also parent. **[1]**

13. Field along the axis of the dipole

$$E = \frac{1}{4\pi\varepsilon_0}.\frac{2p}{d^3} = \frac{1}{4\pi\varepsilon_0}.\frac{2(q \times r)}{d^3}$$

$\therefore E \propto \frac{qr}{d^3}$ **[1]**

14. When the dipole is rotated through at an angle of 90° about it's perpendicular axis then given point comes out to be on equator. So field will become $\frac{E}{2}$ at the given point. **[1]**

15. $U = -PE \cos\theta$.

It has minimum value when $\theta = 0°$.

i.e. $U_{min} = -PE \cos 0° = -PE$ **[1]**

Topic 2: Electric Flux

Summary

- Electric flux is proportional to number of lines leaving a surface, outgoing lines with positive sign, incoming lines with negative sign.

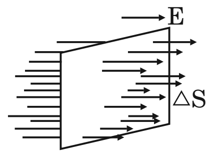


Fig. Electric flux

- Through a small area element ΔS, the flux Δϕ of electric field E is given by

  $\Delta\phi = E.\Delta S$

  And the vector area element ΔS is

  $\Delta S = \Delta S\hat{n}$

Where ΔS is the magnetic of the area element and $\hat{n}$ is normal to the area element, which can be considered planar for the sufficiently small ΔS.

Gauss's Law and its application

- The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed by S.

$$\phi = E\int dA = \frac{q_{enclosed}}{\varepsilon_0}$$

- The law is mainly useful in determining electric field E, when the source distribution has simple symmetry:
  - ➢ Thin infinitely long straight wire of uniform linear charge density λ

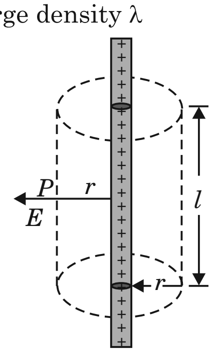


Fig. Thin infinitely long Straight wire

$$E = \frac{\lambda}{2\pi\varepsilon_o r}\hat{n}$$

Where, r is the radial (perpendicular) distance of the point from the wire and $\hat{n}$ is the radial unit vector in the plane normal to the wire passing through the point.

- Infinite plane sheet (thin) of uniform surface charge density σ

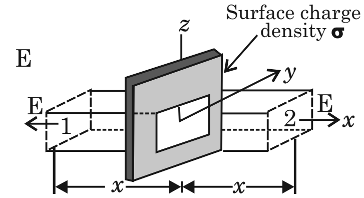


Fig. Infinite plane sheet (thin)

$$E = \frac{\sigma}{2\varepsilon_o}\hat{n}$$

Where $\hat{n}$ is a unit vector normal to the plane and going away from it.

- Thin spherical shell of uniform surface charge density σ

$$E = \frac{q}{4\pi\varepsilon_o r^2}\hat{r} \qquad (r \geq R)$$

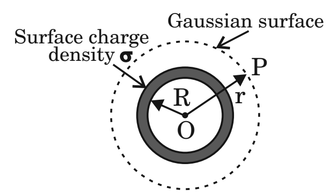


Fig.: Thin uniformly surface charged spherical shell (r > R)

(For r > R)

E = 0 (r < R)

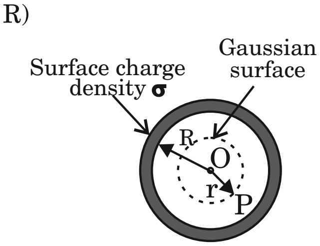


Fig.: Thin uniformly surface charged spherical shell (r < R)

(For r < R)

Where r is the distance of the point from the center of the shell whose radius is R with the total charge q. The electric field outside the shell is the same as the total charge is concentrated at the center. A solid sphere of uniform volume charge density shows the same result. Inside the shell at all the points, the field is zero.

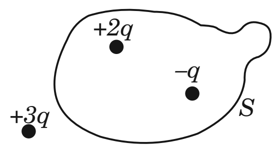
PREVIOUS YEARS' EXAMINATION QUESTIONS

TOPIC 2

1 Mark Questions

1. What is the electric flux through a cube of side 1 cm which encloses an electric dipole? **[DELHI 2015]**

2. Figure shows three point charges +2q, -q and +3q. Two charges +2q and –q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'? **[DELHI 2015]**



3. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased? **[DELHI 2016]**

4. If the net electric flux through a closed surface is zero, then we can infer
   (a) no net charge is enclosed by the surface.
   (b) uniform electric field exists within the surface.
   (c) electric potential varies from point to point inside the surface.
   (d) charge is present inside the surface.
   [DELHI 2020]

5. A square sheet of side 'a' is lying parallel to XY plane at z = a. The electric field in the region is $\vec{E} = cz^2\hat{k}$. The electric flux through the sheet is
   (a) a^4c (b) $\frac{1}{3}a^3c$
   (c) $\frac{1}{3}a^4c$ (d) 0
   [DELHI TERM I, 2022]

2 Marks Questions

6. Given a uniform electric field $\vec{E} = 5\times10^3\hat{i}N/C$, find the flux of this field through a square of 10 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square if the plane makes a 30° angle with the x-axis? **[DELHI 2014]**

7. Given a uniform electric field $\vec{E} = 2\times10^3\hat{i}N/C$. Find the flux of this field through a square of side 20 cm, whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x-axis? **[DELHI 2014]**

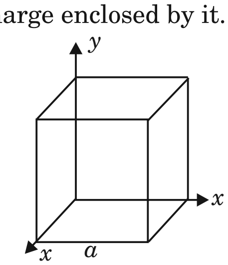
8. Given a uniform electric field $\vec{E} = 4\times10^3\hat{i}N/C$, find the flux of this field through a square of 5 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30°with the x-axis? **[DELHI 2014]**

3 Marks Question

9. Using Gauss's law to obtain the expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for r > R and r < R. **[ALL INDIA 2011]**

5 Marks Questions

10. (*a*) An electric dipole of dipole moment $\vec{p}$ consists of point charges +q and –q separated by a distance 2a apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on ts axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit
    (*b*) Given the electric field in the region $\vec{E} = 2\hat{x}l$, find the net electric flux though the cube and the charge enclosed by it.



OR

(*a*) Explain, using suitable diagrams, the difference in the behavior of a (i) conductor and (ii) a dielectric in the presence of external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.

(*b*) A thin metallic spherical shell of radius a carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at its centre C and another charge +2Q is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A, (ii) the electric flux through the shell.

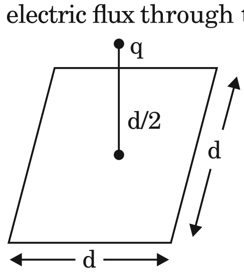
[DELHI 2015]

11. (*a*) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet.

(*b*) An infinitely large thin plane sheet has a uniform surface charge density +σ. Find the amount of work done in bringing a point charge q from infinity to a point, distance r, in front of the charged plane sheet

[ALL INDIA 2017]

12. (*a*) Define electric flux. Is it a scalar or a vector quantity? A point charge q is at a distance of $\frac{d}{2}$ directly above the centre of a square of side 'd', as shown in the figure. Use Gauss's theorem to obtain the expression for the electric flux through the square.



(*b*) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

OR

Use Gauss' law to derive the expression for the electric field $(\vec{E})$ due to a straight uniformly charged infinite line of charge density λC/m.

[ALL INDIA 2018]

13. (a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance *x* from the centre of shell, such that

(i) $0 < x < R$, and

(ii) $x > R$

(*b*) An electric field is uniform and acts along + x direction in the region of positive x. It is also uniform with the same magnitude but acts in – x direction in the region of negative x. The value of the field is E = 200 N/C for x > 0 and E = – 200 N/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at x = + 10 cm and the other is at x = – 10 cm.

Find :

(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder.

[DELHI 2020]

Solutions

1. From Gauss law the net flux passing through a surface is proportional to the charge enclosed within the surface. Since , net charge enclosed by electric dipole is zero hence flux will be zero. **[1]**

2. From gauss law net flux is ratio of total charge enclosed divided by $(S) = \frac{q}{\varepsilon_o}$ from the figure total charge enclosed is +2q – q = q. Hence

$(S) = \frac{q}{\varepsilon_o}$ **[1]**

3. According to Gauss's law, $\phi = \int \varepsilon \cdot ds = \frac{q_{en}}{\varepsilon_o}$ [½]

Where q_{en} is the total charge enclosed by the surface. From above formula it is clear that electric flux does not depend on radius, hence it remains constant.

Flux depends only on the charge enclosed.

Hence, the electric flux remains constant.

4. (a) No net charge is enclosed by the surface, if the net electric flux through a closed surface is zero. **[1]**

5. (a) $E = cz^2 k$

Where, z = Φ, = ?

We know that, $\varphi = \int E.ds$

ds = dxdyk

$$\varphi = \int \left(ca^2\right) kdxdyk = \int_0^z ca^2 dxdy$$

$$= \int_0^z ca^2 dx = \int_0^z ca^2 dy = ca^2 [a][a] = ca^4$$ **[1]**

6. When the plane is parallel to the y-z plane:

Electric flux, ϕ = EA

Here, $\vec{E} = 5 \times 10^3 jN/C$

$A = 10cm^2, \hat{i} = 10^{-2}\hat{i}m^2 = 10^{-2}im^2$ **[1]**

$\phi = 5 \times 10^3 \hat{i} 10^{-2} \hat{i} \Rightarrow \phi = 50$ Weber or Nm^2C^{-1}

When the plane makes a 30° angle with the x-axis, the area vector makes 60° with the x-axis.

$\phi = \vec{E}.\vec{A} \Rightarrow \phi = EA\cos\theta$

$\phi = 5 \times 10^3 \times 10^{-2} \cos 60°$

$\phi = \frac{50}{2}$

$\Rightarrow \phi = 25$ Weber or $Nm^2\ C^{-1}$ **[1]**

7. When the plane is parallel to the y-z plane:

$\phi = \vec{E}.\vec{A}$

$\vec{E} = 2\times10^3\hat{i}$

$A = (20cm)^2\hat{i} = 0.04M^2\hat{i}$

A = (20 cm)^2 i = (20 × 10^{-2})^2 = 0.04m^{2}i

$\therefore \phi = (2\times10^3\hat{i})\cdot(0.04\hat{i}) \Rightarrow \phi = 82$

Weber or 80 Nm^{2}C^{-1} **[1]**

When the plane makes an 30°angle with the x-axis, the area vector makes an 60° angle with the x-axis.

$\phi = \vec{E}\cdot\vec{A} \Rightarrow \phi = EA\cos\theta$

$\phi = 2\times10^3\times0.04\cos60^o$

$\phi = 2 \times 10^3 \times 0.04 \cos 30°$

$\phi = 2\times10^3\times0.04\times\frac{1}{2}$

$\Rightarrow \phi$ = 40 Weber or 40 Nm^{2}C^{-1} **[1]**

8. When the plane is parallel to the y-z plane:

Electric flux, $\phi = \vec{E}\cdot\vec{A}$

Here, $\vec{E} = 4\times10^3\hat{i}N/C$

$\vec{A} = (5\,cm)^2\hat{i} = 0.25\times10^{-2}\hat{i}m^2$

$\phi = (4\times10^3\hat{i})\cdot(25\times10^{-4}\hat{i})$

$\Rightarrow \phi$ = 10 Weber or Nm^{2}C^{-1} **[1]**

When the plane makes an angle of 30° with the x-axis, the area vector makes an angle of 60° with the x-axis.

$\phi = \vec{E}\cdot\vec{A} \Rightarrow \phi = EA\cos\theta$

$\Rightarrow \phi = (4 \times 10^3)(25 \times 10^{-4}) \cos 60°$

$\Rightarrow \phi = \frac{10}{2}$

$\Rightarrow \phi$ = 5 Weber or Nm^{2}C^{-1} **[1]**

9. **[½]**

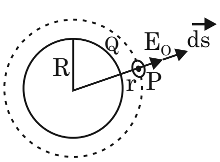


Fig.: Spherical Gaussian surface

Consider a spherical Gaussian surface of radius r (›R), concentric with given shell. If E is electric field outside the shell, then by symmetry, electric field strength has same magnitude E$_o$ on the Gaussian surface and is directed radially outward. Also the direction of normal at each point is radially outward, so angle between E$_o$ and ds is zero at each point. Hence, electric flux through Gaussian surface **[½]**

$= \phi_s E_o\, ds$

$= \phi_s E_o\, ds \cos 0° = E_o\, 4\pi r^2 ds$

Now, Gaussian surface is outside the given charged shell, so charge enclosed by the Gaussian surface is Q. Hence, by Gauss's theorem

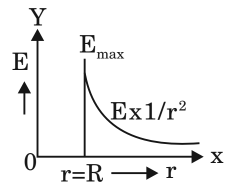
$\phi_s E_o \cdot ds = \frac{1}{\varepsilon_0}\times \text{charge} - \text{enclosed}$

Add sign of integration in this formula

$\Rightarrow E_o \cdot 4\pi r^2 = \frac{1}{\varepsilon_o}\times Q$

$\Rightarrow E_o = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$ **[1]**

Thus, electric field outside a charged thin spherical shell is same as if the whole charge Q is concentrated at the centre. Graphically,



[½]

E is proportional to 1/r^2 not multiple as shown in the figure.

For $r < R$, there is no strength of electric field inside a charged spherical shell. For $r > R$, electric field outside a charged thin spherical shell is same as if the whole charge Q is concentrated at the centre.

10. (*a*) Electric field at a point on the axial line

$|\overline{E_{+q}}| = \frac{kq}{(x-a)^2} \; |\overline{E_{-q}}| = \frac{kq}{(x+a)^2}$ **[1]**

$\left[\because k = \frac{1}{4\pi\varepsilon_o}\right]$

$\left[\because \overline{P} = 2aq\right]$

If x>>>a,

In vector form, $\vec{E} = \frac{2p}{4\pi\varepsilon_o x^3}$ **[1]**

(*b*) Since, the electric field is parallel to the faces parallel to xy and xz planes, the electric flux through them is zero.

Electric flux through the left face, **[1]**

$\phi_L = (E_L)(a^2) \cos 180°$

$\phi_L = (0\;)(a^2) \cos 180° = 0$

Electric flux through the right face,

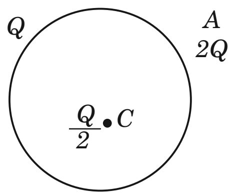
$\phi_R = (E_R)(a^2)\cos 0°$

$\phi_R = (2a)(a^2) \times 2a^3$

Total flux $(\phi) = 2a^3 = \frac{q_{enclosed}}{\varepsilon_o}$ **[1]**

$\therefore q_{enclosed} = 2a^3\varepsilon_o$

OR



[1]

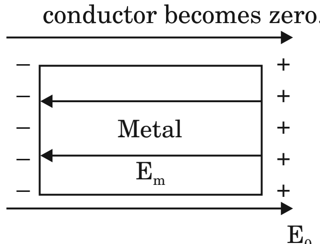
(*a*) (*i*) Conductor $E_o \rightarrow$ External field

$E_m \rightarrow$ Internal field created by the redistribution of electrons inside the metal

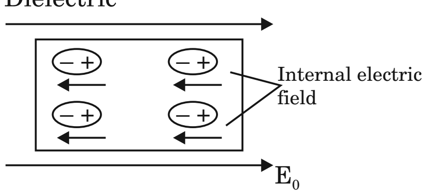
When a conductor like a metal is subjected to external electric field, the electrons experience a force in the opposite direction collecting on the left side. **[1]**

A positive charge is therefore induced on the right hand side. This creates an opposite electric field (E_m) that balances out (E_o).

Hence, the net electric field inside the conductor becomes zero. **[1]**



(*ii*) Dielectric



When external electric field is applied, dipoles are created (in case of non-polar dielectrics). The placement of dipoles is as shown in the given figure. An internal electric field is created which reduces the external electric field.

Polarization of dielectric (P) is defined as the dipole moment per unit volume of the polarized dielectric.

$P = \chi_e \varepsilon_0 E$

Where, χ_e susceptibility **[1]**

$E \rightarrow$ Electric field

(*b*) Net force on the charge $\frac{Q}{2}$, placed at the centre of the shell, is zero.

Force on charge 2Q kept at a point A **[1]**

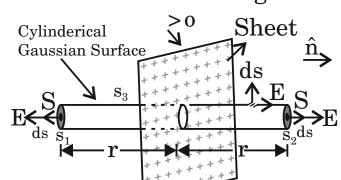
$$F = E \times 2Q = \frac{I\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_o r^2}$$

$$F = \frac{k3Q^2}{r^2}$$

[1]

Electric flux through the shell, $\phi = \frac{Q}{\varepsilon_o}$

11. (*a*) Gaussian surface for a thin infinite plane sheet of uniform charge density



[1]

Let σ be the surface charge density of the sheet. From symmetry, E on either side of the sheet must be perpendicular to the plane of the sheet, having same magnitude at all points equidistant from the sheet. We take a cylindrical cross-sectional area A and length 2r as the Gaussian surface. On the curved surface of the cylinder E and $\hat{n}$ are perpendicular to each other. Therefore flux through curved surface = 0. Flux through the flux surface = EA + EA = 2EA

∴ Total electric flux over the centre surface of cylinder $\phi = 2EA$ **[1]**

Total charge enclosed by the cylinder, $q = \sigma A$

acc. to Gauss' law, $\phi_E = \frac{q}{\varepsilon_0}$

$\therefore 2EA = \frac{\sigma A}{\varepsilon_0}$

or $E = \frac{\sigma}{2\varepsilon_0}$ **[1]**

(*b*) Let V_0 be the potential on the surface at sheet that at a distance r from it

$dV = \vec{E} \cdot \vec{dr}$

$V_0 - V = \frac{\sigma}{2\varepsilon_0} r$

$V = V_0 - \frac{\sigma}{2\varepsilon_0} r$

12. (*a*) Electric flux is defined as, $\phi_\varepsilon = E.\ ds$

It is scalar quantity. Electric flux through square is $\phi_\varepsilon = \frac{q}{\varepsilon_0 6}$ **[3]**

(*b*) Flux will not change, i.e. $\phi_\varepsilon = \frac{q}{\varepsilon_0 6}$ **[2]**

OR

To calculate the field, imagine a cylindrical Gaussian surface,as shown in the figure. Since the field is every where radial,flux through the two ends of the cylindrical Gaussian surface is zero. At the cylindrical part of the surface, E is normal to the surface at every point,and its magnitude is constant, since it depends on r. The surface area of the curve if $2\pi rl$, where l is the length of the cylinder. **[1]**

Flux through the Gaussian surface

= flux through the curved cylindrical part of the surface

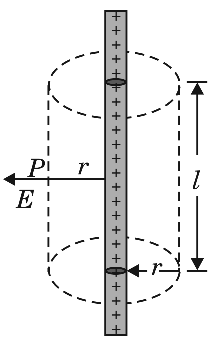
$= E \times 2\pi rl$

The surface includes charge equal to λl. Gauss's law then gives

$$E \times 2\pi rl = \frac{\lambda l}{\phi_o}$$ **[1]**

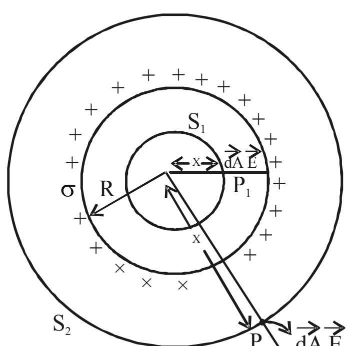
$$\text{i.e., } E = \frac{\lambda}{2\pi r\phi_o}$$ **[1]**

Vectorially, E at any point is given by $E = \frac{\lambda}{2\pi r\phi_o}\hat{n}$



[2]

13.(a) **[1]**



Here, Two gaussian spheres are S_1 and S_2

For points P_1 $(x < R)$ and P_2 $(x > R)$. Now,

(i) By Gauss's law,

Net outward flux through S_1

$$\phi = \oint \vec{E}.\vec{dA} = \frac{}{\varepsilon}$$

$\Rightarrow$ E = 0

[$\because$ change enclosed by $S_1 = 0$] **[1]**

(ii) Net outward flux through S_2,

$$\phi = \oint_{S_2} \vec{E} \cdot \vec{dA} = \frac{q_2}{\varepsilon_0}$$

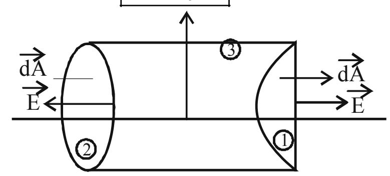
$$\Rightarrow \quad E\oint_{S_2} dA = \frac{\sigma(4\pi R^2)}{\varepsilon_0}$$

$$\text{Since } \oint_{S_2} dA = 4\pi x^2$$

$$\therefore \quad E = \frac{\sigma(4\pi R)^2}{(4\pi x^2)\varepsilon_o}$$

$$\Rightarrow \quad \boxed{E = \frac{\sigma R^2}{\varepsilon_o x^2}}$$ **[1]**

(b)



(i) Net outward flux through cylinder :

$\phi = f_1 + f_2 + f_3$

$= E(pr^2) + E(pr^2) + O$

$= 2E\ pr^2$

$= 2 \times 200 \times 3.14 \times (5 \times 10^{-2})^2$

$= 400 \times 3.14 \times 25 \times 10^{-4}$

$= 3.14$ N-m²/C **[1]**

(ii) Net charge, present inside the cylinder,

$q = \phi\ e_o$

$\Rightarrow$ $q = 3.14 \times 8.854 \times 10^{-12}$

$= 27.801 \times 10^{-12}$ C **[1]**

MULTIPLE CHOICE QUESTIONS

1. A Cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by

(*a*) $2\pi R^2E$ (*b*) $\frac{\neq R^2}{E}$

(*c*) $\frac{\left(\frac{\pi R^2}{\pi R}\right)}{E}$ (*d*) zero

2. An electric charge q is placed at the centre of a cube of side a. The electric flux on one of its faces will be

(*a*) $\frac{q}{6\varepsilon_o}$ (*b*) $\frac{q}{\varepsilon_o a^2}$

(*c*) $\frac{q}{4\pi\varepsilon_o a^2}$ (*d*) $\frac{q}{\varepsilon_o}$

3. Total electric flux coming out of a unit positive charge put in air is

(*a*) ε_o (*b*) ε_o^{-1}

(*c*) $(4\rho\varepsilon_o)^{-1}$ (*d*) $4\pi\varepsilon_o$

4. For a given surface the Gauss's law is stated as $\oint E \, . \, ds = 0$. From this we can conclude that

(*a*) E is necessarily zero on the surface

(*b*) E is perpendicular to the surface at every point

(*c*) The total flux through the surface is zero.

(*d*) The flux is only going out of the surface

5. A cube of side ℓ is placed in a uniform field E, where $E = E\hat{i}$. The net electric flux through the cube is

(*a*) zero (*b*) ℓ^2E

(*c*) $4\ \ell^2E$ (*d*) $6\ \ell^2E$

6. A charge q is placed at the centre of the open end of cylindrical vessel. The flux of the electric field through the surface of the vessel is

(*a*) zero (*b*) $\frac{q}{\varepsilon_o}$

(*c*) $\frac{q}{2\varepsilon_o}$ (*d*) $\frac{2q}{\varepsilon_o}$

7. According to Gauss's Theorem, electric field of an infinitely long straight wire is proportional to

(*a*) r (*b*) $\frac{1}{r^2}$

(*c*) $\frac{1}{r^3}$ (*d*) $\frac{1}{r}$

8. The S.I. unit of electric flux is

(*a*) Weber (*b*) Newton per coulomb

(*c*) Volt × meter (*d*) Joule per coulomb

9. Gauss's law is true only if force due to a charge varies as

(*a*) r^{-1} (*b*) r^{-2}

(*c*) r^{-3} (*d*) r^{-4}

10. An electric dipole is put in north-south direction in a sphere filled with water. Which statement is correct

(*a*) Electric flux is coming towards sphere

(*b*) Electric flux is coming out of sphere

(*c*) Electric flux entering into sphere and leaving the sphere are same

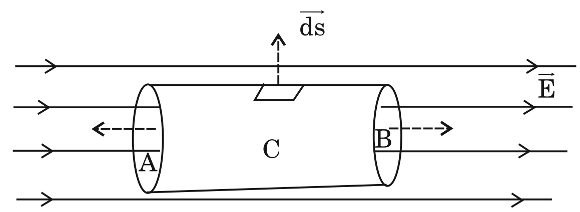
(*d*) Water does not permit electric flux to enter into sphere.

Answer Keys

1. (*d*)	**2.** (*a*)	**3.** (*b*)	**4.** (*c*)	**5.** (*a*)
6. (*c*)	**7.** (*d*)	**8.** (*c*)	**9.** (*b*)	**10.** (*c*)

Solutions

1. Flux through surface A $\phi_A = E \times \pi R^2$ and $\phi_B = E \times \pi R^2$.



Flux through curved surface

$C = \int \vec{E} \, . \, d\vec{s} = \int E \, ds \cos 90° = 0$

$\therefore$ Total flux through cylinder = $\phi_A + \phi_B + \phi_C = 0$ **[1]**

2. By Gauss's theorem,

Electric flux $(\phi) = \frac{q}{6\varepsilon_o}$ **[1]**

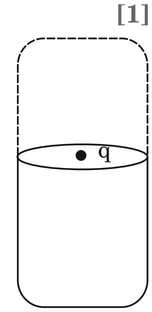
3. Total flux coming out from unit charge

$\phi = \vec{E} \, . \, d\vec{s} = \frac{1}{\varepsilon_o} \times 1 = \varepsilon_o^{-1}$ **[1]**

4. The total flux through the surface is zero. **[1]**

5. As there is no charge residing inside the cube, hence net flux is zero. **[1]**

6. To apply Gauss's theorem it is essential that charge should be placed inside a closed surface. So, imagine another similar cylindrical vessel above it as shown in figure (dotted).



$\therefore$ Required flux $\phi = \frac{q}{2\varepsilon_o}$

[1]

7. $E = \frac{\lambda}{2\pi\varepsilon_o r} \Rightarrow E \propto \frac{1}{r}$ **[1]**

8. S.I. unit of electric flux is

$\frac{N \times m^2}{C} = \frac{J \times m}{C}$ = volt × metre **[1]**

9. Gauss's law is true only if force due to a charge varies as r^{-2}. **[1]**

10. In electric dipole the flux coming out from positive charge is equal to the flux coming in at negative charge i.e. total charge on sphere = 0. From Gauss law, total flux passing through the sphere = 0. **[1]**