BEST SELLER

For **2024** Exam

OSWAAL BOOKS®

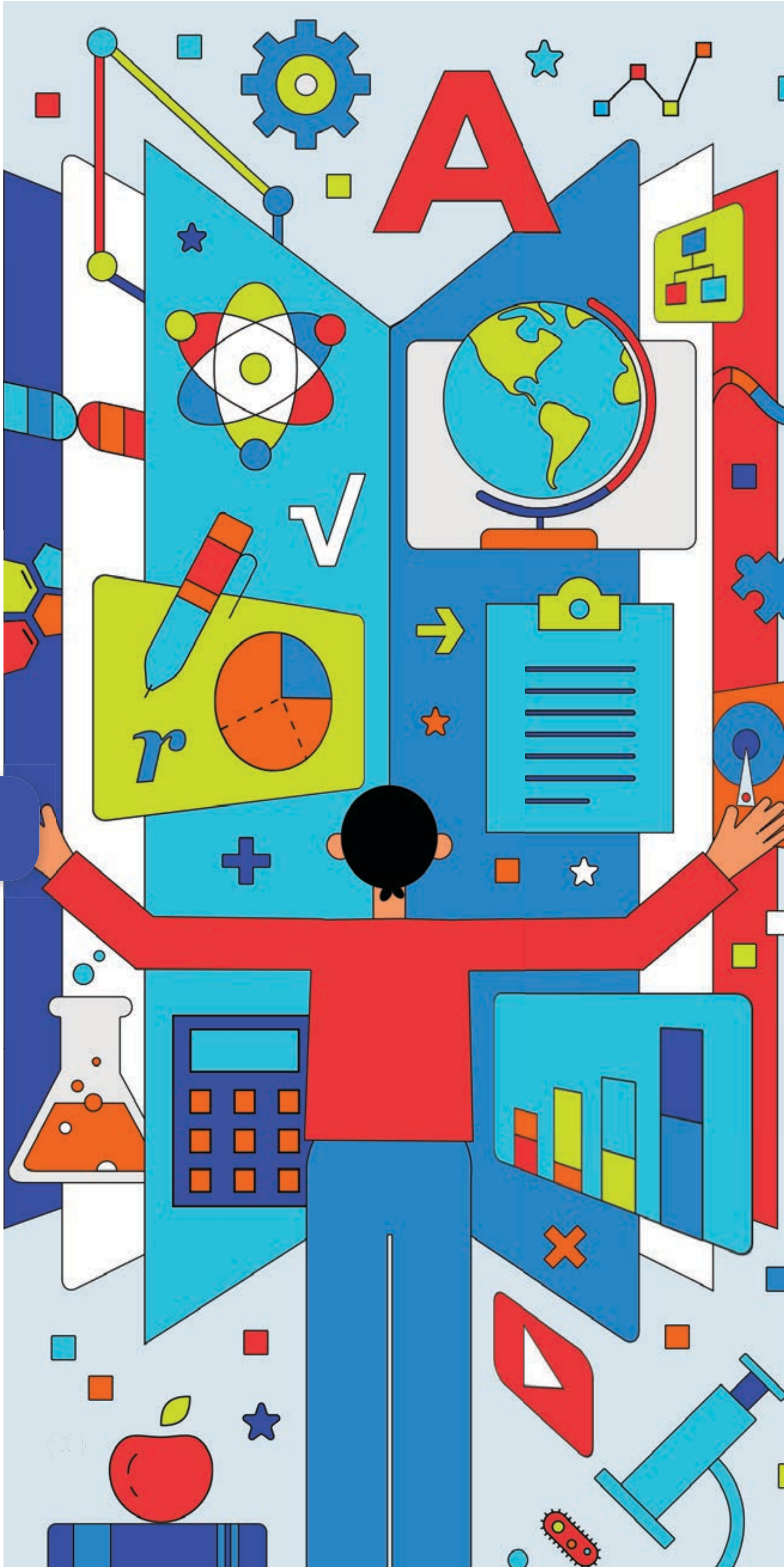
LEARNING MADE SIMPLE

CBSE

Chapterwise & Topicwise

SOLVED PAPERS CLASS 12 QUESTION BANK

PHYSICS



Get the #OswaalEdge

1. **100% Updated for 2023-24** with Latest Syllabus & Fully Solved Board Papers
2. **Crisp Revision** with Topic wise Revision Notes, Smart Mind Maps & Mnemonics
3. **Extensive Practice** with 3000+ Questions & Board Marking Scheme Answers
4. **Concept Clarity** with 1000+ Concepts & 50+ Concept Videos
5. **NEP 2020 Compliance** with Art Integration & Competency-based Questions

19th EDITION

YEAR 2023-24

ISBN "9789356349469"

SYLLABUS COVERED

CENTRAL BOARD OF SECONDARY EDUCATION DELHI

PUBLISHED BY

OSWAAL BOOKS & LEARNING PVT. LTD.

1/11, Sahitya Kunj, M.G. Road,
Agra - 282002, (UP) India

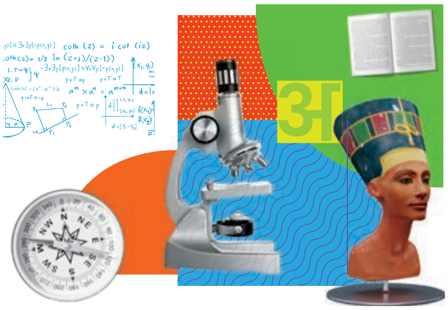
1/1, Cambourne Business Centre
Cambridge, Cambridgeshire
CB 236DP, United kingdom

0562-2857671

contact@oswaalbooks.com

www.OswaalBooks.com

Contents



- Latest CBSE Syllabus 6 - 12
- Sample Question Paper-2022-23 Fully Solved (Issued by Board dated 16th Sep. 2022) 17 - 33
- Solved Paper-2022 Term-II (Delhi & Outside Delhi Sets) 34 - 57
  (To download Solved paper for Term-I 2021-22 & Latest Topper's Answers 2020, scan the QR Code given on Page 57)
- Supplement : New Typology of Questions Introduced by CBSE for 2023-24 Examination 58 - 64

UNIT I : ELECTROSTATICS

1. Electric Charges and Fields 1 - 33
2. Electrostatic Potential and Capacitance 34 - 60
   - Self Assessment Paper-1 61 - 62

UNIT II : CURRENT ELECTRICITY

3. Current Electricity 63 - 82
   - Self Assessment Paper-2 83 - 85

UNIT III : MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

4. Moving Charges and Magnetism 86 - 112
5. Magnetism and Matter 113 - 124
   - Self Assessment Paper-3 125 - 127

UNIT IV : ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENTS

6. Electromagnetic Induction 128 - 150
7. Alternating Currents 151 - 185
   - Self Assessment Paper-4 186 - 188

UNIT V : ELECTROMAGNETIC WAVES

8. Electromagnetic Waves 189 - 205
   - Self Assessment Paper-5 206 - 207

UNIT VI : OPTICS

9. Ray Optics and Optical Instruments 208 - 237
10. Wave Optics 238 - 255
   - Self Assessment Paper-6 256 - 257

UNIT VII : DUAL NATURE OF RADIATION AND MATTER

11. Dual Nature of Radiation and Matter 258 - 284
   - Self Assessment Paper-7 285 - 287

UNIT VIII : ATOMS & NUCLEI

12. Atoms 288 - 311
13. Nuclei 312 - 324
   - Self Assessment Paper-8 325 - 326

UNIT IX : ELECTRONIC DEVICES

14. Semiconductor Electronics : Materials, Devices and Simple Circuits 327 - 350
   - Self Assessment Paper-9 351 - 353
   - Practice Paper-1 354 - 361
   - Practice Paper-2 362 - 368

How to use this Book

Chapter Navigation Tools

- **Syllabus** — Prescribed by CBSE
- **Topicwise & Conceptwise Segregation** — For Focused & Systematic Study
- **Revision Notes** — Chapter Summary Developed by Oswaal Experts
- **QR Codes** — For Concept Videos
- **Mind Maps** — For better retention of concepts
- **Keywords** — For quick recall of concepts
- **Fundamentals Facts** — To explore the endless World of Knowledge
- **Mnemonics** — To Memorise Better
- **Latest Typologies of Questions** — Objective SA/LA/ Case-based Questions, Picture based Questions
- **Previous Years' Board Papers** — To decode the paper pattern
- **Academically Important Questions** — To Look out for Highly Expected Questions for the upcoming exams
- **Practice Questions** — For Better Practice
- **Commonly Made Errors & Answering Tips** — To write perfect Answers
- **Topper's Answers** — To Learn to write your way to success
- **Reflections** — To Ask youself about your learnings
- **Self Assessment & Practice Papers** — For Chapterwise Assessment

What is on your wishlist for this Academic Year?

- Do better than the previous year
- Perfect every concept, every topic, and every question from the very beginning

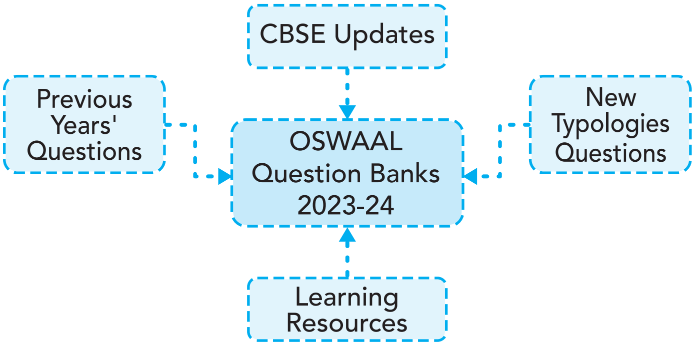
You said it, we heard it!

Practice means to perform, repeatedly in the face of all obstacles, some act of vision, of faith, of desire. Practice is a means of inviting the perfection desired.

-Martha Graham

As we usher into a brand-new Academic Year 2023-24, Oswaal Books, with its all-new Question Banks, empowers you to perfect your learning, consistently!

These Question Banks have been updated for 2023-24 with utmost care. They are a unique blend of all the **CBSE Board Updates, Previous Years' Questions,** and specially curated Questions as per the **Latest Typologies** along with best-in-class **Learning Resources**.



All these together will charge you with the much-needed confidence to face the boards and emerge champions. But what makes it so Unique?

1. **100% Updated** with Latest Syllabus & Fully Solved Board Papers
2. **Crisp Revision** with Topic wise Revision Notes, Smart Mind Maps & Mnemonics
3. **Extensive Practice** with 3000+ Questions & Board Marking Scheme Answers
4. **Concept Clarity** with 1000+concepts & 50 + Concept Videos
5. **NEP 2020 Compliance** with Art Integration and Competency -Based Questions

For those who are looking to ramp up their preparation and to 'PERFECT' every nuance of concepts studied, these Question Banks are a must in your Boards arsenal. This is the perfect time to start your exciting journey with these Question Banks and fill in learning gaps, throughout the year with utmost ease & confidence.

This Question Bank would not have been made possible without the valuable contributions of the esteemed members of the Oswaal Editorial Board-Authors, Editors, Subject matter experts, Proofreaders & DTP operators who worked day and night to bring this incredible book to you. We are also highly grateful to our dear students for all their valuable and impeccable inputs in the making of this one-of-a-kind exam preparation tool.

All the best Students!! Be the perfectionist that you are!

Team Oswaal Books

Syllabus

Latest Syllabus

PHYSICS (Code No. 042)

CLASS–XII (THEORY)

Time : 3 Hours **Max Marks 70**

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

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 fleld.

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).

Syllabus

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 polarization, 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 (no derivation, formulae only).

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, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, 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 rules, 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 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; Current loop as a magnetic dipole and its magnetic dipole moment, moving coil galvanometer its current sensitivity and conversion to ammeter and voltmeter.

Chapter–5 : Magnetism and Matter

Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only), magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only), torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only), magnetic field lines.

Magnetic properties of materials-Para-, dia- and ferro-magnetic substances with examples, Magnetization of materials, effect of temperature on magnetic properties.

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, Self and mutual induction.

Chapter–7 : Alternating Current

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

AC generator, Transformer.

Unit V : Electromagnetic Waves 04 Periods

Chapter–8 : Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea 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 optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction 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 (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only).

Syllabus

Unit VII : Dual Nature of Radiation and Matter **08 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.

Experimental study of photoelectric effect.

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 his orbit, of 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.

Practicals

Total Periods 60

The record to be submitted by the students at the time of their annual examination has to include :

- Record of at least 8 Experiments [with 4 from each section], to be performed by the students.
- Record of at least 6 Activities [with 3 each from section A and section B], to be performed by the students.
- The Report of the project carried out by the students.

Evaluation Scheme

Time: 3 hours **Max. Marks: 30**

Two experiments one from each section	7+7 Marks
Practical record [experiments and activities]	5 Marks
One activity from any section	3 Marks
Investigatory Project	3 Marks
Viva on experiments, activities and project	5 Marks
Total	**30 marks**

SECTION–A

Experiments :

1. To determine resistivity of two / three wires by plotting a graph for potential difference versus current.
2. To find resistance of a given wire / standard resistor using metre bridge.
3. To verify the laws of combination (series) of resistances using a metre bridge.

   OR

   To verify the laws of combination (parallel) of resistances using a metre bridge.
4. To determine resistance of a galvanometer by half-deflection method and to find its figure of merit.
5. To convert the given galvanometer (of known resistance and figure of merit) into a voltmeter of desired range and to verify the same.

   OR

   To convert the given galvanometer (of known resistance and figure of merit) into an ammeter of desired range and to verify the same.
6. To find the frequency of AC mains with a sonometer.

Activities

1. To measure the resistance and impedance of an inductor with or without iron core.
2. To measure resistance, voltage (AC/DC), current (AC) and check continuity of a given circuit using multimeter.
3. To assemble a household circuit comprising three bulbs, three (on/off) switches, a fuse and a power source.
4. To assemble the components of a given electrical circuit.
5. To study the variation in potential drop with length of a wire for a steady current.
6. To draw the diagram of a given open circuit comprising at least a battery, resistor/rheostat,

key, ammeter and voltmeter. Mark the components that are not connected in proper order and correct the circuit and also the circuit diagram.

SECTION–B

Experiments :

1. To find the value of v for different values of u in case of a concave mirror and to find the focal length.
2. To find the focal length of a convex mirror, using a convex lens.
3. To find the focal length of a convex lens by plotting graphs between u and v or between $1/u$ and $1/v$.
4. To find the focal length of a concave lens, using a convex lens.
5. To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and angle of deviation.
6. To determine refractive index of a glass slab using a travelling microscope.
7. To find refractive index of a liquid by using convex lens and plane mirror.
8. To find the refractive index of a liquid using a concave mirror and a plane mirror.
9. To draw the I-V characteristic curve for a p-n junction diode in forward and reverse bias.

Activities

1. To identify a diode, an LED, a resistor and a capacitor from a mixed collection of such items.
2. Use of multimeter to see the unidirectional flow of current in case of a diode and an LED and check whether a given electronic component (e.g., diode) is in working order.
3. To study effect of intensity of light (by varying distance of the source) on an LDR.
4. To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab.
5. To observe diffraction of light due to a thin slit.
6. To study the nature and size of the image formed by a (i) convex lens, or (ii) concave mirror, on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).
7. To obtain a lens combination with the specified focal length by using two lenses from the given set of lenses.

Suggested Investigatory Projects

1. To study various factors on which the internal resistance/EMF of a cell depends.
2. To study the variations in current flowing in a circuit containing an LDR because of a variation in
   (a) the power of the incandescent lamp, used to 'illuminate' the LDR (keeping all the lamps at a fixed distance).
   (b) the distance of a incandescent lamp (of fixed power) used to 'illuminate' the LDR.
3. To find the refractive indices of (a) water (b) oil (transparent) using a plane mirror, an equi convex lens (made from a glass of known refractive index) and an adjustable object needle.
4. To investigate the relation between the ratio of (i) output and input voltage and (ii) number of turns in the secondary coil and primary coil of a self-designed transformer.
5. To investigate the dependence of the angle of deviation on the angle of incidence using a hollow prism filled one by one, with different transparent fluids.
6. To estimate the charge induced on each one of the two identical styrofoam (or pith) balls suspended in a vertical plane by making use of Coulomb's law.
7. To study the factor on which the self-inductance of a coil depends by observing the effect of this coil, when put in series with a resistor/(bulb) in a circuit fed up by an A.C. source of adjustable frequency.
8. To study the earth's magnetic field using a compass needle -bar magnet by plotting magnetic field lines and tangent galvanometer.

Practical Examination for Visually Impaired Students of Class XI and XII Evaluation Scheme

Time: 2 hours **Max. Marks: 30**

Identification/Familiarity with the apparatus	5 marks
Written test (based on given/prescribed practicals)	10 marks
Practical Record	5 marks
Viva	10 marks
Total	**30 marks**

Syllabus

General Guidelines

- The practical examination will be of two-hour duration.
- A separate list of ten experiments is included here.
- The written examination in practicals for these students will be conducted at the time of practical examination of all other students.
- The written test will be of 30 minutes duration.
- The question paper given to the students should be legibly typed. It should contain a total of 15 practical skill based very short answer type questions. A student would be required to answer any 10 questions.
- A writer may be allowed to such students as per CBSE examination rules.
- All questions included in the question papers should be related to the listed practicals. Every question should require about two minutes to be answered.
- These students are also required to maintain a practical file. A student is expected to record at least five of the listed experiments as per the specific instructions for each subject. These practicals should be duly checked and signed by the internal examiner.
- The format of writing any experiment in the practical file should include aim, apparatus required, simple theory, procedure, related practical skills, precautions etc.
- Questions may be generated jointly by the external/internal examiners and used for assessment.
- The viva questions may include questions based on basic theory/principle/concept, apparatus/ materials/chemicals required, procedure, precautions, sources of error etc.

Class XII

A. Items for Identification/ familiarity with the apparatus for assessment in practicals (All experiments)

Meter scale, general shape of the voltmeter/ ammeter, battery/power supply, connecting wires, standard resistances, connecting wires, voltmeter/ammeter, meter bridge, screw gauge, jockey Galvanometer, Resistance Box, standard Resistance, connecting wires, Potentiometer, jockey, Galvanometer, Lechlanche cell, Daniell cell [simple distinction between the two vis-à-vis their outer (glass and copper) containers], rheostat connecting wires, Galvanometer, resistance box, Plug-in and tapping keys, connecting wires battery/power supply, Diode, Resistor (Wire-wound or carbon ones with two wires connected to two ends), capacitors (one or two types), Inductors, Simple electric/ electronic bell, battery/power supply, Plug-in and tapping keys, Convex lens, concave lens, convex mirror, concave mirror, Core/hollow wooden cylinder, insulated wire, ferromagnetic rod, Transformer core, insulated wire.

B. List of Practicals

1. To determine the resistance per cm of a given wire by plotting a graph between voltage and current.

2. To verify the laws of combination (series/ parallel combination) of resistances by Ohm's law.

3. To find the resistance of a given wire / standard resistor using a meter bridge.

4. To determine the resistance of a galvanometer by half deflection method.

5. To identify a resistor, capacitor, inductor and diode from a mixed collection of such items.

6. To observe the difference between
   (i) a convex lens and a concave lens
   (ii) a convex mirror and a concave mirror and to estimate the likely difference between the power of two given convex /concave lenses.

7. To design an inductor coil and to know the effect of
   (i) change in the number of turns
   (ii) Introduction of ferromagnetic material as its core material on the inductance of the coil.

8. To design a (i) step up (ii) step down transformer on a given core and know the relation between its input and output voltages.

Note : The above practicals may be carried out in an experiential manner rather than recording observations.

Prescribed Books:

1. Physics, Class XI, Part -I and II, Published by NCERT.
2. Physics, Class XI, Part -I and II, Published by NCERT.
3. Laboratory Manual of Physics for class XII Published by NCERT.
4. The list of other related books and manuals brought out by NCERT (consider multimedia also).

❑❑

Syllabus

QUESTION PAPER DESIGN

Theory (Class: XI/XII)

Maximum Marks: 70 **Duration: 3 hrs.**

S. No.	Typology of Questions	Total Marks	Approximate Percentage
1.	**Remembering :** Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers. **Understanding :** Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas	27	38%
2.	**Applying :** Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	22	32%
3.	**Analysing :** Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations **Evaluating :** Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria. **Creating :** Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.	21	30%
	Total Marks	**70**	**100%**
	Practical	**30**	
	Gross Total	**100**	

Note :

The above template is only a sample. Suitable internal variations may be made for generating similar templates keeping the overall weightage to different form of questions and typology of questions same.

❑❑

NEP Derived Learning Resources Prescribed by CBSE for Year 2023-24

Artificial Intelligence (AI)

Mode of Assessment

Elective Subject (Classes 8, 9 & 10)
+
Integrated with other subjects like: Mathematics, Science, Physics, Economics, Sociology, Languages from classes 9-12

Skills to be Developed

- Analysis & Critical Thinking
- Interaction and cooperation
- Innovativeness and initiative
- Vocational ethics
- Communication skills

Implications For Students

Students should opt for this curriculum to:

- Become future ready & become at par with their counterparts at a global level.
- Visualise jobs of the future and prepare for them.

Art Integration Learning (AIL)

For Activities Scan the Code

Mode of Assessment

Art-Integrated Projects as Subject Enrichment Activity

Skills to be Developed

- Art-based enquiry
- Investigation & Exploration
- Critical Thinking
- Creativity

Implications For Students

- At least one Art-Integrated Project in each subject shall be taken up by all students of classes I to XII.
- In a minimum one project work of students from classes I – XII, it is mandatory to integrate any art form of the paired State/UT, as defined under Ek Bharat Shrestha Bharat Programme.

Competency Based Assessment (CBA)

Mode of Assessment

Competency based Questions makes the students understand and apply what they learn in real life situations

Skills to be Developed

- Analysis
- Critical Thinking
- Conceptual Clarity

Implications For Students

40% of the Questions will be asked in the form of:

- MCQs, True/False, Matching Types & Cloze/Gap filling Questions
- Stand Alone Short & Long Answer Questions
- Linked Questions (Source & Case-based Questions)

Hear it from our Happy Readers!

Good Book!
According to me, it is a brilliant book for CBSE students. It prepares students really well for the upcoming 2022-23 exams. Thankfully, Maths is no more a worry. Must buy!

Priyanka

All concepts have been explained with examples which simplifies the understanding of the concepts and makes practice very easy. It is worth the money.

Siddharth Gupta

This question bank is the best. It helps me to improve my skills and knowledge. My teacher recommended this book and it helps me a lot to increase my grades.

Avishake Kar

Great Book
This is really a nice book. It helps my son a lot in studies. Many of his friends recommended Oswaal Question Bank to him, so we bought it. It is good and helpful.

Amrik Singh Gujral

Very good book for 12th class preparation. This book contains Previous Years' Questions which is very helpful in exams. It also includes VSAQs, SAQs and one mark questions for exam practice. One must read this book to achieve high percentile in exams.

Priya J.

Outstanding Book!
It is really an outstanding book.
With this question bank, we are able to get 90+ % in CBSE Board.
It is really helpful.

Om Lingyat

I would definitely recommend this book for 12th Boards. It is covering the latest and updated syllabus with great-quality of questions.

Aryan

Fantastic book!
Along with Previous Years Questions & Board Marking scheme answers this book also includes new typology of questions: MCQs, Assertion-Reason, VSA ,SA , LA & case-based questions. Fantastic to study!!

Sumit

UNIT – I: ELECTROSTATICS

CHAPTER

1

ELECTRIC CHARGES AND FIELDS

Syllabus

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).

In this chapter you will study

Electric charge, 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).

List of Topics

Topic-1: Electric Field and Dipole **Page No. 1**

Topic-2 : Gauss's Theorem and its Applications **Page No. 15**

Topic-1 Electric Field and Dipole

Concepts Covered *• Electric charge, • Electrostatic charge, • Properties of electric charge, • Coulomb's law, • Principle of superposition, • Electric field, • Electric field lines, • Electric dipole, • Torque on a dipole, • Electric dipole moment, • Electric field due to dipole*

Revision Notes

Electric Charge

Scan to know more about this topic

Electric Charges & Field

- Electric charge is the property of a matter due to which, it experiences a force when placed in an electromagnetic field.
- Point charge is an accumulation of the electric charges at a point, without spatial extent.
- Electrons are the smallest and lightest fundamental particles in an atom having negative charge as these are surrounded by invisible field known as electrostatic field.
- Protons are comparatively larger and heavier than electrons with positive electrical charge which is similar in strength as electrostatic field in an electron with opposite polarity.
- Two electrons or two protons will tend to repel each other as they carry like charges, negative and positive respectively.
- The electron and proton will get attracted towards each other due to their unlike charges.
- The charge present on the electron is equal and opposite to charge on the proton.

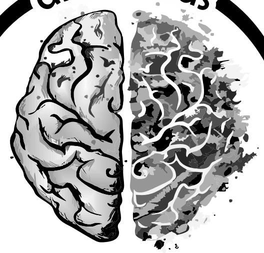
  Charge on a proton $= + 1.6 \times 10^{-19}$ C

  and, charge on an electron $= - 1.6 \times 10^{-19}$ C

Scan to know more about this topic

Electric Field

Electric Charges and Fields



Trace the Mind Map
- First Level
- Second Level
- Third Level

Electric charges

Electric field lines
- Always normal to conducting surface
- Lines originating from +ve charge
- Terminating at –ve charge
- Never intersect each other
- Do not form closed loop
- Are imaginary lines.

Quantization of charge

All charges must be a multiple of charge (e)
$Q = ne$
Where n is an integer

- Two kinds of charges + ve and – ve
- S.I. unit is Coulomb (C)
  1 C = charge flowing through a wire in 1s if current in it is 1A
- $e = 1.602 \times 10^{-19}$C.

Conservation of charge

It is not possible to create or destroy net charge of an isolated system.

Electric Field

Electric field due to point charge

$\vec{E} = \frac{\vec{F}}{q} = k' \frac{Q}{r^2}$ (N/C)

$\because$ unit = N/C

- Due to discrete distribution of charges
  $\vec{E} = \sum_{i}^{n} \vec{E}_i$
- Due to continuous distribution of charge
  $\vec{E} = k' \int \frac{dQ}{r^3} \vec{r}$
  $|\vec{E}| = k' \int \frac{dQ}{r^2}$

Coulomb's Law

- Force between two charged particles
  $\vec{F} = \frac{k\, q_1\, q_2 \vec{r}}{r^3} = \frac{k q_1\, q_2 \hat{r}}{r^2}$, force is attractive when q_1 and q_2 are of opposite sign, otherwise repulsive
  $|\vec{F}| = \frac{k\, q_1\, q_2}{r^2}$
  $k = \frac{1}{4\pi\varepsilon_0} \approx 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$
- Force between multiple charges
  $\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \ldots\ldots = \frac{q_1}{4\pi\varepsilon_0} \sum_{i=2}^{n} \frac{q_i}{r_{1i}^2} \hat{r}_{1i}$

where $\hat{r}$ is the unit vector along charge particle under consideration
$\hat{r}_{1i}$ = distance between Ist and i^{th} particle

"The electric force with which two charges attract or repel one another are not affected by the presence of other charges". It is known as Superposition Principle.

In 1985, Charles Augustin de Coulomb gave Coulomb's law

Electric Dipole moment, $\vec{p} = q\vec{d}$

- Electric field due to dipole at axial position,
  $\vec{E} = \frac{1}{4\pi\,\varepsilon_0}\left(\frac{2p}{r^3}\right)\hat{r}$
- Electric field due to dipole at an equatorial position,
  $|E| = \frac{1}{4\pi\,\varepsilon_0}\left(\frac{p}{r^3}\right)$
- Torque on an electric dipole placed in an electric field $(\vec{E})$
  $\vec{\tau} = \vec{p} \times \vec{E} = p\, E \sin\theta$

Gauss' Theorem

$\oint \vec{E}.\vec{ds} = q_{in}/\varepsilon_0 = \phi$

where, q_{in} = net charge enclosed

ϕ = flux through a closed surface

Applications of Gauss' Law

- Electric Field due to linear charge distribution
  $E = \lambda/2\pi\, \varepsilon_0 r$,
  λ = linear charge density
- Electric Field due to a plane sheet of charge
  $E = \sigma/2\varepsilon_0$,
  σ = charge per unit area
- Electric Field due to a charged conducting plate
  $E = \sigma/\varepsilon_0$,
  σ = charge per unit area
- Electric Field inside a conductor = 0

Electric field due to uniformly charged spherical shell at :
- Outside point,
  $E = Q/4\pi\varepsilon_0 r^2$
- Internal point,
  $E = 0$
- The surface,
  $E = Q/4\pi\varepsilon_0 R^2$

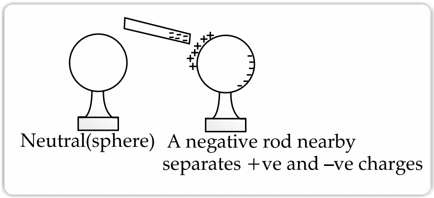
Electric flux

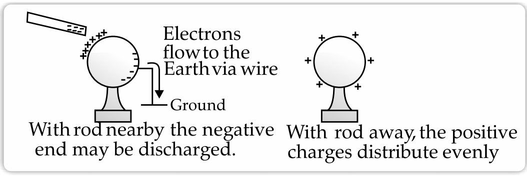
$\Delta\phi = \vec{E}.\Delta\vec{S}$, $\Delta\vec{S}$ = area vector
$\vec{E}$ = electric field

$\phi = \int \vec{E}.\vec{ds}$

Electrostatic Charge

- Electrostatic charge means the charge is at rest.
- Electrostatic charge is a fundamental physical quantity like length, mass and time.





- Charge on a body is expressed as $q = \pm ne$
- The magnitude of charge is independent of the speed of the particle.
- Based on the flow of charge across them, materials are classified as:
  - **Conductors:** Allow **electric charge** to flow freely, e.g., metals.
  - **Semi-conductors:** Behave as the conductor or insulator depending on the number of free electrons and holes availability. e.g., silicon.
  - **Insulators:** Do not allow electric charge to flow, e.g., rubber, wood, plastic, etc.
- **Net charge on a body is given by:**
  - **Charging by <u>friction</u>:** Charging insulators
  - **Charging by conduction:** Charging metals and other conductors
  - **Charging by induction:** Wireless charging

Charging by Rubbing

- On rubbing a glass rod and silk cloth piece together, glass rod gets positively charged whereas silk cloth gets negatively charged.
- If a plastic rod is rubbed with wool, it becomes negatively charged.

Charging by Induction

- Charging by induction means charging without contact.
- If a negatively charged rod is brought near **neutral metal** with insulator mounting, it repels free electrons and attracts positive charges on metal.

Key Words

<u>Electric Charge:</u> Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field.

<u>Friction:</u> It is the opposing force.

<u>Neutral metal:</u> Metal having no net charge.

- If far end is connected to Earth by a wire, electrons will flow towards ground while positive charges are kept captive by the rod.
- When the rod is removed, the captive positive charge is distributed evenly.

Properties of Electric Charge

Addition of charges

- If a system contains three point charges q_1, q_2, and q_3, then the total charge of the system will be the algebraic addition of q_1, q_2 and q_3, i.e., charges will add up.

$$q = q_1 + q_2 + q_3$$

Conservation of charges

- Electric charge is always conserved. It is the sum of positive and negative charges present in an isolated system, which remains constant.
- Charge can neither be created nor destroyed in the process, but only exists in positive-negative pairs.

Quantization of charges

Scan to know more about this topic

Electric Dipole

- Electric charge is always quantized i.e., electric charge is always an integral multiple of charge 'e'.
- Net charge q_{net} of an object having N_e electrons, N_p protons and N_n neutrons is:

$q_{net} = -eN_e + eN_p + 0N_n = e(N_p - N_e) = \pm ne$

- Neutron (n): $m = 1.675 \times 10^{-27}$ kg; $q = 0$
- Proton (p): $m = 1.673 \times 10^{-27}$ kg; $q = +1.6 \times 10^{-19}$ C
- Electron (e): $m = 9.11 \times 10^{-31}$ kg; $q = -1.6 \times 10^{-19}$ C

Coulomb's Law

- The force of attraction or repulsion between two point charges q_1 and q_2 separated by a distance r is directly proportional to product of magnitude of charges and inversely proportional to square of the distance between charges, written as:

$$F = k\frac{|q_1||q_2|}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

where,

F = Force of attraction/repulsion between charges q_1 and q_2.

q_1, q_2= Magnitudes of charge 1 and charge 2 respectively

r = Distance between charges q_1, q_2

k = Constant whose value depends on medium where charges are kept, $k = \dfrac{1}{4\pi\varepsilon_0}$

As $\varepsilon = K'\varepsilon_0$, $k = \dfrac{1}{4\pi K'\varepsilon_0}$

ε_0 = Permittivity of vacuum or free space $= 8.854 \times 10^{-12}$ F/m

K' = Relative permittivity of medium or dielectric constant.

- For vacuum, relative permittivity, $K' = 1$,
- As $\varepsilon = K'\varepsilon_0$, therefore the force of attraction/repulsion between two electric charges q_1, q_2 placed in the vacuum and medium will be:

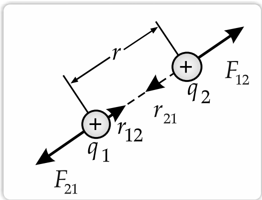
$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_2}{r^2} \text{ (vacuum) and}$$

$$F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\cdot\frac{q_1 q_2}{r^2} \text{ (medium)}$$

- The unit coulomb (C) is derived from the SI unit ampere (A) of the electric current.
- Current is the rate at which charge moves past a point or through a region, $i = \frac{dq}{dt}$, hence 1 C=(1 A) × (1 s).
- The vector form of Coulomb force with $\hat{r}_{12}$ = unit vector from q_1 to q_2 is given as:

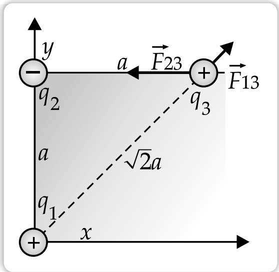
$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{r}_{12} \text{ and } \vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21}$$

$$\Rightarrow \vec{F}_{21} = -\vec{F}_{12}$$



Principle of Superposition

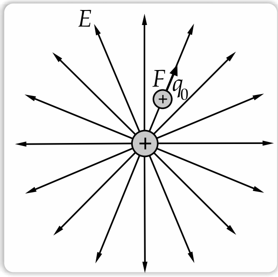
- The force on any charge due to other charges at rest is the vector sum of all the forces on that charge due to the other charges, taken one at a time.
- The individual forces are unaffected due to presence of other charges.
- Force exerted by q_1 on q_3 = $\vec{F}_{13}$
- Force exerted by q_2 on q_3 = $\vec{F}_{23}$



- Net force exerted on q_3 is vector sum of $\vec{F}_{13}$ and $\vec{F}_{23}$

Electric field

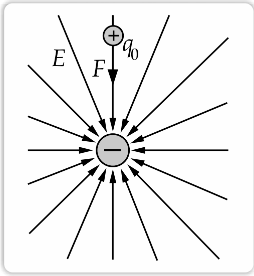
- The space around a charge up to which its electric force can be experienced is called electric field.



- If a test charge q_0 is placed at a point where electric field is E, then force on the test charge is $F = q_0 E$
- The electric field strength due to a point source charge 'q' at an observation point 'A' at a distance 'r' from the source charge is given by:

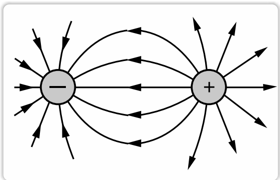
$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^3} \vec{r} \text{ or } E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

- The unit of electric field is N/C.
- Electric field inside the cavity of a charged conductor is zero.
- If a charged/uncharged conductor is placed in an external field, the field in the conductor is zero.
- In the case of a charged conductor, electric field is independent of the shape of the conductor.



Electric field lines

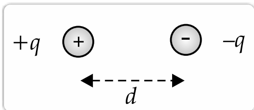
- Electric field lines are imaginary lines that originates from the positive charge and terminates at negative charge.
- Direction of electric field lines around positive charge is imagined by positive test charge q_0 located around source charge.



- Electric field has the same direction as force on the positive test charge.
- Electric field lines linked with negative charge are directed inward described by force on positive test charge q_0.
- The electric field lines never intersect each other.
- Strength of electric field is encoded in density of field lines.

Electric Dipole

- The system formed by two equal and opposite charges separated by a small distance is called an electric dipole.
- The electric field exists due to a dipole.



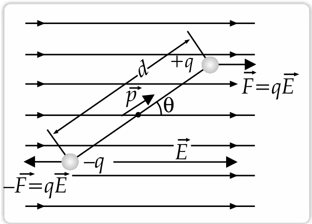
- The force on a dipole in a uniform electric field is zero in both stable as well as unstable equilibrium.
- The potential energy of a dipole in an uniform electric field is minimum for a stable equilibrium and maximum for an unstable equilibrium.

Torque on a dipole

- In a dipole, when the net force on dipole due to electric field is zero and center of mass of dipole remains fixed, the forces on charged ends produce net torque τ about its center of mass.

$$\tau = F\,d\sin\theta = qE\,d\sin\theta = pE\sin\theta$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$

- $\boxed{d = 2a}$



- If $\theta = 0^\circ$ or 360°, dipole exists in stable equilibrium state.
- If $\theta = 180^\circ$, dipole exists in an unstable equilibrium state.

- In the uniform electric field, the dipole experiences torque, the net force on dipole is zero.
- In the uniform electric field, the dipole experiences a rotatory motion.
- In the non-uniform electric field, dipole experiences torque and net force.
- In the non-uniform electric field, dipole experiences rotatory and translatory motion.
  - The torque aligns the dipole with the electric field and it becomes zero.
  - The direction of the torque is normal to the plane going inward.

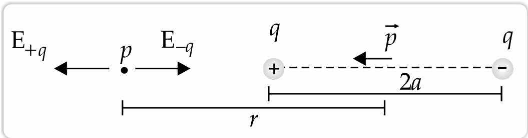
Electric Dipole Moment

- Dipole moment is a vector quantity whose unit is coulomb-metre (Cm).
- Dipole moment vector of electric dipole is $\vec{p} = \vec{q}\times 2a$ between pair of charges q, $-q$, along the line, separated by distance $2a$.

Electric field due to a dipole

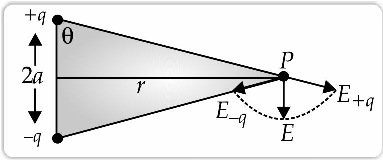
- For point P at distance r from the centre of the dipole on charge q, for $r >> a$, total field at point P is

$$E = \frac{4qa}{4\pi\varepsilon_0 r^3}$$
$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3} \text{ (if } a << r)$$



- For point P on the equatorial plane due to charges $+q$ and $-q$, electric field of dipole at a large distance,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$



OBJECTIVE TYPE QUESTIONS (1 mark each)

A Multiple Choice Questions

Q. 1. 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 charge of object Z? U [CBSE Term I 2021]

(A) positively charged only
(B) negatively charged only
(C) neutral or positively charged
(D) neutral or negatively charged

Ans. Option (C) is correct.

Explanation: X is negatively charged. Since it is repelled by Y, this means Y is also negatively charged. Now, if Z is neutral or positively charged then it will be attracted by Y.

Q. 2. In an experiment three microscopic latex spheres are spread 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 [CBSE Term I 2021]

(A) +5e, –4e, +5e **(B)** +6e, +6e, –7e
(C) –4e, +3.5e, +5.5e **(D)** +5e, –8e, +7e

Ans. Option (B) is correct.

Explanation: When three spheres are brought in contact the net charge will be –3e + 3e + 5e = 5e
When separated this 5e charge will be distributed.
In option (A), Total charge is 6e. So, this option is not correct.
In option (B), Total charge is 5e. So, this option is correct.
In option (C), Total charge is 5e. But option have charges in fraction which violates quantization of charge principle. Hence this option is not correct.
In option (D), Total charge is 4e. Hence this option is not correct.
So, (B) is the correct option.

Q. 3. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes: E [CBSE Term I 2021]

(A) –0.80 C (B) +0.80 C
(C) +1.80 C (D) +0.20 C

Ans. Option (D) is correct.

Explanation: Charge on 1 electron = – 1.6×10^{-19}C

So, Charge on 5×10^{18} electrons

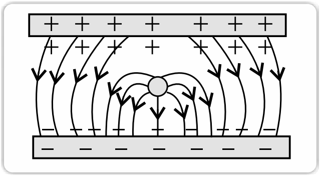
$= -5 \times 10^{18} \times 1.6 \times 10^{-19}$ C = – 0.8 C [$\because$ q = ne]

Already existing charge = 1 C

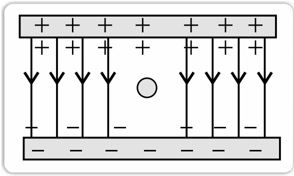
So, net charge after electron gain = 1 + (– 0.8) = 0.2

Q. 4. Which of the diagrams correctly represents the electric field between two charged plates if a neutral conductor is placed in between the plates? Ap [CBSE Term I 2021]

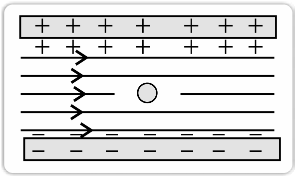
(A)



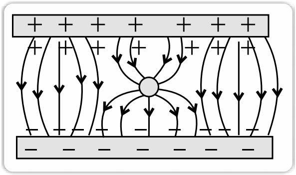
(B)



(C)

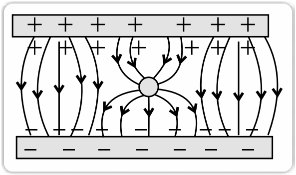


(D)



Ans. Option (D) is correct.

Explanation:



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 shown in the diagram.

Q. 5. 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 E [CBSE Term I 2021]

(A) $\frac{E}{4}$ (B) 0 (C) $2E$ (D) $4E$

Ans. Option (C) is correct.

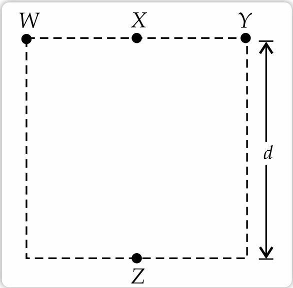
Explanation: Electric field due to the point charge

$$= E = \frac{K \times 2q}{r^2}$$

Electric field due to the spherical shell

$$= E' = \frac{K \times q}{(r/2)^2} = 2E$$

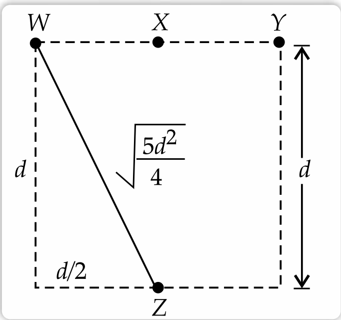
Q. 6. Four objects W, X, Y and Z, each with charge $+q$ are held fixed at four points of a square of side d as shown in the figure. Objects X and Z are on the midpoints of the sides of the square. The electrostatic force exerted by object W on object X is F. Then the magnitude of the force exerted by object W on Z is A [CBSE Term I 2021]



(A) $\frac{F}{7}$ (B) $\frac{F}{5}$ (C) $\frac{F}{3}$ (D) $\frac{F}{2}$

Ans. Option (B) is correct.

Explanation: Force on X by W is $F = \frac{kq^2}{(d/2)^2} = \frac{4kq^2}{d^2}$



$$WZ = \sqrt{d^2 + (d/2)^2}$$

$$= \sqrt{\frac{5d^2}{4}}$$

Force on Z by W is $F' = \frac{kq^2}{\frac{5d^2}{4}}$

$$= \frac{4kq^2}{5d^2}$$

$$= \frac{F}{5}$$

Q. 7. Plastic rod rubbed with fur and glass rod rubbed with silk U

(A) repel each other
(B) mix up with each other
(C) attract each other
(D) None of the above

Ans. Option (C) is correct.

Explanation: Rubbing a rod with certain materials will cause the rod to become charged. A plastic rod when rubbed with fur becomes negatively charged and a glass rod when rubbed with silk becomes positively charged.

Q. 8. Electric charge between two bodies can be produced by: U

(A) sticking **(B)** rubbing
(C) oiling **(D)** passing AC current

Q. 9. Electric charges under the action of electric forces are called: U

(A) electrostatic **(B)** electric flux
(C) electric field **(D)** electric field lines

Ans. Option (A) is correct.

Explanation: Electrostatic charges are the charges under electric forces.

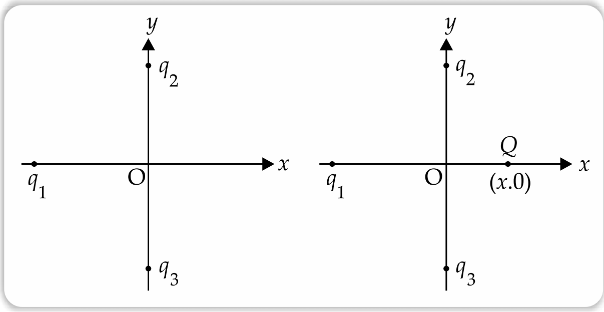
Q. 10. Law stating that "force is directly proportional to product of charges and inversely proportional to square of the separation between them" is called U

(A) Newton's law. **(B)** Coulomb's law
(C) Gauss's law. **(D)** Ohm's law

Ans. Option (B) is correct.

Explanation: Coulomb's law states that: The magnitude of the electrostatic force of attraction or repulsion between two-point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distances between them.

Q. 11. In the given figure, two positive charges q_2 and q_3 fixed along the y-axis, exert a net electric force in the + x direction on a charge q_1 fixed along the x-direction. If a positive charge Q is added at (x, 0), the force on q_1 A



(A) shall increase along the positive x-axis.
(B) shall decrease along the positive x-axis.
(C) shall point along the negative x-axis.
(D) shall increase but the direction changes because of the intersection of Q with q_2 and q_3.

Ans. Option (A) is correct.

Explanation: Net force on charge q_1, by other charges q_2 and q_3 is along the + x-direction, so nature of force between q_1 and q_2 and q_1 and q_3 is attractive. This is possible when charge q_1 is negative. Now, if a positive charge Q is placed at (x, 0), then, the force on q_1 will increase. The direction will be along positive x-axis.

Q. 12. The magnitude of electric force, F is: U

(A) directly proportional to the product of both charges.
(B) directly proportional to the distance between both charges.
(C) directly proportional to the square of the distance between both charges.
(D) constant.

Q. 13. A body is negatively charged means: U

(A) It has only negative charges.
(B) Positive charges have been neutralized by negative charges.
(C) The quantity of negative charge present is more than the quantity of positive charge present.
(D) The positive are displaced from their original positions.

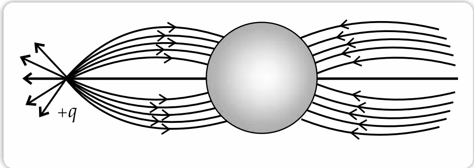
Q. 14. When a body is charged by conduction, its mass U

(A) remains same. **(B)** increases.
(C) decreases. **(D)** increase or decrease.

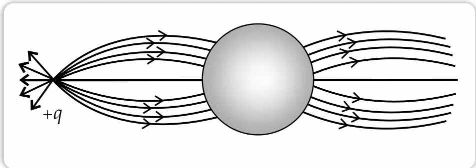
Ans. Option (D) is correct.

Q. 15. A point positive charge is brought near an isolated conducting sphere in Figure. The electric field is best given by: E

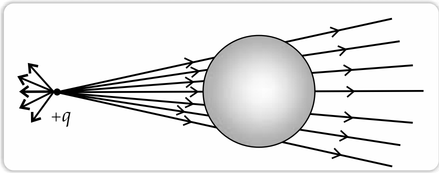
(i)



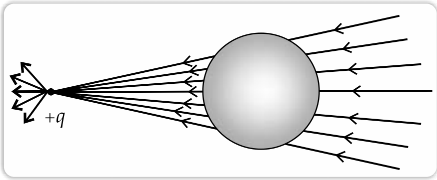
(ii)



(iii)



(iv)



These questions are for practice and their solutions are available at the end of the chapter.

(A) Fig (i) **(B)** Fig (iii)

(C) Fig (ii) **(D)** Fig (iv)

Ans. Option (C) is correct.

Explanation: When a point positive charge is brought near an isolated conducting sphere, then there develops some negative charge on left side of the sphere and an equal positive charge on the right side of the sphere. Electric lines of force emanating from the point positive charge end normally on the left side of the sphere. And due to positive charge on the right side of the sphere, the electric lines of force emanate normally from the right side. So, the electric field is best given by Fig (ii).

Q. 16. A point charge +*q*, is placed at a distance *d* from an isolated conducting plane. The field at a point P on the other side of the plane is: [A]

(A) directed perpendicular to the plane and away from the plane.

(B) directed perpendicular to the plane but towards the plane.

(C) directed radially away from the point charge.

(D) directed radially towards the point charge.

Ans. Option (A) is correct.

Explanation: When you place a positive charge near a conducting plane, then electric field lines from positive charges will enter into the conducting plane (from the side where positive charge is kept) and emerge from opposite side of the plane.

In both cases, the direction of electric field lines will always be perpendicular to the surface of the plane.

Q. 17. A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed: [U]

(A) perpendicular to the diameter.

(B) parallel to the diameter.

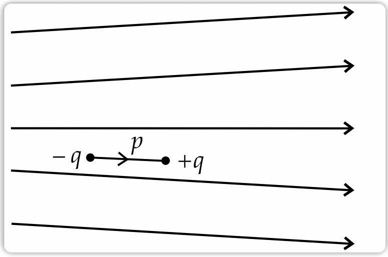
(C) at an angle tilted towards the diameter.

(D) at an angle tilted away from the diameter.

Ans. Option (A) is correct.

Explanation: As the side or diameter of hemisphere is plane surface, and whole hemisphere is charged with positive charge so, the electric field line of forces emerging outward will be perpendicular to the plane surface or diameter.

Q. 18. The Figure shows electric field lines in which an electric dipole *p* is placed as shown. Which of the following statement is correct? [Ap]



(A) The dipole will not experience any force.

(B) The dipole will experience a force towards the right.

(C) The dipole will experience a force towards the left.

(D) The dipole will experience a force upwards.

Ans. Option (C) is correct.

Explanation: We know electric field emerges radially outward from positive point charge.

In the figure given above, space between field lines is increasing (or density of electric field line is decreasing). In other words, the electric force is decreasing while moving from left to right.

Thus, the force on charge $-q$ is greater than the force on charge $+q$ and in turn, dipole will experience a force towards left direction.

B Assertion & Reason

Directions: In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

(A) Both Assertion (A) and Reason (R) are true, and Reason (R) is the correct explanation of Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Q. 1. Assertion (A): In a non-uniform electric field, a dipole will have translatory as well as rotatory motion.

Reason (R): In a non-uniform electric field, a dipole experiences a force as well as torque. [A]

Ans. Option (A) is correct.

Explanation: When an electric dipole is placed in a uniform electric field at an angle θ with the field, the dipole experiences a torque.

The torque produced by two parallel forces qE acting as couple $= \tau = q\text{E}\,(2l \sin\theta)$

In case of non-uniform field, force acting on both the ends of the dipole will not be equal. So, there will be a combination of couple and a net force. In this way, dipole will have both rotational as well as linear motion.

So, both assertion and reason are true. Reason also explains the assertion.

Q. 2. Assertion (A): Electric lines of force cross each other.

Reason (R): The resultant electric field at a point is the superposition of the electric fields at that point. [U]

Q. 3. Assertion (A): When bodies are charged through friction, there is the transfer of charge from one body to another. No charge is created or destroyed.

Reason (R): This is according to the law of conservation of electric charge. [A]

Ans. Option (A) is correct.

These questions are for practice and their solutions are available at the end of the chapter.

Explanation: When two bodies are rubbed, electrons move from one body to another. The body which loses electrons becomes positively charged. The body which receives the electron becomes negatively charged. So, the assertion is true.

Law of conservation of electric charge states that electric charge can neither be created nor destroyed. In a closed system, the amount of charge remains same. Hence the reason is also true and properly explains the assertion.

Q. 4. Assertion (A): If two spherical conductors of different radii have the same surface charge densities, then their electric field intensities will be equal.

Reason (R): Surface charge density = $\frac{\text{Total charge}}{\text{area}}$ E

Ans. Option (B) is correct.

Explanation: If σ be the surface charge density of the two spheres of radius r and R, then electric fields for the two spheres are respectively:

$$E_1 = \frac{K4\pi r^2\sigma}{r^2} = K4\pi\sigma$$

$$E_2 = \frac{K4\pi R^2\sigma}{R^2} = K4\pi\sigma$$

So, electric field intensities are equal. The assertion is true.

Surface charged density is charge per unit area = Total charge/area.

So, reason is also true.

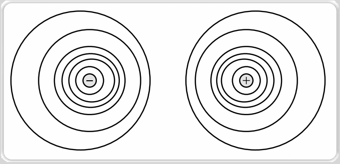
But the reason does not explain the assertion.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (1 mark each)

Q. 1. Draw the equipotential surfaces for an electric dipole. A I U **[CBSE Delhi Outside Set 1 2019]**

Ans.



1

(Even if a student mentions or draws equatorial plane, award 1 mark.)

[CBSE Marking Scheme, 2019]

Q. 2. Does the charge given to a metallic sphere depend on whether it is hollow or solid ? Give reason for your answer. A I U **[CBSE Delhi Set 1 2017]**

Ans. No. ½

Because the charge resides only on the surface of the conductor. ½

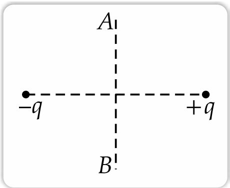
[CBSE Marking Scheme, 2017]

Q. 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 ? A

[CBSE Delhi Set 1 2016]

Ans. Positive. **[CBSE Marking Scheme, 2016] 1**

Q. 4. A charge 'q' is moved form a point A above a dipole of dipole moment 'p' to a point B below the dipole in the equatorial plane without acceleration. Find the work done in the process.



A **[CBSE Delhi Outside Set 1 2016]**

Ans. No work is done.

$W = qV_{AB} = q \times 0 = 0$ **1**

[CBSE Marking Scheme, 2016]

Q. 5. A plastic rod and a glass rod are rubbed with fur and silk respectively. What will happen if they are brought close to each other ? U

Ans. They will attract to each other.

[*Explanation:* If a plastic rod is rubbed with fur, it becomes negatively charged. If glass rod is rubbed with silk, it becomes positively charged. Since they are being oppositely charged, they will be attracted.] **1**

Q. 6. What is the name of the electrical force acting between two charges at rest ? U

Ans. Electrostatic force.

[Coulomb force acts between two charges at rest. Coulomb force is also known as electrostatic force since the force is acting between two static charges.] **1**

Q. 7. Name the law which states "force is directly proportional to the product of charges and inversely proportional to the square of the separation between them" ? U

Ans. Coulomb's law. **1**

Q. 8. Do electrostatic field lines form closed loops for point charges ? U

Ans. No. Electrostatic field lines never form closed loops for point charges. **1**

Q. 9. If E_1 and E_2 be the electric field strength of a short dipole on its axial line and on its equatorial line respectively, then what is the relation between E_1 and E_2 ? U

Ans. $E_1 = 2E_2$ **1**

[Explanation: Electric field at a point on equatorial line of a dipole is Kp/r^3 and that on axial line is $2Kp/r^3$.]

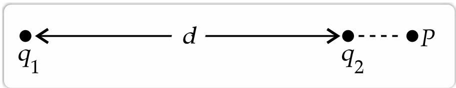
Commonly Made Error

- Students sometimes get confused and cannot remember the correct relation between electric field at a point on the equatorial line of a dipole and that on axial line.

Answering Tip

- Remember that the equatorial line is the perpendicular line at a point half-way of a dipole. So, the electric field at a point on the equatorial line will be half of the electric field at a point on the axial line.

Q. 10. Two point charges 'q_1' and 'q_2' are placed at a distance 'd' apart as shown in the figure. The electric field intensity is zero at a point 'P' on the line joining them as shown. Write two conclusions that you can draw from this. A I U



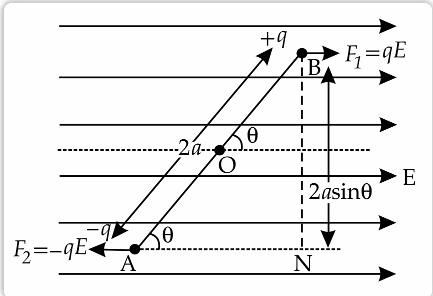
Ans. (i) The two point charges (q_1 and q_2) should be of opposite nature. ½

(ii) Magnitude of charge q_1 must be greater than that of charge q_2. ½

Short Answer Type Questions-I (2 marks each)

Q. 1. Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium. A **[CBSE Delhi Set 2020]**

Ans. An electric dipole AB consisting of charge $+q$ and $-q$ and of length $2a$ is placed in uniform electric field E making an angle θ with the direction of electric field.



Force acting on $-q$ is $-qE$

Force acting on $+q$ is qE

These two forces are equal and opposite to each other. Hence, a torque on the dipole is developed.

Torque = Force × perpendicular distance between the forces

Or, $\tau = qE \times 2a\sin\theta$

Or, $\tau = (q \times 2a)E\sin\theta$

∴ $\tau = pE\sin\theta$ (where p is dipole moment)

The dipole will attain stable equilibrium when it will be oriented along the direction of the electric field. **1**

Q. 2. Write an expression for the work done on an electric dipole with a dipole moment of p in a uniform electric field E to move it from a stable to an unstable equilibrium state. E

Ans. The torque on a dipole is given by the formula

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

Integrate the work done from θ_1 to θ_2 to find the work done,

$$W = \int_{\theta_1}^{\theta_2} pE\sin\theta$$

$$= pE(\cos\theta_1 - \cos\theta_2)$$ **1**

According to the question $\theta_1 = 0°$ & $\theta_2 = 180°$

On Substituting the values, in above

$$W = pE(\cos 0° - \cos 180°)$$

$$= pE(1-(-1))$$

$$= 2pE$$

Therefore, the equation of work done is $W = 2pE$. **1**

Q. 3. What is the force between two tiny charged spheres positioned 30 cm apart in air with charges of 2×10^{-7} C and 3×10^{-7} C? E

Ans. The magnitude of the repulsive force is 6×10^{-3} N

The charge on the first and second sphere are $q_1 = 2 \times 10^{-7}$ C and $q_2 = 3 \times 10^{-7}$ C respectively.

The separation between the spheres is of 30 cm or $r = 0.3$ m.

The connection, gives the electrostatic force between the spheres is $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$.

The value of is $\dfrac{1}{4\pi\varepsilon_0}$ is 9×10^9 Nm^{2}C^{-2}.

Substitute the values into the formula,

$$F = \frac{(9\times10^9)(2\times10^{-7})(3\times10^{-7})}{(0.3)^2}$$

$$= 6\times10^{-3}\text{ N}$$ **1½**

As a result, there is a force of 6×10^{-3} N between the two tiny charged spheres. The charges are of the same kind. So, repulsive force will be present between these charges. ½

Q. 4. In air, the electrostatic force on a small 0.4 μC charge sphere due to another small –0.8 μC charge sphere is 0.2 N. What is the difference between

the two spheres in terms of distance? Ap

Ans. The given electrostatic force on the first sphere is $F = 0.2\ \text{N}$.

The charge on the first and second sphere are $q_1 = 0.4\ \mu C = 0.4 \times 10^{-6}$ C and $q_2 = -0.8\ \mu C = -0.8 \times 10^{-6}$ C respectively.

The connection, gives the electrostatic force between the spheres $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$.

The value of $\dfrac{1}{4\pi\varepsilon_0}$ is $9 \times 10^9\ \text{Nm}^2\text{C}^{-2}$.

Substitute the values into the formula,

$$0.2 = \frac{(9\times10^9)(0.4\times10^{-6})(0.8\times10^{-6})}{r^2}$$ **1**

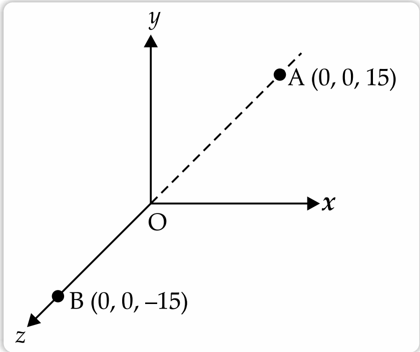
$$r^2 = 144\times10^{-4}$$

$$r = 0.12\ \text{m}$$

The two spheres are separated by 0.12 m. **1**

Q. 5. Two charges, q_A = 2.5 × 10^{-7}C and q_B = – 2.5 × 10^{-7}C, are situated at positions *A* (0, 0, 15 cm) and *B* (0, 0, –15 cm) respectively, in a system. What is the system's total charge and electric dipole moment? E

Ans. Both charges can be found in the coordinate frame of reference as shown in the diagram.



The charge at point A and point B are $q_A = 2.5 \times 10^{-7}$C and $q_B = -2.5 \times 10^{-7}$C respectively.

Add both the charges to get the total charge in the system,

$$q = q_A + q_B$$
$$= 2.5\times10^{-7} - 2.5\times10^{-7}\ \text{C}$$
$$= 0\ \text{C}$$

Therefore, total system's charge is 0 C.

Total distance between both the charges,

$$d = 15 + 15\ \text{cm}$$
$$= 30\ \text{cm}$$ **1**

The dipole moment is given by the product of charge and the distance between them.

The dipole moment,

$$p = q_A d = q_B d$$
$$= 2.5\times10^{-7}\times0.3$$
$$= 7.5\times10^{-8}\ \text{Cm}$$

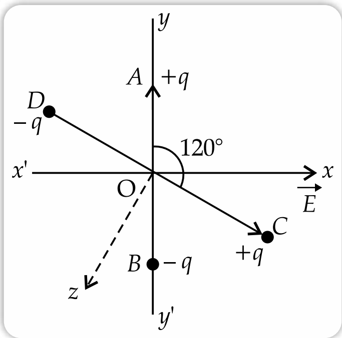
Therefore, the system's electric dipole is 7.5×10^{-8} Cm along positive z-axis. **1**

Short Answer Type Questions-II (3 marks each)

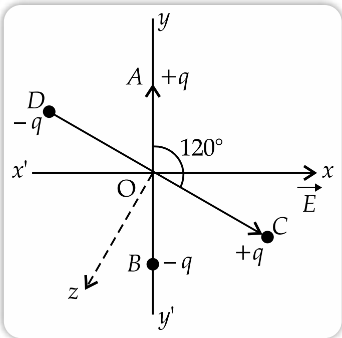
Q. 1. Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the Ap

(a) dipole moment of the arrangement, and

(b) magnitude and direction of the net torque acting on it. A I E **[CBSE Foreign Set-II 2020]**



Ans.



(a) Given: AB and CD are two dipoles kept at an angle of 120° to each other.

Now, the resultant dipole moment is,

$$\vec{p} = \sqrt{p^2 + p^2 + 2pp\cos120^\circ}$$
$$= \sqrt{2p^2 + 2p^2\cos120^\circ}$$
$$= \sqrt{2p^2 + 2p^2\left(-\frac{1}{2}\right)}$$
$$= \sqrt{2p^2 - p^2}$$
$$= \sqrt{p^2} = p$$ **1½**

Hence, the resultant dipole moment of arrangement is p, making an angle either 60° with y-axis or 30° with x-axis.

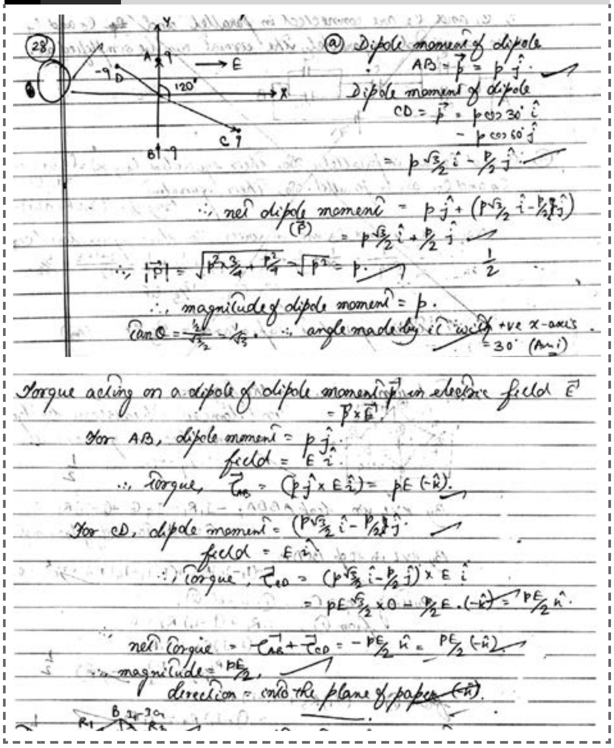
(b) $\vec{\tau} = \vec{p} \times \vec{E}$

$$\tau = pE\sin\theta$$
$$= pE\sin 30°$$
$$= \frac{1}{2}pE$$

The direction of torque is perpendicular to both p and E, and hence along negative z-direction i.e., $-z$-axis. **1½**

Ans.

Topper Answer, 2020


(a) Dipole moment of dipole AB = $\vec{p} = p\hat{j}$

Dipole moment of dipole CD = $\vec{p} = p\cos 30°\,\hat{i} - p\cos 60°\,\hat{j}$ $= p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}$

∴ net dipole moment ($\vec{P}$) = $p\hat{j} + (p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j})$ $= p\frac{\sqrt{3}}{2}\hat{i} + \frac{p}{2}\hat{j}$

∴ $|\vec{P}| = \sqrt{\frac{p^2 3}{4} + \frac{p^2}{4}} = \sqrt{p^2} = p$

∴ magnitude of dipole moment = p.

$\tan\theta = \frac{1/2}{\sqrt{3}/2} = \frac{1}{\sqrt{3}}$ ∴ angle made by it with +ve x-axis = 30° (Ans)

Torque acting on a dipole of dipole moment $\vec{p}$ in electric field $\vec{E}$ = $\vec{P} \times \vec{E}$

For AB, dipole moment = $p\hat{j}$, field = $E\hat{i}$

∴ torque, $\vec{\tau}_{AB} = (p\hat{j} \times E\hat{i}) = pE(-\hat{k})$

For CD, dipole moment = $(p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j})$, field = $E\hat{i}$

∴ torque, $\vec{\tau}_{CD} = (p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}) \times E\hat{i}$ $= pE\frac{\sqrt{3}}{2} \times 0 - \frac{p}{2}E(-\hat{k}) = \frac{pE}{2}\hat{k}$

net torque = $\vec{\tau}_{AB} + \vec{\tau}_{CD} = -\frac{pE}{2}\hat{k} = \frac{pE}{2}(-\hat{k})$

magnitude = $\frac{pE}{2}$, direction = into the plane of paper $(-\hat{k})$.

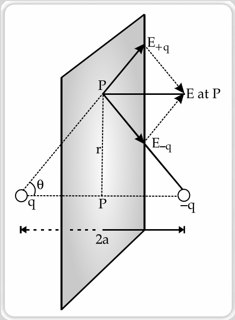
3

Q. 2. (i) Derive the expression for the electric field at a point on the equatorial line of an electric dipole.

(ii) Depict the orientation of the dipole in (i) stable, (ii) unstable equilibrium in a uniform electric field. A I E **[CBSE Delhi Set-I 2018]**

Ans. (a) Derivation of expression of electric field on equatorial line of the dipole **2**

(b) Depiction of orientation for stable and unstable equilibrium. **½+½**



(i) Let the point 'P' be at a distance 'r' from the mid point of the dipole.

$$E_{+q} = \frac{q}{4\pi\varepsilon_0(r^2+a^2)} \quad ½$$

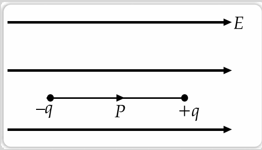
$$E_{-q} = \frac{q}{4\pi\varepsilon_0(r^2+a^2)} \quad ½$$

Both are equal and their directions are as shown in the figure, hence net electric field,

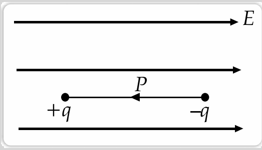
$$E_{+q} = \left[-(E_{+q}+E_{-q})\cos\theta\right]\hat{p} \quad ½$$

$$E_p = -\frac{2qa}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}\hat{p} \quad ½$$

(ii) In stable equilibrium, θ = 0° **½**



In unstable equilibrium, θ = 180° **½**



[CBSE Marking Scheme, 2017]

Commonly Made Error

- Students are often confused with the two terms: equatorial line and axial line.

Answering Tip

- Axial line is the line joining the two charges of a dipole. The line perpendicular to the axial line passing through the centre of the dipole is called an equatorial line.

Q. 3. 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

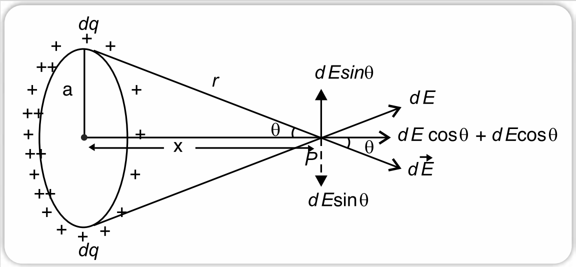
show that for points at large distances from the ring, it behaves like a point charge.

A I A **[CBSE Delhi Set-I 2016]**

Ans. Obtaining an expression for electric field intensity **2**

Showing behavior at a large distance **1**

(i)



½

Net Electric Field at point $P = \int_0^{2\pi a} dE\cos\theta$

dE = Electric field due to a small element having charge dq

$= \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$ ½

Let λ = Linear charge density

$= \frac{dq}{dl}$ ½

$dq = \lambda dl$

Hence, $E = \int_0^{2\pi a}\frac{1}{4\pi\varepsilon_0}.\frac{\lambda dl}{r^2}\times\frac{x}{r}$, where $\cos\theta = \frac{x}{r}$

$= \frac{\lambda x}{4\pi\varepsilon_0 r^3}(2\pi a)$ ½

$= \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(x^2+a^2)^{\frac{3}{2}}}$,

where total charge $Q = \lambda \times 2\pi a$

(ii) At large distance i.e., $x >> a$ ½

$E \simeq \frac{1}{4\pi\varepsilon_0}.\frac{Q}{x^2}$ ½

This is the electric field due to a point charge at distance x.

(**NOTE:** Award two marks for this question, if a student attempts this question but does not give the complete answer)

[CBSE Marking Scheme, 2016]

Q. 4. (i) Obtain the expression for the torque $\vec{\tau}$ experienced by an electric dipole of dipole moment $\vec{p}$ in a uniform electric field $\vec{E}$.

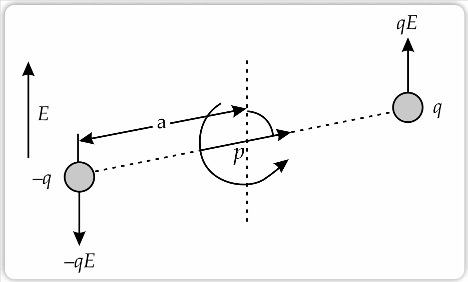
(ii) What will happen if the field were not uniform?

A&U **[CBSE Delhi Set-III 2017]**

Ans. (i) Obtaining the expression for torque experienced by an electric dipole **2**

(ii) Effect of non-uniform electric field **1**

(i)



Force on + q, $\vec{F} = q\vec{E}$

Force on – q, $\vec{F} = -q\vec{E}$

Magnitude of torque

$\tau = qE \times 2a\sin\theta$

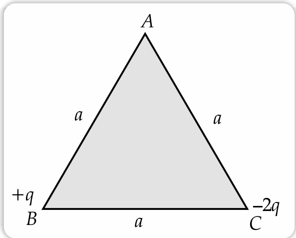
$= 2qa\,E\sin\theta$

$\vec{\tau} = \vec{p}\times\vec{E}$ **2**

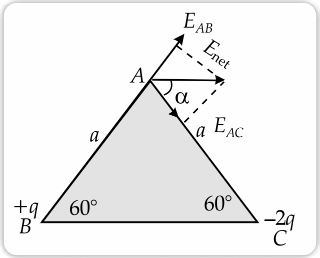
(ii) If the electric field is non uniform, the dipole experiences a translatory force as well as a torque. **1**

[CBSE Marking Scheme, 2017]

Q. 5. Two point charges + q and – $2q$ are placed at the vertices 'B' and 'C' of an equilateral triangle ABC of side 'a' as given in the figure. Obtain the expression for (i) the magnitude and (ii) the direction of the resultant electric field at the vertex A due to these two charges. A I A



Ans. (i) The magnitude



½

$\left|\vec{E}_{AB}\right| = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{a^2} = E$ ½

$\left|\vec{E}_{AC}\right| = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2q}{a^2} = 2E$ ½

$E_{net} = \sqrt{(2E)^2+(E^2)+2\times 2E\times E\cos 120°}$

$E_{net} = \sqrt{(2E)^2+E^2+2\times 2E\times E\times\left(-\frac{1}{2}\right)}$

$$E_{net} = \sqrt{4E^2 + E^2 - 2E^2}$$

$$E_{net} = E\sqrt{3} = \frac{1}{4\pi\varepsilon_0}\frac{q\sqrt{3}}{a^2} \qquad \tfrac{1}{2}$$

(ii) The direction of resultant electric field at vertex A

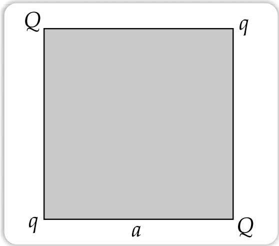
$$\tan\alpha = \frac{E_{AB}\sin 120^\circ}{E_{AC} + E_{AB}\cos 120^\circ} \qquad \tfrac{1}{2}$$

$$\tan\alpha = \frac{E \times \frac{\sqrt{3}}{2}}{2E + E \times \left(\frac{-1}{2}\right)} = \frac{1}{\sqrt{3}}$$

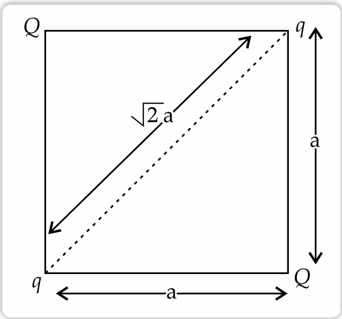
$$\alpha = 30^\circ \text{ (with side } AC) \qquad \tfrac{1}{2}$$

Q. 6. Four point charges Q, q, Q and q are placed at the corners of a square of side 'a' as shown in the figure. Find the resultant electric force on a charge Q. A

[CBSE Board Paper, 2018]



Ans.



Since, electric force $= \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

Hence, electric force on Q by other charge Q

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q \cdot Q}{(\sqrt{2}a)^2} \qquad 1$$

Now, the electric force on Q due to both q

$$= \frac{\sqrt{2}}{4\pi\varepsilon_0} \cdot \frac{Q \cdot q}{a^2} \qquad 1$$

Hence, the resultant electric force,

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{2a^2} + \frac{\sqrt{2}}{4\pi\varepsilon_0}\frac{Qq}{a^2}$$

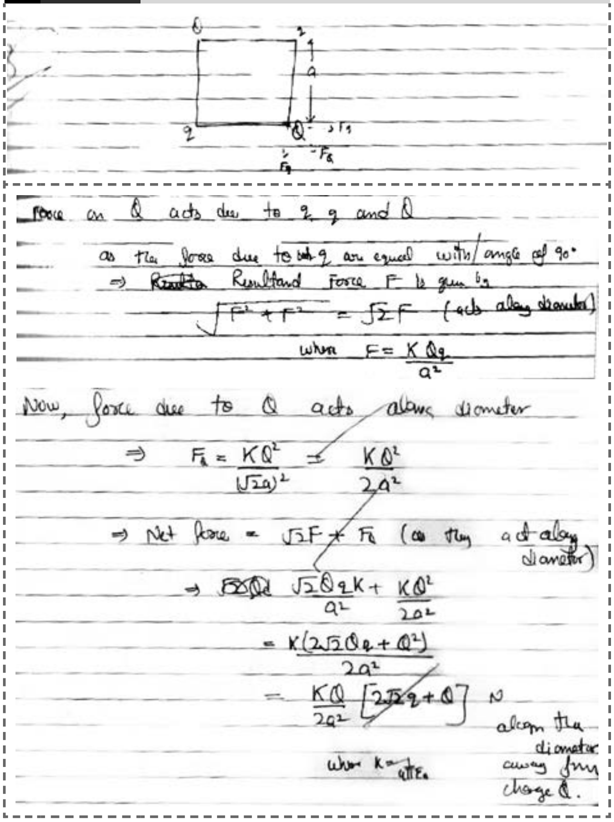
$$= \frac{Q}{4\pi\varepsilon_0} \times \frac{1}{2a^2}\left(Q + 2\sqrt{2}q\right)$$

or, $F = \frac{KQ}{2a^2}(Q + 2\sqrt{2}q)$

[acts along the diameter away from the Q.]

$$\left[\because k = \frac{1}{4\pi\varepsilon_0}\right] \qquad 1$$

Topper Answer, 2018


Force on Q acts due to q, q and Q
as the force due to both q are equal with angle of 90°
⇒ Resultant Force F is given by
$\sqrt{F^2 + F^2} = \sqrt{2}F$ (acts along diameter)
where $F = \frac{KQq}{a^2}$
Now, force due to Q acts along diameter
⇒ $F_1 = \frac{KQ^2}{(\sqrt{2}a)^2} = \frac{KQ^2}{2a^2}$
⇒ Net force $= \sqrt{2}F + F_1$ (as they act along diameter)
⇒ $\frac{\sqrt{2}Qqk}{a^2} + \frac{KQ^2}{2a^2}$
$= \frac{K(2\sqrt{2}Qq + Q^2)}{2a^2}$
$= \frac{KQ}{2a^2}[2\sqrt{2}q + Q]$ N along the diameter away from charge Q.
where $k = \frac{1}{4\pi\varepsilon_0}$

3

Long Answer Type Questions (5 marks each)

Q. 1. (a) Define an ideal electric dipole. Give an example.

(b) Derive an expression for the torque experienced by an electric dipole in a uniform electric field. What is net force acting on this dipole?

(c) An electric dipole of length 2 cm is placed with its axis making an angle of 60° with respect to uniform electric field of 10^5 N/C. If it experiences a torque of $8\sqrt{3}$ Nm, calculate the

(i) The magnitude of the charge on the dipole.

(ii) Its potential energy. U & A

[CBSE SQP 2020-2021]

Ans. Definition of ideal dipole and example ½ + ½

Derivation of torque 2

Putting values in correct formula and solving value of charge and potential energy

$Q = 8 \times 10^{-3}$ C 1

$U = -8$ J 1

(a) Ideal electric dipole: An ideal electric dipole consists of two very large charges $+q$ and $-q$ separated by a very small distance. An ideal dipole has almost no size. ½

Example: Molecules of water, ammonia, etc are examples of ideal electric dipoles. ½

(b) Consider an electric dipole consisting of two charges $+q$ and $-q$ and separated by a distance $2l$ is placed in a uniform electric field $\vec{E}$ so that that dipole makes an angle θ with the electric field.

Force acting on $-q$ is $-q\vec{E}$

Force acting on $+q$ is $+q\vec{E}$

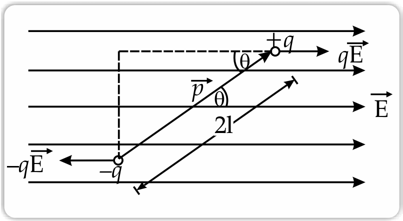
The magnitude of torque developed

$= q\text{E} \times$ perpendicular distance between the forces

$= q\text{E} \times 2l \sin\theta$

$= q \times 2l\, \text{E} \sin\theta$

$= p\text{E}\sin\theta$ [p is the dipole moment]



2

(c) Torque $= q \times 2l \times \text{E}\sin\theta$

Or, $8\sqrt{3} = q \times 0.02 \times 10^5 \times \sin 60°$

∴ $q = 8 \times 10^{-3}$ C 1

Potential energy $= -q \times 2l \times \text{E}\cos\theta$

$= -8 \times 10^{-3} \times 0.02 \times 10^5 \times \cos 60°$

$= -8$ J 1

Q. 2. (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 2 m apart in the 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.

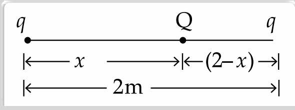
A **[CBSE Delhi Set-I 2019]**

Ans. (a) Derivation for the expression of the electric field on the equatorial line 3

(b) Finding the position and nature of Q 1 + 1

(a) Try it yourself. See Q. No. 2(i) of 3 marks questions. 3

(b)



½

The system is in equilibrium, therefore net force on each charge of the system will be zero.

For the total force on 'Q' to be zero

$$\frac{1}{4\pi\varepsilon_0}\frac{qQ}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(2-x)^2}$$ ½

$x = 2 - x$

$2x = 2$ ½

$x = 1$ m

(Give full credit of this part, if a student writes directly 1 m by observing the given condition)

For the equilibrium of charge "q", the nature of charge Q must be opposite to the nature of charge q.

[CBSE Marking Scheme 2019] ½

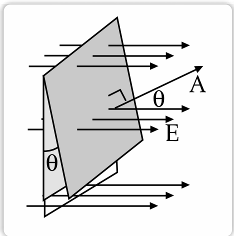
Topic-2 Gauss' Theorem and its Applications

Concepts Covered • *Electric flux,* • *Continuous charge distribution,* • *Gauss' theorem*

Revision Notes

Electric Flux

- Electric flux is proportional to algebraic number of electric field lines passing through the surface, outgoing lines with positive sign, incoming lines with negative sign.



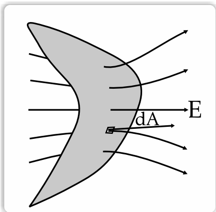
- Due to arbitrary arrangement of electric field lines, electric flux can be quantified as $\phi_E = EA$
- If vector A is perpendicular to the surface, magnitude of vector A parallel to electric field is $A\cos\theta$

  $A_{II} = A\cos\theta$

  $\phi_E = EA_{II} = EA\cos\theta$
- In non-uniform electric field, the flux will be $\phi_E = \int E.dA$

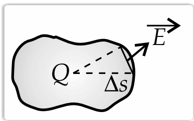
Continuous Charge Distribution

- It is a system in which the charge is uniformly distributed over the material. In this system, infinite number of charges are closely packed and have minor space among them. Unlike the discrete charge system, the continuous charge distribution is uninterrupted and continuous in the material. There are three types of continuous charge distribution system.



- For linear charge distribution (λ), $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int^{x}\frac{\lambda}{r^2}d\hat{r}$
(Where, λ = linear charge density)

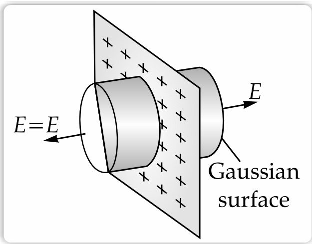
- For surface charge distribution (σ), $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int^{s}\frac{\sigma}{r^2}dS\hat{r}$
(Where, σ = surface charge density)



- For volume charge distribution (ρ), $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int^{V}\frac{\rho}{r^2}dV\hat{r}$
(Where, ρ = volume charge density)

Gauss' theorem

- The net outward normal electric flux through any closed surface of any shape is equal to $1/\varepsilon_0$ times to net charge enclosed by the surface.
- The electric field flux at all points on Gaussian surface is $\phi = E\oint dA = \frac{q}{\varepsilon_0}$.
- If there is a positive flux, net positive charge is enclosed.
- If there is a negative flux, net negative charge is enclosed.
- If there is zero flux, no net charge is enclosed.
- The expression for electric field due to a point charge on Gaussian surface is $E = \frac{q}{4\pi\varepsilon_0 r^2}$



- In an insulating sheet, the charge remains in the sheet, so electric field, $E = \frac{\sigma}{2\varepsilon_0}$
- Gauss theorem works in cases of cylindrical, spherical and rectangular symmetries.
- The field outside the wire points radially outward which depends on distance from wire, $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{n}$, where, λ is linear charge density.
- **Closed surface:** It is a surface which divides the space inside and outside region, where one can't move from one region to another without crossing the surface.

Scan to know more about this topic
Gauss Theorem

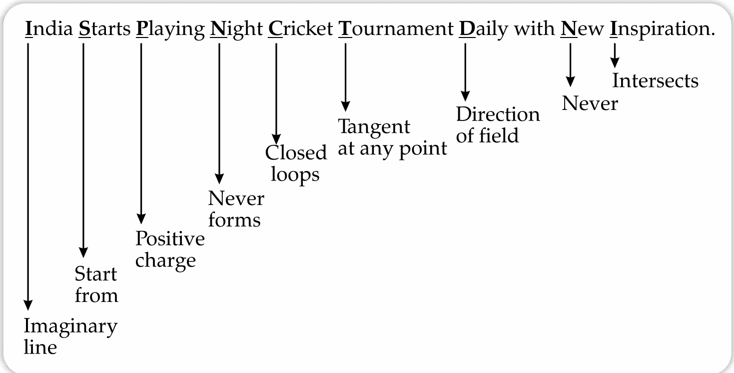
- **Gaussian surface:** It is a hypothetical closed surface having similar symmetry as problem on which we are working.
- **Electrostatic Shielding:** It is the phenomenon of protecting a certain region of space from external electric field.
- **Dielectric:** The non-conducting material in which charges are easily produced on the application of electric field is called dielectric. e.g., air, H_2 gas, glass, mica, paraffin wax, transformer oil, etc.

Mnemonics

Concept: Characteristics of Electric field lines

Mnemonic: India Starts Playing Night Cricket Tournament Daily with New Inspiration.

Interpretation:

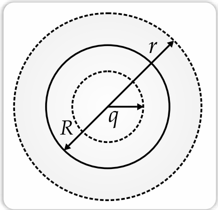


Key Formulae

- Coulomb's force: $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$;

  where all alphabets have their usual meanings.
- Electric field due to point charge q:

  $E = \frac{k|q|}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$
- Electric field due to a dipole at a point on the dipole axis: $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3}$ $(r >>> a)$
- Electric field due to a dipole at a point on an equatorial plane: $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^3}$ $(r >>> a)$



- Torque on an electric dipole placed in an electric field, $\tau = pE\sin\theta$
- Electric flux through an area A: $\phi = E.A = EA\cos\theta$
- Electric flux through a Gaussian surface: $\phi = \oint E.dS$
- Gauss's Law: $\phi = \frac{q_{enc}}{\varepsilon_0}$
- Electric Field due to an infinite line of charge:

  $E = \frac{\lambda}{2\pi\varepsilon_0 r} = \frac{2k\lambda}{r}$

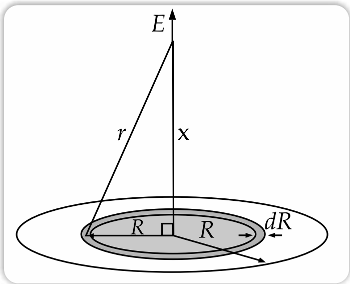
  where, E = electric field [N/C],
  λ = charge per unit length [C/m]

ε_0 = permittivity of free space = 8.85×10^{-12} [$C^2/N\,m^2$], r = distance (m), $k = 9 \times 10^9\ Nm^2C^{-2}$

- Electric field due to a ring at a distance x is:

  $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{qx}{(r^2+x^2)^{3/2}}$
- When, $x >>> r$: $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x^2}$
- When $x <<< r$: $E = 0$
- Electric field due to a charged disc:

  $E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{R^2+x^2}}\right]$



where ,
E = electric field [N/C]
σ = charge per unit area [C/m^2]
$\varepsilon_0 = 8.85 \times 10^{-12}$ [C^2/Nm^2]
x = distance from charge [m]
R = radius of the disc [m]

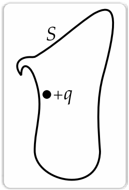
- Electric field due to a thin infinite sheet: $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

OBJECTIVE TYPE QUESTIONS

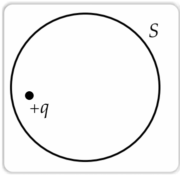
A Multiple Choice Questions

Q. 1. The electric flux through the surface: Ap

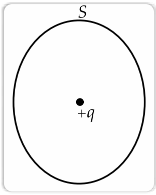
(i)



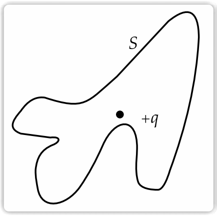
(ii)



(iii)



(iv)



(A) in Figure (iv) is the largest.
(B) in Figure (iii) is the least.

(C) Figure (ii) is the same as Figure (iii) but is smaller than Figure (iv).

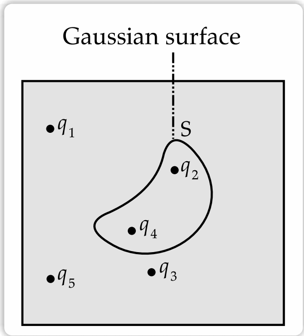
(D) is the same for all the figures.

Ans. Option (D) is correct.

Explanation: Electric flux, through the closed surface (or space) depends only on the charge enclosed inside the surface. Here, charges inside all figures are same. So, electric flux will remain same.

Q. 2. Five charges q_1, q_2, q_3, q_4, and q_5 are fixed at their positions as shown in Figure. S is a Gaussian surface. The Gauss's law is given by: A

$$\oint E.dS = q / \varepsilon_0$$



Which of the following statement is correct?

(A) E on the LHS of the above equation will have a contribution from q_1, q_5, and q_3, while q on the RHS will have a contribution from q_2 and q_4 only.

(B) E on the LHS of the above equation will have a contribution from all charges, while q on the RHS will have a contribution from q_2 and q_4 only.

(C) E on the LHS of the above equation will have a contribution from all charges, while q on the RHS will have a contribution from q_1, q_3 and q_5 only.

(D) Both E on the LHS and q on the RHS will have contributions from q_2 and q_4 only.

Ans. Option (B) is correct.

Explanation: As all charges are positive (or of same signs), so electric field lines on R.H.S. of Gaussian surface will be due to q_2 and q_4 only.

On L.H.S. of Gaussian surface, the electric field lines on 'E' will be due to q_1, q_2, q_3, q_4 and q_5. So, answer (B) is verified.

Q. 3. If there is only one type of charge in the universe, then: U

(A) $\oint E.dS \neq 0$ on any surface.

(B) $\oint E.dS = \varepsilon_0/q$ if the charge is outside the surface.

(C) $\oint E.dS$ can not be defined.

(D) $\oint E.dS = q/\varepsilon_0$ if charges of magnitude q is inside the surface.

Q. 4. What is the value of electric flux on a surface whose area is meter square when an electric field of 2 V/m intersects at an angle of 60° degree? A

(A) 4 Vm **(B)** 5 Vm

(C) 1 Vm **(D)** 3 Vm

Ans. Option (C) is correct.

Explanation: The electric flux is given by

$\phi = EA \cos \theta$.

On substituting the given values,

$$\phi = 2 \cdot 1(\cos 60°)$$
$$= 2 \cdot \frac{1}{2}$$
$$= 1$$

Therefore, the correct answer is 1 Vm.

Concept Applied

Electric flux

Q. 5. Gauss' law is effective for: U

(A) any enclosed area

(B) only near uniform surfaces

(C) any unobstructed surface

(D) only open irregular surfaces

Q. 6. What is the electric flux connected to Earth if there is only one sort of charge q on the planet? U

(A) It can be zero through any Earth's surface.

(B) The Earth has infinite flux.

(C) If the charge is placed outside of the Earth, it is zero and if the charge is placed inside the Earth, it is $\frac{q}{\varepsilon_0}$.

(D) It's impossible to define.

Ans. Option (C) is correct.

Explanation: The Earth's surface can be viewed as a closed surface.

According to Gauss's law, the total electric flux emerging from a closed surface is $\phi = \frac{q}{\varepsilon_0}$.

As a result, if the charge q is placed within Earth, the electric flow through Earth will be $\phi = \frac{q}{\varepsilon_0}$.

If the charge is placed outside the Earth, then

These questions are for practice and their solutions are available at the end of the chapter.

$q = 0$ so, the flux through the Earth is zero, because 0.

As a result, if the charge is placed outside of the Earth, the correct answer is zero, and if the charge is placed inside the Earth, the correct answer is one.

Therefore, the correct option is (C).

Q. 7. The electric flux is caused by: U

(A) The intensity of the electric field

(B) Area of the surface

(C) Angle of the surface with respect to the electric field

(D) Each one of these

Q. 8. A $+q$ charge is placed in the centre of a cubical box. The total flux coming out of a wall has a value of: A

(A) $\frac{q}{6\varepsilon_0}$ (B) $\frac{q}{\varepsilon_0}$

(C) $\frac{6q}{\varepsilon_0}$ (D) $\frac{q}{3\varepsilon_0}$

Ans. Option (A) is correct.

Explanation: According to the Gauss' theorem, the flux through a surface is given by $\phi = \frac{q}{\varepsilon_0}$.

A cube has 6 faces, so the flux trough 6 faces will be,

$$6\phi = \frac{q}{\varepsilon_0}$$

$$\phi = \frac{q}{6\varepsilon_0}$$

Therefore, the correct answer is $\frac{q}{6\varepsilon_0}$.

Q. 9. A point charge q is put immediately above the centre of a cube with side x at a distance of $\frac{x}{2}$. The flow of flux through the cube is E

(A) $\frac{q}{6\varepsilon_0}$ (B) $\frac{q}{2\varepsilon_0}$

(C) $\frac{q}{4\varepsilon_0}$ (D) $\frac{q}{\varepsilon_0}$

Ans. Option (B) is correct.

Explanation: According to the Gauss's theorem, the flux through a surface is given by $\phi = \frac{q}{\varepsilon_0}$.

A point charge q will be at the face of a cube with side x if it is put at a distance $\frac{x}{2}$ exactly above the centre.

The charge q is shared evenly by two cubes if it is put at C, the centre of one of the cube's faces.

Therefore, the total flow through the faces of the provided cube is equal to $\frac{q}{2\varepsilon_0}$.

Q. 10. When a ring is put in an electric field and its plane is parallel to the field, the electric flux associated with the ring, U

(A) Will be negative (B) Will be positive

(C) Will be zero (D) Cannot evaluate

Ans. Option (C) is correct.

Explanation: The electric flux associated with the area is given by $\phi = EA \cos \theta$, here the electric field is E and the area is A and the symbol θ denotes the angle between the surface and the electric field.

Because the ring's plane is parallel to the electric field, the angle formed by the surface and the electric field is 90°.

As $\cos 90° = 0$ so, $\phi = 0$.

Therefore, the ring's electric flux will be zero.

Q. 11. When a square loop with a surface area of 50 cm^2 is placed in a homogeneous electric field with an intensity of 50 N/C and the angle between the surface and the electric field is 60°, the electric flux associated with the loop is: E

(A) 1250 Vm (B) 125 Vm

(C) 0.125 Vm (D) 1.25 Vm

Ans. Option (C) is correct.

Explanation: The area is 50 cm^2 or 50×10^{-4} m^2.

Substitute $E = 50$, $A = 50 \times 10^{-4}$ and $\theta = 60°$ into $\phi = EA \cos \theta$,

$$\phi = 50 \times 50 \times 10^{-4} \times \cos 60°$$

$$= 50 \times 50 \times 10^{-4} \times \frac{1}{2}$$

$$= 0.125 \text{ Vm}$$

Therefore, the correct answer is 0.125 Vm.

Q. 12. When an electric field rotates a circular ring along its axis, the electric flux associated with the ring: U

(A) Will decrease (B) Will increase

(C) Remains the same (D) I'm not sure

Ans. Option (C) is correct.

Explanation: If the electric field is E and the area is A, the electric flux associated with the area is $\phi = EA \cos \theta$.

Where θ represents the angle formed between the surface and the electric field.

When a circular ring is rotated in an electric field along its axis, its alignment with the electric field

These questions are for practice and their solutions are available at the end of the chapter.

remains constant, hence the value of θ remains constant.

It follows that the area of the circular ring, the electric field strength, and the angle between the circular loop and the electric field will remain unchanged when the circular ring is rotated along its axis in the electric field.

It is concluded that E, A, and θ are constant so, the electric flux value will be constant as well.

Q. 13. Suppose a closed square loop whose area is $5\hat{i}-6\hat{j}$ is placed in an electric field of $2\hat{i}-4\hat{j}$, then what will be the electric flux? E

(A) $\left(2\hat{i}-4\hat{j}\right)$ Vm **(B)** 34 Vm

(C) 10 Vm **(D)** $\left(3\hat{i}-2\hat{j}\right)$Vm

Ans. Option (B) is correct.

Explanation: The electric flux is the dot product of electric field and the area so,

$$\begin{aligned}\phi &= \vec{E}\cdot\vec{A}\\ &= \left(2\hat{i}-4\hat{j}\right)\cdot\left(5\hat{i}-6\hat{j}\right)\\ &= 10+24\\ &= 34\text{ Vm}\end{aligned}$$

Therefore, the correct answer is 34 Vm.

Q. 14. Which of the following is called as "The number of electric force lines that pass through a unit region"? U

(A) Density **(B)** Electric flux

(C) Electric field **(D)** Nothing

Ans. Option (B) is correct.

Explanation: Electric flux is defined as the number of electric lines of force moving through a unit region.

Therefore, the correct answer is electric flux.

B Assertion & Reason

Directions: In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

(A) Both Assertion (A) and Reason (R) are true, and Reason (R) is the correct explanation of Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Q. 1. Assertion (A): In a cavity of a conductor, the electric field is zero.

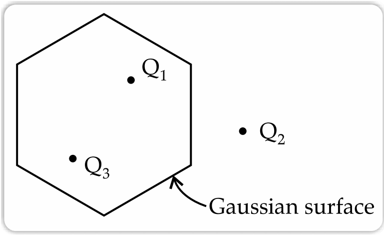
Reason (R): Charges in a conductor reside only at its surface. U

Ans. Option (A) is correct.

Explanation: The charge enclosed by the Gaussian surface surrounding the cavity is zero. Hence, the electric field is also zero. So, the assertion is true.

Charges in a conductor reside only at its surface. So, in cavity there is no charge. So, the reason is also true and properly explains the assertion.

Q. 2. Assertion (A): Three point charges Q_1, Q_2 and Q_3 are shown in the figure. The flux over the Gaussian surface depends on only one charge point. A



Reason (R): Electric flux depends on the all charges enclosed by the Gaussian surface.

Ans. Option (D) is correct.

Explanation: According to Gauss's law, electric flux depends on the enclosed charges only. Here the enclosed charges are Q_1 and Q_3 only. Hence the assertion is false and the reason is true.

Q. 3. Assertion (A): Using Gauss' law, it is possible to find the electric field at any point.

Reason (R): Gauss' law is applicable for any type of charge distribution. U

Ans. Option (C) is correct.

Explanation: Considering suitable Gaussian surface, we can easily find the electric field at any point. So, the assertion is true.

But it is very difficult to apply Gauss law, if the charge distribution is so that the Gaussian surface is complicated in shape. So, reason is false.

Q. 4. Assertion (A): When the inverse square law is not obeyed, Gauss' law shows deviation.

Reason (R): The conservation of charges leads to Gauss' law. U

Ans. Option (B) is correct.

Explanation: The total electric flux out of a closed surface is equal to the charge enclosed divided by the permittivity, according to Gauss' law.

Inverse square dependency of the electric field on distance is the basis of Gauss' theorem.

Therefore, both assertion and reason are correct but reason is not correct explanation of assertion.

Q. 5. Assertion (A): The electric field near an electric dipole cannot be calculated using Gauss law.

Reason (R): The charge distribution of an electric dipole is not symmetrical. A

Ans. Option (A) is correct.

Explanation: The Gauss' law can be applied to any closed surface. When the charge distribution has spherical or cylindrical symmetry or is distributed uniformly throughout the plane, Gauss law is most beneficial. A system of two equal and opposite point charges separated by a very tiny and finite distance is called an electric dipole.

Therefore, both assertion and reason are correct and reason is correct explanation of assertion.

Q. 6. Assertion (A): When one body may not be charged there can be Coulomb attraction between them.
Reason (R): Coulomb attraction occurs when two bodies are charged in opposite directions. U

Ans. Option (B) is correct.
Explanation: Even when one body is charged and the other is not, Coulomb attraction exists.
Therefore, both assertion and reason are correct but reason is not correct explanation of assertion.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (1 mark each)

Q. 1. What will be the ratio of the surface charge density of the inner surface to that of the outer surface of a hollow conducting sphere if a point charge is placed at the centre of the hollow conducting sphere having internal radius 'r' and outer radius '$2r$' ? U **[CBSE Delhi Set-I 2020/Modified]**

Ans. – 4: 1. **1**
Explanation: If + q charge is placed at the centre of the hollow sphere, charge on inner surface will be $-q$. So, charge density at the inner surface = $-q/4\pi r^2$.
Charge on outer surface will be $+q$. So, charge density at the outer surface = $q/4\pi(2r)^2$
So, the required ratio = $[-q/4\pi r^2]/[q/4\pi(2r)^2]$
= – 4: 1

Q. 2. State Gauss' law in electrostatics. U **[Delhi Set-I, II, III 2016]**

Ans. Gauss' law in electrostatics: "The surface integral of electrostatic field $\vec{E}$ produced by any source over any closed surface S enclosing a volume V in the vacuum, i.e., total electric flux, over the closed surface S in the vacuum, is $\frac{1}{\varepsilon_0}$ times i.e., the total charge (Q) contained inside S,

$$\phi_E = \oint \vec{E}.d\vec{S} = \frac{Q_{enclosed}}{\varepsilon_0}$$ **1**

[CBSE Marking Scheme, 2016]

Commonly Made Error

- Most of the candidates are unable in stating Gauss' law correctly. Key words like net charges, closed surface etc. are missed by students. Some candidates write magnetic flux instead of electric flux.

Answering Tip

- Student should keep the precaution about the keywords while doing the practice of Gauss law.

Q. 3. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased? U **[CBSE Delhi Set-I 2016]**

Q. 4. What is the electric flux through a cube of side 1 cm which encloses an electric dipole ? AI U

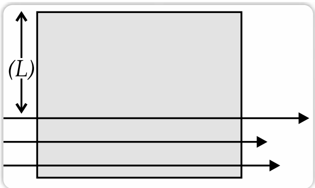
Ans. Zero (as the net charge enclosed by the surface is zero.) **[CBSE Marking Scheme, 2015] 1**

Detailed Answer:
In a cubic surface, the net electric charge will be zero since dipole carries equal and opposite charges. It is observed that the net electric flux through closed cubic surface will be

$$= \frac{\text{Charge enclosed}}{\varepsilon_0}$$

and because the charge enclosed is zero,
∴ electric flux is also zero. **1**

Q. 5. A square surface of side L meters is in the plane of the paper. A uniform electric field E volt m^{-1} is also in the plane of the paper and is limited only to the lower half of the square surface as shown in the figure. What is the electric flux (in SI unit) associated with the surface? U



Ans. The electric flux will be zero. **1**

[**Explanation:** As the electric field lines are parallel to the surface of the square, so there will not be any field lines crossing the surface. Hence the electric flux through the surface will be zero.]

Commonly Made Error

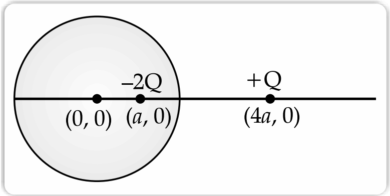
- Most of the students are unable to find the electric field from Gauss's law properly.

Answering Tip

- The given figure should be carefully studied to know that the electric field lines are parallel to the surface and electric field lines will cross the surface.

Q. 6. Two charges of magnitudes –2Q and +Q are located at points (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin ? A I U

Ans. Gauss theorem states that the electric flux through a closed surface enclosing a charge is equal to $\left(\frac{1}{\varepsilon_0}\right)$ times the magnitude of the charge enclosed.



The sphere encloses a charge of – 2Q, so

$$\phi = \frac{2Q}{\varepsilon_0}$$ **1**

Q. 7. On which factors does the electric flux through a closed Gaussian surface depend upon ?

U [CBSE Delhi Set-I 2020/Modified]

Q. 8. What will be the changes in outward electric flux if the radius of the Gaussian spherical surface of radius R enclosing a charge Q is doubled ? A I A

Ans. Flux will remain same.

Explanation: According to Gauss's law, the flux depends on the charge enclosed and the permittivity of the medium. It does not depend on the surface area. **1**

Q. 9. Is Gauss' law valid for an open surface? U

Ans. No. Gauss' law is not valid for any open surface. **1**

Q. 10. A charge Q is kept at the centre of the cube. What is the electric flux through the two opposite faces of the cube? A

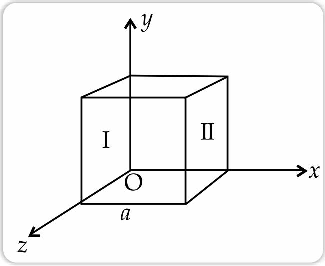
Ans. Electric flux (ϕ) $= \frac{1}{\varepsilon_0} \times \frac{2}{6} = \frac{1}{3\varepsilon_0}$ **1**

Q. 11. Is electric flux a scalar or a vector quantity? Give reason. U

Short Answer Type Questions-I (2 marks each)

Q. 1. Given the electric field in the region $\vec{E} = 2x\hat{i}$, find the net electric flux through the cube and the charge enclosed by it.

A I A & U [Delhi Set-I, II, III 2015]



Ans. From the given diagram,

Only the face perpendicular to the direction of x-axis, contribute to the electric flux. The remaining faces of the cube gives zero contribution. ½

Total flux, $\phi = \phi_I + \phi_{II}$

$$= \oint_I \vec{E}.\vec{ds} + \oint_{II} \vec{E}.\vec{ds}$$ ½

$$= 0 + 2(a).\,a^2$$ ½

$$= 2a^3$$ ½

Charge enclosed, $q = \varepsilon_0\phi = 2a^3\varepsilon_0$

Q. 2. An electric flux of -3×10^{-14} Nm^2/C passes through a spherical Gaussian surface is caused by a point charge. Compute the point charge's value. U & Ap

Ans. The total electric flux via a closed Gaussian surface is provided by Gauss' theorem, $\phi = \frac{q}{\varepsilon_0}$.

Substitute $\phi = -3 \times 10^{-14}$ and $\varepsilon_0 = 8.85 \times 10^{-12}$ into the Gauss' theorem,

$$-3\times10^{-14} = \frac{q}{8.85\times10^{-12}}$$

$$q = \left(-3\times10^{-14}\right)\left(8.85\times10^{-12}\right)$$

$$= -2.655\times10^{-25}\text{ C}$$

These questions are for practice and their solutions are available at the end of the chapter.

Therefore, the value of point charge is -2.655×10^{-25} C. **2**

Q. 3. Find the flux of a uniform electric field $\hat{E} = 5 \times 10^3\, \hat{i}$ N/C held through a square of 10 cm on a side with a plane parallel to the YZ-plane. What would be the flux across the same square if the plane intersected the X-axis at a 30° angle? U & A

Ans. The given value of electric field intensity is $|E| = 5 \times 10^3\, \hat{i}$ N/C.

The length of one side of the square is 10 cm or 0.1 m. So, the area of the square will be 0.01 m^2.

The square's plane is parallel to the YZ-plane. So, there is no angle between the unit vector normal to the plane and the electric field, $\theta = 0°$.

Substitute $|E| = 5 \times 10^3$, $A = 0.01$, and $\theta = 0°$ into the flux through the plane $\phi = |E|\, A \cos\theta$,

$$\phi = 5\times10^3(0.01)\cos 0°$$
$$= 5\times10^3(0.01)$$
$$= 50 \text{ N-m}^2/\text{C}$$

Therefore, the flux when the square's plane is parallel to the YZ-plane is 50 N-m^2/C.

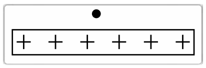
When the plane makes a 30° angle with the x axis then, $\theta = 60°$.

Substitute $|E| = 5 \times 10^3$, $A = 0.01$, and $\theta = 60°$ into the flux through the plane $\phi = |E|\, A \cos\theta$,

$$\phi = 5\times10^3(0.01)\cos 60°$$
$$= 5\times10^3(0.01)(0.5)$$
$$= 25 \text{ N-m}^2/\text{C}$$

Therefore, the flux when the square's plane is intersected the X-axis at a 30° angle is 25 Nm^2/C. **2**

Q. 4. A particle whose mass 5×10^{-6}g is held over a huge horizontal charge sheet with a density of 4×10^{-6} C/m^2. What charge should be applied to this particle such that it does not fall when released? U & E



Ans. Given surface charge density is 4×10^{-6} C/m^2 and the mass of the particle is 5×10^{-6} g.

The electric field, $E = \dfrac{\sigma}{2\varepsilon_0}$

$$= \frac{4\times10^{-6}}{2\left(8.85\times10^{-12}\right)}$$
$$= 2.26\times10^5 \text{ N/C}$$

Therefore, the electric field is 2.26×10^5 N/C.

The electric force qE acts in the upward direction if the particle is given a charge q. The particle's weight is balanced by this force, $F = qE$.

The force F is downward force. So, $mg = qE$.

Substitute the values into the formula,

$$\left(5\times10^{-6}\right)(9.8) = q\left(2.26\times10^5\right)$$
$$q = \frac{\left(5\times10^{-6}\right)(9.8)}{2.26\times10^5}$$
$$= 2.2\times10^{-10} \text{ C}$$

Therefore, the charge applied is 2.21×10^{-10} C. **2**

Q. 5. Why can't you compute the field of a cube using Gauss' law? U

Ans. Because the electric field of a cube fluctuates along any segment of the Gaussian surface, Gauss law cannot be used to calculate its field. In this case, Gauss' law is applied to all closed surfaces of any shape. Furthermore, when the charge distribution is symmetrical, the validity of this law is determined. **2**

Short Answer Type Questions-II (3 marks each)

Q. 1. A hollow conducting sphere of inner radius r_1 and outer radius r_2 has a charge Q on its surface. A point charge $-q$ is also placed at the centre of the sphere.

(a) What is the surface charge density on the (i) inner and (ii) outer surface of the sphere ?

(b) Use Gauss' law of electrostatics to obtain the expression for the electric field at a point lying outside the sphere.

U & A **[CBSE Delhi Outside Set-I 2020]**

Ans. (a) Charge placed at the centre of the hollow sphere is $-q$. Hence, a charge of magnitude $+q$ will be induced to the inner surface. Therefore, total charge on the inner surface of the shell is $+q$.

Surface charge density at the inner surface,

$$\sigma_{inner} = \frac{\text{Total charge}}{\text{Inner surface area}} = \frac{+q}{4\pi r_1^2} \quad \mathbf{1}$$

A charge of $-q$ is induced on the outer surface of the sphere. A charge of magnitude Q is placed on the outer surface of the sphere. Therefore, total charge on the outer surface of the sphere is $Q - q$.

Surface charge density at the outer surface,

$$\sigma_{outer} = \frac{\text{Total charge}}{\text{Outer surface area}} = \frac{Q-q}{4\pi r_2^2} \quad \mathbf{1}$$

(b) Electric field at a point lying outside the sphere at a distance r from the centre of the sphere:

Applying Gauss' theorem

$$\text{Flux} = \phi = \frac{\text{Charge enclosed}}{\varepsilon_o}$$

Or, $E \times 4\pi r^2 = \dfrac{Q-q}{\varepsilon_0}$

$$\therefore E = \frac{Q-q}{4\pi r^2 \varepsilon_0}$$ 1

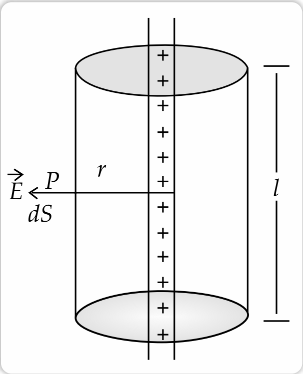
Q. 2. An infinitely long thin straight wire has a uniform linear charge density λ.

(a) Obtain the expression for the electric field (E) at a point lying at a distance x from the wire, using Gauss' law.

(b) Show graphically the variation of this electric field E as a function of distance x from the wire.

AI A [CBSE Delhi Outside Set-I 2020]

Ans.



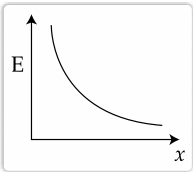
(a) Electric field due to an infinitely long straight wire having uniform linear charge density λ:
x = Distance of the point P from the wire where the electric field is to be evaluated
E = Electric field at the point P
A Gaussian cylinder of length l, radius x is considered.
An infinitesimally small area dS on the Gaussian surface is considered.
The electric field is the same at all points on the curved surface of the cylinder and directed radially outward. So, E and dS are along the same direction.
The total electric flux (ϕ) through the curved surface $= \int EdS \cos\theta$
Since E and ds are along the same direction, so $\theta = 0°$
So, $\phi = E(2\pi xl)$
The net charge enclosed by the Gaussian surface is, $q = \lambda l$
∴ By Gauss law,

$$\phi = \frac{1}{\varepsilon_0} q$$

Or, $\therefore \dfrac{1}{\varepsilon_0} q = E(2x\pi l)$

$$\therefore E = \frac{\lambda}{2\pi x \varepsilon_0}$$

(b)



3

Q. 3. Two large charged plane sheets of charge densities σ and – 2σ C/m² are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points

(i) to the left of the first sheet, (ii) to the right of the second sheet, and (iii) between the two sheets.

A [CBSE Delhi Outside Set-I 2019]

Ans. Diagram 1+½

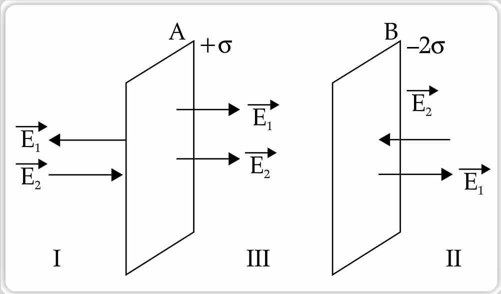
Deducing electric field expression

(i) To the left of the first sheet ½

(ii) To the right of the second sheet ½

(iii) Between the two sheets ½

Diagram:



1½

The electric field in the region left of first sheet

$$E_I = E_1 + E_2$$

$$E_I = \frac{\sigma}{\varepsilon_0} - \frac{\sigma}{2\varepsilon_0}$$

$$E_I = +\frac{\sigma}{2\varepsilon_0}$$ ½

It is towards the right,

The electric field in the region to the right of the second sheet,

$$E_{II} = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{\varepsilon_0}$$

$$E_{II} = -\frac{\sigma}{2\varepsilon_0}$$ ½

It is towards the left.

The electric field between the two sheets

$$E_{III} = E_I + E_{II}$$

$$E_{III} = \frac{\sigma}{\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$E_{III} = \frac{3\sigma}{2\varepsilon_0}$$ ½

The electric field is towards the right.

[CBSE Marking Scheme, 2019]

Q. 4. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q.

(a) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell.

(b) Is the electric field inside a cavity (with no charge) zero-independent of the fact whether the shell is spherical or not? Explain.

A I A & U **[CBSE Delhi Outside Set-I 2019]**

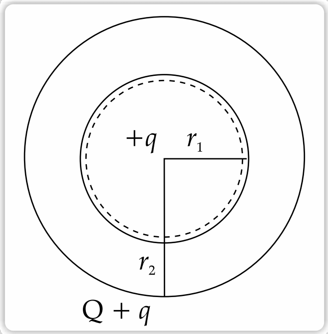
Ans. Diagram ½

Finding the surface charge density in the inner and the outer surface of the shell **1+½**

The electric field in the cavity **1**

Diagram:

(a)



½

The charge induced on the inner surface of the shell will be $-q$.

The surface charge density on inner surface of the shell is $\sigma_1 = -\dfrac{q}{4\pi r_1^2}$ **1**

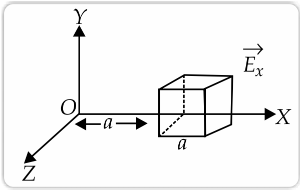
The surface charge density on the outer shell is

$$\sigma_2 = -\frac{Q+q}{4\pi r_2^2}$$ ½

(b) Consider a Gaussian surface inside the shell, net flux is zero since $q_{net} = 0$. According to Gauss' law, it is independent of the shape and size of shell. **1**

[CBSE Marking Scheme, 2019]

Q. 5. Define electric flux and write its SI unit. The electric field components in the figure shown are:



$E_x = \alpha x$, $E_y = 0$, $E_z = 0$ where $\alpha = \dfrac{100\,\text{N}}{\text{C m}}$. Calculate the charge within the cube, assuming $a = 0.1$ m.

Ap **[Delhi Outside Comptt. I, II, III 2018]**

Ans. Definition of Electric flux 1

SI unit ½

Formula (Gauss' Law) ½

Calculation of Charge within the cube 1

Electric Flux is the dot product of the electric field and area vector. **1**

Also accept,

$$\phi = \int \vec{E} \cdot \vec{dS}$$

SI Unit: Nm^2/C or Volt-metre ½

For a given case,

$$\phi = \phi_1 + \phi_2 = \left[E_x(at\ x = 2a) - E_x(at\ x = a)\right]a^2$$

$$= \left[\alpha(2a) - \alpha(a)\right]a^2$$

$$= \alpha a^3$$

$$= 100 \times (0.1)^3 = 0.1\ Nm^2/C$$ ½

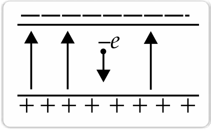
But $\phi = \dfrac{q}{\varepsilon_0}$

$\therefore$ $q = \varepsilon_0\phi = 8.854 \times 10^{-12} \times 10^{-1}$ C

$= 0.8854$ pC **1**

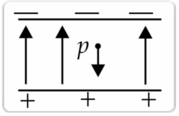
[CBSE Marking Scheme, 2018]

Q. 6. An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N/C



(a)

Calculate the time it takes to fall through this distance starting from rest.



(b)

If the direction of the field is reversed (Fig. b) keeping its magnitude unchanged, calculate the time taken by a proton to fall through this distance starting from rest.

A I Ap **[Delhi Outside Comptt. I, II, III 2018]**

Ans. Relevant formulae 1

Calculation of time taken by the electron 1

Calculation of time taken by the proton 1

We have

Force = qE

Acceleration,

$$a = \frac{qE}{m}$$ ½

Also

$$s = \frac{1}{2}at^2 \quad \text{as } u = 0$$

$$\therefore \quad t = \sqrt{\frac{2s}{a}}$$ ½

(i) For the electron,

$$a = \frac{eE}{m}$$

$$t = \sqrt{\frac{2sm}{eE}}$$

$$\therefore \quad t = \sqrt{\frac{2 \times 1.5 \times 10^{-2} \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 2.0 \times 10^4}}$$

$= 2.92$ ns **1**

(ii) For proton,

$$t = \sqrt{\frac{2 \times 1.5 \times 10^{-2} \times 1.67 \times 10^{-27}}{1.6 \times 10^{-19} \times 2 \times 10^4}}$$

$= 0.125$ μs **1**

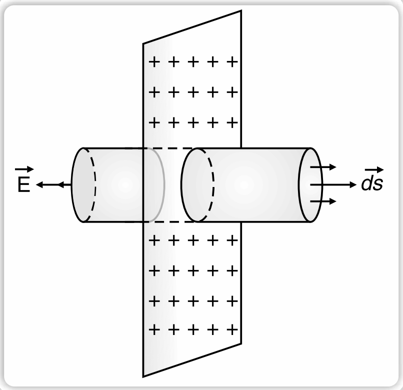
[CBSE Marking Scheme, 2018]

Q. 7. Use Gauss' law to find the electric field due to a uniformly charged infinite plane sheet. What is the direction of the field for positive and negative charge densities?

AI A & U **[CBSE Delhi Outside Set-I 2016]**

Ans. Derivation for electric field due to infinite plane Sheet of charge **2**

Directions of field ½ + ½



Symmetry of situation suggests that $\vec{E}$ is perpendicular to the plane. A Gaussian surface is considered through P like a cylinder of flat caps parallel to the plane and one cap passing through P. The plane being the plane of symmetry for the Gaussian surface.

$$\oint \vec{E}.\vec{dS} = \int_{\text{through caps}} \vec{E}.\vec{dS}$$

$\vec{E} \perp \vec{dS}$ for all over the curved surface and hence $\vec{E}.\vec{dS} = 0$

$$\int_{\text{caps}} EdS = 2E\Delta S$$

$$\Delta S = \text{area of each cap}$$

By Gauss' law

$$\oint \vec{E}.\vec{dS} = \frac{q}{\varepsilon_0} = \frac{\sigma \Delta S}{\varepsilon_0}$$

$$\therefore \quad 2E\Delta S = \frac{\sigma\Delta S}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$ **2**

If σ is positive $\vec{E}$ points normally outwards/away from the sheet.

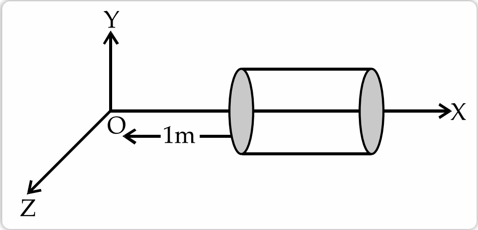
If σ is negative, $\vec{E}$ points normally inwards/towards the sheet. **1**

[CBSE Marking Scheme, 2016]

Q. 8. A hollow cylindrical box of length 1 m and area of cross-section 25 cm² is placed in a three dimensional co-ordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50\, x\,\hat{i}$, where E is in NC^{-1} and x is in meter. Find

(i) Net flux through the cylinder.

(ii) Charge enclosed by the cylinder.



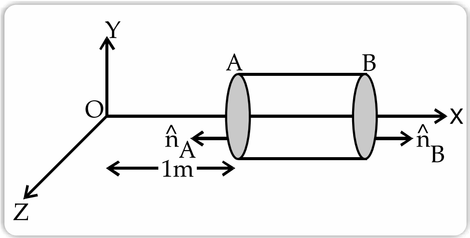
AI E

Ans. (i) Given:

$$\vec{E} = 50x\,\hat{i}$$

and $\Delta S = 25 \text{ cm}^2 \text{ or } 25 \times 10^{-4}\, m^2$

As the electric field is only along the X-axis, hence, flux will pass only through the cross-section of cylinder.



½

The magnitude of the electric field at cross-section A,

$$E_A = 50 \times 1 = 50 \text{ N/C.}$$

The magnitude of the electric field at cross-section B,

$$E_B = 50 \times 2 = 100 \text{ N/C}$$

The corresponding electric fluxes are

$$\oint \phi_A = \vec{E}\,.\,\vec{\Delta S}$$
$$= 50 \times 25 \times 10^{-4} \times \cos 180°$$
$$= -0.125 \text{ Nm}^2/\text{C}^2$$ ½

$$\oint \phi_B = \vec{E}\,.\,\vec{\Delta S}$$
$$= 100 \times 25 \times 10^{-4} \times \cos 0°$$
$$= 0.25 \text{ Nm}^2/\text{C}^2$$ ½

So, the net flux through the cylinder,

$$\oint \phi = \oint \phi_A + \oint \phi_B$$
$$= -0.125 + 0.25$$
$$= 0.125 \text{ Nm}^2/\text{C}^2$$ ½

(ii) Using the Gauss' law,

$$\phi = \oint \vec{E}.d\vec{s} = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \quad 0.125 = \frac{q}{8.85\times10^{-12}}$$

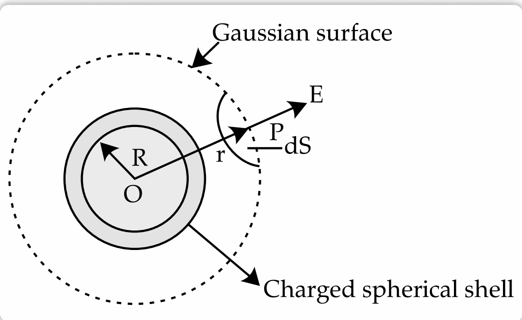
$$\Rightarrow \quad q = 8.85 \times 10^{-12} \times 0.125$$

$$= 1.106 \times 10^{-12}\,\text{C}. \qquad \mathbf{1}$$

Q. 9. Using Gauss' law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (i) outside, and (ii) inside the shell.

Plot a graph showing the variation of the electric field as function of $r > R$ and $r < R$ (r being the distance from the centre of the shell). AI A

Ans. Electric field due to a uniformly charged thin spherical shell:



(i) When point P lies outside the spherical shell: Suppose that we have to calculate electric field at the point P at a distance r ($r > R$) from its centre. Draw the Gaussian surface through point P so as to enclose the charged spherical shell. The Gaussian surface is a spherical shell of radius r and centre O. **1**

Let $\vec{E}$ be the electric field at point P, then the electric flux through area element $d\vec{s}$ is given by,

$$\Delta\phi = \vec{E}\cdot\Delta\vec{S}$$

Since $\Delta\vec{S}$ is also along normal to the surface,

$$\Delta\phi = E{\cdot}dS$$

∴ Total electric flux through the Gaussian surface is given by.

$$\phi = \oint_s EdS = E\oint_s dS$$

Now, $$\oint_s dS = 4\pi r^2$$

$$\therefore \quad \phi = E \times 4\pi r^2 \qquad \text{...(i)}$$

Since the charge enclosed by the Gaussian surface is q, according to the Gauss's law,

$$\phi = \frac{q}{\varepsilon_0} \qquad \text{...(ii)}$$

From equations (i) and (ii), we obtain

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0}$$

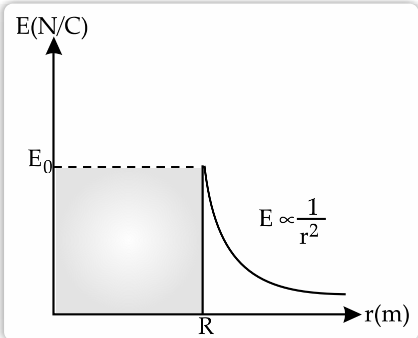
$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2} \qquad (\text{for } r > R) \quad \mathbf{1}$$

(ii) When point P lies inside the spherical shell: In such a case, the Gaussian surface encloses no charge. According to the Gauss's law,

$$E \times 4\pi r^2 = 0$$

i.e., $$E = 0 \qquad (r < R)$$

A graph showing the variation of the electric field as a function of r is shown in the figure.



1

Long Answer Type Questions (5 marks each)

Q. 1. (a) Use Gauss' law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for $r \le$ R and $r \ge$ R.

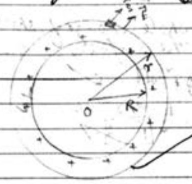
(b) Two point charges of + 1 μC and + 4 μC are kept 30 cm apart. How far from the + 1 μC charge on the line joining the two charges, will the net electric field be zero ? U & A

Ans.

Topper Answer, 2020

35 (a) Let, a point charge q is situated in a region. Electric field due to q at a radial distance r = $\frac{kq}{r^2}\hat{r} = \frac{q}{4\pi\epsilon_0 r^2}$

Now, consider a uniformly charged spherical shell of radius R containing charge q.



Let, we take a spherical Gaussian surface of radius r > R centering at centre of shell, say O.

∴ from symmetry of the figure,
(i) magnitude of $\vec{E}$ throughout the Gaussian surface is constant.
(ii) The angle between $\vec{E}$ and area vector $\vec{S}$ is constant.
Always, $\vec{E} \parallel \vec{S}$

So, using Gauss' law for a sphere of radius r,

$\oint \vec{E}\cdot d\vec{S} = \frac{q_{in}}{\epsilon_0}$

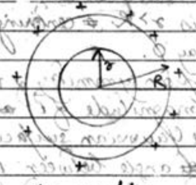
$\Rightarrow \oint E\,dS = \frac{q}{\epsilon_0}$ [$\because \vec{E}\cdot d\vec{S} = E\,dS\cos 0° = E\,dS$]

$\Rightarrow E\cdot 4\pi r^2 = \frac{q}{\epsilon_0} \Rightarrow \boxed{E = \frac{q}{4\pi\epsilon_0 r^2}}$

∴ field due to a distance r = $\frac{q}{4\pi\epsilon_0 r^2}$.

∴ The field at distance r is equal to the field as if whole charge q is placed at its centre O.

Now again, taking Gaussian surface of radius r < R inside the shell,



$\oint \vec{E}\cdot d\vec{S} = \frac{q_{in}}{\epsilon_0}$

∵ whole charge of shell is at the surface, ∴ $q_{in} = 0$.

$\Rightarrow \oint \vec{E}\cdot d\vec{S} = 0$

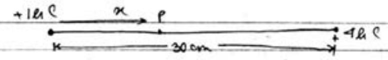
$\Rightarrow E\cdot 4\pi r^2 = 0$

$\Rightarrow \boxed{\vec{E} = 0}$

graph:

P.T.O.

(b)



Let, the electric field is 0 at distance x cm from 1μC charge. Let, the point be P.

∴ field at P due to 1μC charge = $\frac{k\times 1\mu C}{x^2}\hat{i}$

field at P due to 4μC charge = $\frac{k\times 4\mu C}{(30-x)^2}(-\hat{i})$

∴ net field is 0,

$\frac{k\times 1\mu C}{x^2} = \frac{k\times 4\mu C}{(30-x)^2}$

$\Rightarrow \frac{x^2}{(30-x)^2} = \frac{1}{4} \Rightarrow \frac{x}{30-x} = \pm\frac{1}{2}$

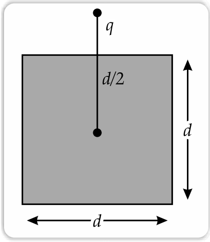
∴ $\frac{x}{30-x} = \frac{1}{2}$ $\Rightarrow 2x = 30 - x$ $\Rightarrow x = 10$

$\frac{x}{30-x} = -\frac{1}{2}$ $\Rightarrow 2x = x - 30$ $\Rightarrow x = -30$ (absurd, since field in same direction)

∴ field is 0 at distance 10 cm from 1μC charge. Ans.

Q. 2. (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' law 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. A & U **[CBSE Delhi 2018]**

Ans. (a) Definition of electric flux 1

Stating scalar/ vector ½

Gauss's Theorem ½

Derivation of the expression for electric flux 1

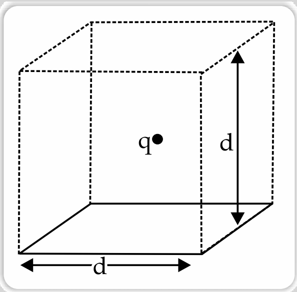
(ii) Explanation of change in electric flux 2

(i) Electric flux through a given surface is defined as the dot product of electric field and area vector over that surface. 1

Alternatively, $\phi = \int_s \vec{E} \cdot d\vec{S}$

Electric flux, through a surface equals the surface integral of the electric field over that surface. ½

It is a scalar quantity. ½



Constructing a cube of side 'd' so that charge 'q' gets placed within of this cube (Gaussian surface) According to Gauss' law the Electric flux,

$$\phi = \frac{\text{Charge enclosed}}{\varepsilon_0}$$

$$= \frac{q}{\varepsilon_0}$$ ½

This is the total flux through all the six faces of the cube.

Hence, electric flux through the square

$$\frac{1}{6} \times \frac{q}{\varepsilon_0} = \frac{q}{6\varepsilon_0}$$ ½

(ii) If the charge is moved to a distance d and the side of the square is doubled, the cube will be constructed to have a side $2d$ but the total charge enclosed in it will remain the same. Hence the total flux through the cube and therefore the flux through the square will remain the same as before. [Deduct 1 mark if the student just writes No change/not affected without giving any explanation.] **1+1**

Q. 3. (a) Use Gauss' theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

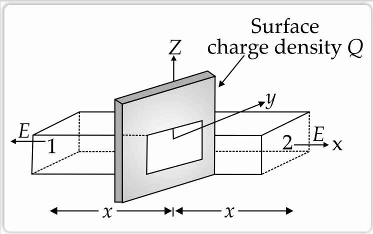
(b) An infinitely large thin plane sheet has a uniform surface charge density +σ. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

AI A **[CBSE Delhi Outside Set-I 2017]**

Ans. (a) Using Gauss's theorem to find E due to an infinite plane sheet of charge 3

(b) Expression for the work done to bring charge q from infinity to r 2

(a)



2

$$\oint E.dS = \frac{q}{\varepsilon_0}$$

The electric field E points outwards normal to the sheet. The field lines are parallel to the Gaussian surface except for surfaces 1 and 2.

Hence the net flux $= \oint E.dS = \frac{q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = 2EA$

where A is the area of each of the surfaces 1 and 2.

$$\therefore \oint E.dS = \frac{q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = 2EA$$

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

(b) $$W = q\int_{\infty}^{r} \vec{E}.\vec{dr}$$ ½

$$= q\int_{\infty}^{r}(-Edr)$$ ½

$$= -q\int_{\infty}^{r}\left(\frac{\sigma}{2\varepsilon_0}\right)dr$$ ½

$$= \frac{q\sigma}{2\varepsilon_0}|\infty - r|$$

$$= (\infty)$$ **[CBSE Marking Scheme, 2017]** ½

COMPETENCY BASED QUESTIONS

Case based MCQs

I. Read the following text and answer any four of the following questions on the basis of the same:

Faraday Cage: A Faraday cage or Faraday shield is an enclosure made of conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the encloser is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage.

Q. 1. Which of the following material can be used to make a Faraday cage ?

(A) Plastic **(B)** Glass

(C) Copper **(D)** Wood

Ans. Option (C) is correct.

Explanation: A Faraday cage or Faraday shield is an enclosure made of a conducting material.

Since copper is the only metal given in the list of options, copper is the correct answer.

Q. 2. Example of a real-world Faraday cage is:

(A) car **(B)** plastic box

(C) lighting rod **(D)** metal rod

Ans. Option (A) is correct.

Explanation: Cars are example of Faraday Cages in the real world. Cars can help keep us safe from lightning. Its metal body acts as a Faraday Cage.

Q. 3. What is the electrical force inside a Faraday cage when it is struck by lightning ?

(A) The same as the lightning

(B) Half that of the lightning

(C) Zero

(D) A quarter of the lightning

Ans. Option (C) is correct.

Explanation: The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero.

Q. 4. If isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have a charge equal to:

(A) Zero **(B)** $+q$

(C) $-q$ **(D)** $+2q$

Ans. Option (C) is correct.

Explanation: If a charge is placed inside an ungrounded Faraday shield without touching the walls of the internal face of the shield becomes charged with $-q$, and $+q$ accumulates on the outer face of the shield. If the cage is grounded, the excess charges will be neutralized by the ground connection.

Q. 5. A point charge of 2 C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be:

(A) 1.9×10^5 Nm^2/C entering the surface.

(B) 1.9×10^5 Nm^2/C leaving the surface.

(C) 2.26×10^5 Nm^2/C leaving the surface.

(D) 2.26×10^5 Nm^2/C entering the surface.

Ans. Option (D) is correct.

Explanation: The number of electric field lines passing through the cube normally and leaving the surface = Q/ε_0

$$Q = 2\,\mu C = 2 \times 10^{-6}\,C$$

$$\varepsilon_0 = 8.85 \times 10^{-12}\,C^2/Nm^2$$

$$\therefore Q/\varepsilon_0 = 2.26 \times 10^5\,Nm^2/C$$

II. Read the given text and answer any four of the following questions on the basis of the same:

Triboelectric series:

The triboelectric series is a list that ranks materials according to their tendency to gain or lose electrons. The process of electron transfer as a result of two objects coming into contact with one another and then separating is called triboelectric charging. During such an interaction, one of the two objects will always gain electrons (becoming negatively charged) and the other object will lose electrons (becoming positively charged). The relative position of the two objects on the triboelectric series will define which object gains electrons and which object loses electrons.

In triboelectric series, materials are ranked from high to low in terms of the tendency for the material to lose electron. If an object high up on this list (Glass, for example) is rubbed with an object low down on the list (Teflon, for example), the glass will lose electrons to the teflon. The glass will, in this case, become positively charged and the teflon will become negatively charged. Materials in the middle of the list (steel and wood, for example) are items those do not have a strong tendency to give up or accept electrons.

Tend to lose electrons ↑

Human hand
Glass
Human hair
Nylon
Cat fur
Silk
Cotton
Steel
Wood
Amber
Ebonite
Plastic wrap
Teflon

↓ Tend to gain electrons

Q. 1. Materials in the upper position have _____ tendency to become positively charged.

(A) low **(B)** high
(C) no **(D)** medium

Ans. Option (B) is correct.

Explanation: In triboelectric series, materials are ranked from high to low in terms of the tendency for the material to lose electron i.e., they are ranked high to low tendency of getting positively charged.

Q. 2. Name two materials which do not have a strong tendency to give up or accept electrons.

(A) Ebonite, Nylon **(B)** Plastic wrap, Teflon
(C) Nylon, cat fur **(D)** Steel, wood

Ans. Option (D) is correct.

Explanation: Materials in the middle of the list (steel and wood, for example) are items those do not have a strong tendency to give up or accept electrons.

Q. 3. If human hair is rubbed with amber, how those will be charged?

(A) Both negative
(B) Both positive
(C) Hair will be positively charged, Amber will be negatively charged.
(D) Hair will be negatively charged, Amber will be positively charged.

Ans. Option (C) is correct.

Explanation: Since human hair is placed at the upper portion of the list, it will leave electron and will be positively charged. Since amber is placed at the lower portion of the list, it will accept the electron and will be negatively charged.

Q. 4. Triboelectric charging is the process of electron transfer between two objects

(A) By contact
(B) Without contact
(C) By any one of the above
(D) By none of the above

Ans. Option (A) is correct.

Explanation: The process of electron transfer as a result of two objects coming into contact with one another and then separating is called triboelectric charging.

Q. 5. The object which loses electron becomes _____ charged and the object gains electron becomes ______ charged.

(A) negatively, negatively
(B) positively, positively
(C) positively, negatively
(D) negatively, positively

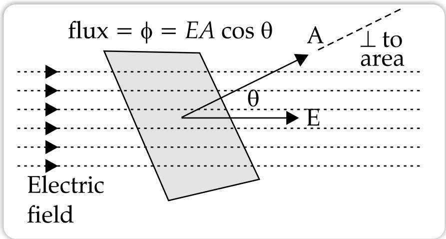
Ans. Option (C) is correct.

Explanation: During triboelectric charging, one of the two objects always gains electrons and become negatively charged. The other object loses electrons and become positively charged.

Case based Subjective Questions

I. Read the following news article and answer any four questions that follows:

The total number of electric field lines passing a given area in a unit time is defined as the electric flux.



If the plane is normal to the flow of the electric field, the total flux is given as:

$$\phi = EA$$

When the same plane is tilted at an angle θ, the projected area is given as A cos θ and the total flux through this surface is given as

$$\phi = EA \cos\theta$$

where,

- E is the magnitude of the electric field.
- A is the area of the surface through which the electric flux is to be calculated.
- θ is the angle made by the plane and the axis parallel to the direction of flow of the electric field.

1. If a unit positive charge is kept in the air, then what is the total flux coming out of unit charge?

Ans. The total flux coming out is ε_0^{-1}.

2. What is the value of electric flux (Φ) on a plane of area 1 m² on which an electric field of 2 V/m crosses with an angle of 30°.

Ans.
$$\phi = \text{EA}\cos\theta$$
$$= (2)(1)(\cos 90° - 30°)$$
$$= (2)(1)(\cos 60°)$$
$$= (2)(1)(1/2)$$
$$= 1 \text{ Vm}$$

3. When is the flux through a surface taken as positive?

Ans. It will be positive when the flux lines are directed outwards.

4. On which factor the net flux through a closed surface in a given medium depends?

Ans. It depends on the net charge enclosed.

5. A plane surface is rotated in a uniform electric field. When is the flux of the electric field through the surface maximum ?

Ans. It is when the surface is perpendicular to the field .

Solutions for Practice Questions (Topic-1)

Multiple Choice Questions

Ans. 8. Option (B) is correct.

Explanation: The triboelectric effect is a type of contact electrification on which certain materials become electrically charged after they come into frictional contact with a different material.

Ans. 12. Option (A) is correct.

Explanation: The magnitude of the electric force F is directly proportional to the amount of an electric charge, q_1, multiplied by the other, q_2, and inversely proportional to the square of the distance 'r' between their centres.

Ans. 13. Option (C) is correct.

Explanation: When a neutral body gains electrons, it becomes negatively charged. It means that the quantity of negative charge present is more than the quantity of positive charge present.

Assertion & Reason

Ans. 2. Option (D) is correct.

Explanation: Electric lines of force never cross each other. If they cross each other, then at that point, we get two directions of electric field, which is not possible. So, the assertion is false. The resultant electric field at a point is a vector sum of the electric fields at that point.

Solutions for Practice Questions (Topic-2)

Multiple Choice Questions

Ans. 3. Option (D) is correct.

Explanation: If a charge q is enclosed inside Gaussian surface then according to Gauss law $\oint \mathbf{E.dS} = q/\varepsilon_0$.

Ans. 5. Option (A) is correct.

Explanation: The Gauss' law is applicable for any closed surface. Hence, option (A) is correct.

Ans. 7. Option (D) is correct.

Explanation: If the electric field is E and the area is A, the electric flux associated with the area is $\phi = EA \cos\theta$.

Where θ represents the angle formed between the surface and the electric field.

The electric flux is clearly dependent on the electric field strength, area, and angle between the surface and the electric field.

Very Short Answer Type Questions

Ans. 3. Electric flux remains unaffected.

[**Note:** (As per the Hindi translation), change in Electric field is being asked, hence give credit if student write answer as decreases]

[CBSE Marking Scheme, 2016]

Ans. 7. The net charge enclosed by the surface and the permittivity of the medium.

[Gauss's laws mathematical expression is $\phi = Q_{enclosed} / \varepsilon_0$]

Ans. 11. The electric flux is the number of electric field lines crossing an imaginary area. So, it is a scalar quantity.

REFLECTIONS

After completion of this chapter, are you now clear with the following concepts:

(a) Quantization of charges

(b) Electrostatic shielding

(c) Charging by induction

(d) Gaussian Surface

(e) Superposition Principle

❑❑