

PHYSICS

Vol.
II

Based on Latest Paper Pattern and Textbook

Van de graff generator:
A Van de Graaff generator will apply a charge to its dome and anything else in contact with the dome. When the object in contact is a person, the person is slowly charged. Similar charges accumulating on the person's hair cause repulsion amongst hair strands causing them to stand up.

Handwritten notes on the chalkboard:
Metal sphere
DC Gen.
 q^+
 $i = \frac{dq}{dt}$; For DC $i \rightarrow I = \frac{\Delta q}{\Delta t}$
 $v = \frac{dw}{dq}$; For DC $v \rightarrow V = \frac{\Delta w}{\Delta q}$
Energy gain = $\Delta W = V \cdot \Delta q$
 $\therefore \Delta z = \frac{V \cdot T \cdot \Delta t}{V \cdot I}$

Std. XII sci.

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PERFECT PHYSICS (Vol. II)

Std. XII Sci.

Salient Features

- Written as per **Latest Board Paper Pattern**
- Subtopic-wise segregation for powerful concept building
- Complete coverage of Textual Exercise Questions, Intext Questions and Numericals
- Marks provided to the Questions as per relevant weightage wherever deemed necessary
- Relevant Previous Years' Board Questions:
March 2013 to July 2023
- Each chapter contains:
 - 'Quick Review' of the chapter for quick revision
 - 'Apply Your Knowledge' section for application of concepts
 - 'Important Formulae' and 'Solved Examples' to cover numerical aspect in detail
 - 'Exercise' to provide Theory questions, Numericals and MCQs for practice
 - 'Competitive Corner' to give the glimpse of prominent competitive examinations
 - 'Topic Test' at the end of each chapter for self-assessment
- Includes Important Features for holistic learning:
 - *About the Chapter* - *Reading Between the Lines* - *NCERT Corner*
 - *Enrich Your Knowledge* - *Gyan Guru* - *Strategy*
 - *Connections* - *Caution*
- Q.R. codes provide:
 - The Video/pdf links boosting conceptual retention
 - Solutions of Numericals for Practice and Topic Tests
 - Model Question Paper along with Solution
- Includes Board Question Paper of February 2024 (Solution in pdf format through QR code)

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PREFACE

Perfect Physics Vol. II, Std. XII Sci. is intended for every Maharashtra State Board aspirant of Std. XII, Science. The scope, sequence, and level of the book are consistent with the latest textbook released by Maharashtra State board.

At a crucial juncture of cracking a career defining board examination, we wanted to create a book that not just develops the necessary knowledge, tools and skills required to excel in the examination in students but also enables them to appreciate the beauty of subject and piques their curiosity.

We believe the students need meaningful content presented in a way that is easy to read and understand rather than being mired down with facts and information. They do much better when they understand why Physics is relevant to their everyday lives.

Comprehension of Physics eventuates naturally when subject is studied systematically with sincere and dedicated efforts.

The Core of Physics lies in its concepts. Therefore, writing clear and lucid explanations of fundamental concepts is our highest priority. Moreover, special care has been taken to ensure that the topics are presented in a logical order.

Every chapter in this book begins with '*About the Chapter*' that offers a brief introduction of the chapter and orients students towards the topic from examination point of view. The coherent Question/Answer approach helps students expand their horizon of understanding of the concepts. Though Physics is communicated in English, it is expressed in Mathematics. To help the students hone their problem-solving skills, ample numericals of different types are amalgamated. Log calculations are presented as seemed necessary to give students idea of solutions expected in board examination.

The scope of the book extends beyond the State Board examination as it also offers a plethora of Multiple Choice Questions (MCQs) in order to familiarize the students with the pattern of competitive examinations.

In addition, the Topic-Test has been carefully crafted to focus on concepts, thus providing the students with a quick opportunity for self-assessment and giving them an increased appreciation of chapter-preparedness. '*Model Question Paper*' based on latest paper pattern is provided along with solution which can be accessed through QR code to help students assess their preparedness for final board examination.

We believe; amongst building concepts, advancing into numbers and equations, it is essential to ponder underlying implications of subject. Students should read from references, visit authentic websites, watch relevant fascinating links and even experiment on their own following proper safety guidelines. We have added several features to nurture the curiosity of students.

As famous hat detective Sherlock Holmes has pointed, **people see, they do not observe**. By becoming attentive to their surroundings students can easily perceive how Physics has touched entire spectrum of life. The very realization is catalytic enough for students to admire and further dive into this compelling subject.

Our **Perfect Physics Vol. II, Std. XII Sci.** adheres to our vision and achieves several goals: **building concepts, developing competence to solve numericals, recapitulation, self-study, self-assessment and student engagement**—all while encouraging students toward cognitive thinking.

The flow chart on the adjacent page will walk you through the key features of the book and elucidate how they have been carefully designed to maximize the student learning.

We hope the book benefits the learner as we have envisioned.

Publisher

Edition: Sixth

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you. Please write to us on: mail@targetpublications.org

KEY FEATURES

'About the Chapter' is a short introduction designed to stimulate students' appetite for the topic.

About the chapter

Reading between the lines

Reading between the lines provides elaboration or missing fragments of concept which is essential for complete understanding of the concept.

Strategy provides a step-by-step process to break a complex numerical problem into simpler parts.

Strategy

Caution

Caution helps students to be watchful against commonly made mistakes.

NCERT Corner covers information from NCERT textbook relevant to topic.

NCERT Corner

Connections

Connections enable students to interlink concepts covered in different chapters.

QR code provides:

- i. Access to a video/PDF in order to boost understanding of a concept or activity
- ii. Solutions to Numericals for Practice
- iii. Solutions to the Topic Tests
- iv. Model Question Paper with solution
- v. Solution to Board Question Paper of February 2024

QR Codes

Continue...

KEY FEATURES

Enrich Your Knowledge

Enrich Your Knowledge presents fascinating information about the concept covered.

Gyan Guru illustrates real life applications or examples related to the concept discussed.

GG-Gyan Guru

Apply Your Knowledge

Apply Your Knowledge includes challenging questions.

Quick review includes tables/ flow chart to summarize the key points in chapter.

Quick Review

Important Formulae

Important Formulae includes all of the key formulae in the chapter.

Competitive Corner includes selective questions from prominent [NEET (UG), JEE (Main), MHT CET] competitive exams based entirely on the syllabus covered in the chapter.

Competitive Corner

Board Questions

Includes relevant Board questions from March 2013 to July 2023

PAPER PATTERN

- There will be single question paper of 70 Marks and practical examination of 30 Marks in Physics.
- Duration of the question paper will be 3 hours.

Section A: (18 Marks)

This section will contain Multiple Choice Questions and Very Short Answer (VSA) type of questions.

There will be 10 MCQs and 8 VSA type of questions, each carrying one mark.

Students will have to attempt all these questions.

Section B: (16 Marks)

This section will contain 12 Short Answer (SA-I) type of questions, each carrying 2 marks.

Students will have to attempt any 8 questions.

Section C: (24 Marks)

This section will contain 12 Short Answer (SA-II) type of questions, each carrying 3 marks.

Students will have to attempt any 8 questions.

Section D: (12 Marks)

This section will contain 5 Long Answer (LA) type of questions, each carrying 4 marks.

Students will have to attempt any 3 questions.

Distribution of Marks According to the Type of Questions

Type of Questions		
MCQ	1 Mark each	10 Marks
VSA	1 Mark each	8 Marks
SA - I	2 Marks each	16 Marks
SA - II	3 Marks each	24 Marks
LA	4 Marks each	12 Marks

Percentage wise distribution of marks	
Theory	63%
Numerical	37%

Disclaimer


This reference book is transformative work based on latest Textbook of Std. XII Physics published by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune. We the publishers are making this reference book which constitutes as fair use of textual contents which are transformed by adding and elaborating, with a view to simplify the same to enable the students to understand, memorize and reproduce the same in examinations.

This work is purely inspired upon the course work as prescribed by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune. Every care has been taken in the publication of this reference book by the Authors while creating the contents. The Authors and the Publishers shall not be responsible for any loss or damages caused to any person on account of errors or omissions which might have crept in or disagreement of any third party on the point of view expressed in the reference book.

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16	Semiconductor Devices	4	5	365
	Board Question Paper: February 2024 (Solution in pdf format through QR code)			399
•	Scan the given Q.R. Code in <i>Quill – The Padhai App</i> to view the Model Question Paper with Solution.			

Chapters 1 to 7 are a part of Std. XII: Perfect Physics (Vol. I)

[Reference: Maharashtra State Board of Secondary and Higher Secondary Education, Pune - 04]

- Note:**
1. * mark represents Textual question.
 2. # mark represents Intext question.
 3. + mark represents Textual examples.
 4.  symbol represents textual questions that need external reference for an answer.

Scan the adjacent QR Code to know more about our **“Model Question Papers with solutions”** book for Std. XII (Sci.) and Gear up yourself to score more in the XII Board Examination.

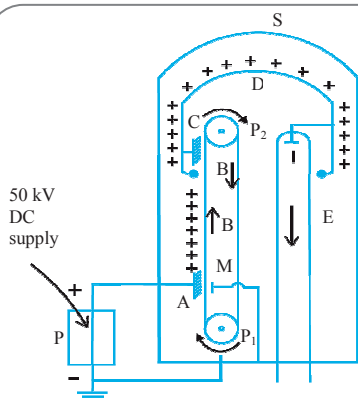


Scan the adjacent QR Code to know more about our **“Board Questions with solution”** book for Std. XII (Sci.) and Learn about the types of questions that are asked in the XII Board Examination.



8

Electrostatics



About the chapter...

The chapter can be divided into three parts. First part introduces students to the application of the Gauss' law of electrostatic to the different symmetrical charge distributions. Second part of the chapter deals with the electric potential and potential energy of system of charges. The chapter further on continues to the study the electric polarisation and introduces concept of capacitors.

Chapter is allotted weightage of 6 marks with option and 4 marks without option. Concepts and computation together form the backbone of this chapter. Therefore, equal emphasis should be given to both theory questions as well as numericals of this chapter. The chapter is important from MCQ's point of view.

CONTENTS AND CONCEPTS

- | | |
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| 8.4 Electric Potential due to a Point Charge, a Dipole and a System of Charges | 8.11 Displacement Current |
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| 8.7 Conductors and Insulators, Free Charges and Bound Charges Inside a Conductor | |

8.1 Introduction

Q.1. Can you recall? (Textbook page no. 186)

i. What are conservative forces? [2 Marks]

Ans:

- If work done by or against a force is independent of the actual path, the force is said to be a conservative force.
- During work done by a conservative force, the mechanical energy is conserved.
- Work done is completely recoverable.

Example: gravitational force, magnetic force etc.

ii. What is potential energy? [1 Mark]

Ans: Potential energy is the work done against conservative force (or forces) in achieving a certain position or configuration of a given system.

iii. What is Gauss' law and what is a Gaussian surface? [3 Marks]

Ans: Gauss' law: The flux of the net electric field through a closed surface equals the net charge enclosed by the surface divided by ϵ_0 .

$$\int \vec{E} \cdot d\vec{s} = \frac{q}{\epsilon_0}$$

where q is the total charge within the surface.

Mathematically,

$$\phi = \oint \vec{E} \cdot d\vec{s} = \frac{q}{\epsilon_0}$$

where ϕ is the total flux coming out of a closed surface and q is the total charge inside the closed surface.

Gaussian surface: All the lines of force originating from a point charge penetrate an imaginary three dimensional surface. The total flux $\phi_E = q/\epsilon_0$. The same number of lines of force will cross the surface of any shape. The total flux through both the surfaces is the same.

Calculating flux involves calculating $\int \vec{E} \cdot d\vec{s}$,

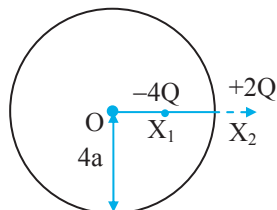
hence it is convenient to consider a regular surface surrounding the given charge distribution. A surface enclosing the given charge distribution and symmetric about it is a



Gaussian surface. For example, if we have a point charge the Gaussian surface will be a sphere. If the charge distribution is linear, the Gaussian surface would be a cylinder with the charges distributed along its axis. Gaussian surface offers convenience of calculating the integral $\int \vec{E} \cdot d\vec{s}$. A Gaussian surface is purely imaginary and does not exist physically.

***Q.2. Two charges of magnitudes $-4Q$ and $+2Q$ are located at points $(2a, 0)$ and $(5a, 0)$ respectively. What is the electric flux due to these charges through a sphere of radius $4a$ with its centre at the origin? [2 Marks]**

Ans:



Given: $d(OX_1) = 2a$
 $d(OX_2) = 5a$
 Radius, $r = 4a$

A Gaussian surface is of radius $4a$ and contains charge $-4Q$ inside.

As the flux depends only upon charge enclosed by Gaussian surface, required flux according to Gauss' law would be,

$$\phi = \frac{q}{\epsilon_0} = \frac{-4Q}{\epsilon_0}$$

Q.3. Write common steps involved in calculating electric field intensity by using Gauss' theorem. [2 Marks]

Ans: Common steps involved in calculating electric field intensity by using Gauss' theorem:

- i. Identify the charge distribution as linear/cylindrical/spherical charge density.
- ii. Visualize a Gaussian surface justifying its symmetry for the given charge distribution.
- iii. Obtain the flux by Gauss' law and mark as equation (1).
- iv. With the electric field intensity E as unknown, obtain electric flux by calculation, using geometry of the structure and symmetry of the Gaussian surface and mark as equation (2).
- v. Equating equation (1) and equation (2), electric field intensity E can be calculated.

Q.4. State importance of Gauss' law. [2 Marks]

Ans:

- i. Gauss' law gives the relationship between the electric charge and its electric field.

- ii. It also provides equivalent methods for finding electric field intensity by relating values of the field at a closed surface and the total charges enclosed by that surface.
- iii. It is a powerful tool which can be applied for the calculation of the electric field when it originates from charge distribution of sufficient symmetry.

SOLVED EXAMPLES

Q.5. A plane area of 100 cm^2 is placed in uniform electric field of 100 N/C such that the angle between area vector and electric field is 60° . Determine the electric flux over the surface. [2 Marks]

Solution:

Given: $ds = 100 \text{ cm}^2 = 100 \times 10^{-4} \text{ m}^2 = 10^{-2} \text{ m}^2$,
 $E = 100 \text{ N/C}$, $\theta = 60^\circ$

To find: Electric flux (ϕ)

Formula: $\phi = E ds \cos \theta$

Calculation: From formula,
 $\phi = 100 \times 10^{-2} \times \cos 60^\circ$

$$\therefore \phi = 1 \times \frac{1}{2}$$

$$\therefore \phi = 0.5 \text{ Nm}^2/\text{C}$$

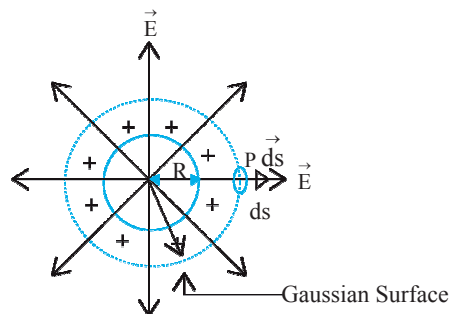
Ans: The electric flux over the surface is $0.5 \text{ Nm}^2/\text{C}$.

8.2 Application of Gauss' law

Q.6. Obtain expression for electric field intensity due to uniformly charged spherical shell or hollow sphere. [4 Marks]

Ans:

- i. Consider a sphere of radius R with its centre at O , charged to a uniform surface charge density σ placed in a dielectric medium of permittivity ϵ ($\epsilon = \epsilon_0 k$). The total charge on the sphere, $q = \sigma \times 4\pi R^2$.
- ii. To find the electric field intensity at a point P , at a distance r from the centre of the charged sphere, imagine a concentric Gaussian sphere of radius r passing through P as shown in the figure below. Let ds be a small area around the point P on the Gaussian surface.



Uniformly charged spherical shell or hollow sphere



- iii. By Gauss' theorem, the net flux through a closed Gaussian surface,

$$\phi = \frac{q}{\epsilon_0} \text{ (for air/vacuum } k=1) \quad \dots(1)$$

where q is the total charge inside the closed surface.

- iv. Due to symmetry and spheres being concentric, the electric field at each point on the Gaussian surface has the same magnitude E and it is directed radially outward. Also, the angle between the direction of E and the normal to the surface of the sphere (ds) is zero i.e., $\cos \theta = 1$

$$\therefore \vec{E} \cdot \vec{ds} = E ds \cos \theta = E ds$$

$$\therefore \text{Flux } d\phi \text{ through the area } ds, d\phi = E ds$$

Total electric flux through the Gaussian surface

$$\phi = \oint \vec{E} \cdot \vec{ds} = \oint E ds = E \oint ds$$

$$\therefore \phi = E 4\pi r^2 \quad \dots(2)$$

- v. From equations (1) and (2),

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

$$\therefore E = \frac{q}{4\pi\epsilon_0 r^2} \quad \dots(3)$$

Substituting $q = \sigma \times 4\pi R^2$ in equation (3),

$$E = \sigma \times \frac{4\pi R^2}{4\pi\epsilon_0 r^2}$$

$$\therefore E = \frac{\sigma R^2}{\epsilon_0 r^2}$$

From equation (3) it can be seen that, the electric field at a point outside the shell is the same as that due to a point charge.

- vi. Direction of electric field is outward if shell or sphere is positively charged and inward if it is negatively charged.
- vii. Thus, it can be concluded that a uniformly charged sphere is equivalent to a point charge at its centre.

viii. **Special cases:**

Case (a): If point P lies on the surface of the charged sphere, $r = R$

$$\therefore E = \frac{q}{4\pi\epsilon_0 R^2} = \frac{\sigma}{\epsilon_0}$$

Case (b): If point P lies inside the sphere
Since there are no charges inside, $\sigma = 0$

$$\therefore E = 0$$

READING BETWEEN THE LINES



- Points (i) to (v) of the above answer are presented as per sequence of common steps described in Q.3.



CAUTION

If charged object is placed in any medium other than air or vacuum, ϵ_0 in expression for electric field intensity will change to $k\epsilon_0$ where k is dielectric constant of that medium.

Q.7. Obtain an expression for electric field intensity due to an infinitely long straight charged wire or charged conducting cylinder.

[4 Marks]

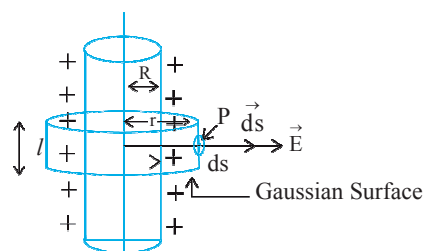
OR

Derive an expression for electric field intensity due to an infinitely long straight charged wire.

[2 Marks][July 23]

Ans:

- i. Consider a uniformly charged wire of infinite length having a constant linear charge density λ (charge per unit length), kept in a medium of permittivity ϵ ($\epsilon = \epsilon_0 k$).
- ii. To find the electric field intensity at P , at a distance r from the axis of the charged wire, imagine a coaxial Gaussian cylinder of length l and radius r (closed at each end by plane caps normal to the axis) passing through the point P as shown in the figure. Consider a very small area ds at the point P on the Gaussian surface.



Infinitely long straight charged wire (cylinder)

- iii. By Gauss' theorem, the net flux through a closed surface,

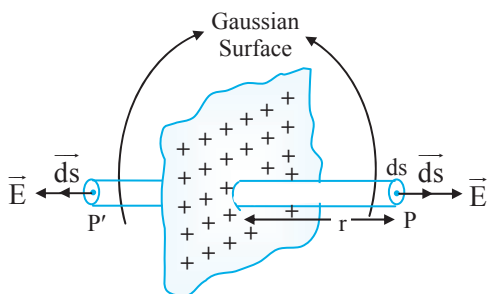
$$\phi = \frac{q}{\epsilon_0} \text{ (for air/vacuum } k = 1) \quad \dots(1)$$

where q is the total charge inside the closed surface.

- iv. By symmetry, the magnitude of the electric field will be the same at all the points on the curved surface of the cylinder and will be directed radially outward. The angle between the direction of \vec{E} and the normal to the curved

Page no. 4 is purposely left blank.

To see complete chapter buy **Target Notes** or **Target E-Notes**

**Charged infinite plane sheet**

- iii. By Gauss' theorem, the net flux through a closed surface

$$\phi = \frac{q}{\epsilon_0} \text{ (for air/vacuum } k = 1) \quad \dots(1)$$

where q is the total charge inside the closed surface.

- iv. By symmetry electric field is perpendicular to plane sheet and directed outwards, having same magnitude at a given distance on either sides of the sheet. The electric field is at right angles to the end caps and away from the plane. Its magnitude is the same at P and P' . The flux passing through the curved surface is zero as the electric field is tangential to this surface.

- \therefore The total flux through the closed Gaussian surface is given by,

$$\begin{aligned} \phi &= [\oint E ds]_P + [\oint E ds]_{P'} + [\oint E ds]_{\text{curved surface}} \\ &= EA + EA \\ &\dots \left(\begin{array}{l} \because \theta = 0 \text{ for ends } P \text{ and } P'; \cos \theta = 1 \\ \text{and } \theta = 90^\circ \text{ for curved surface; } \cos \theta = 0 \end{array} \right) \end{aligned}$$

$$\therefore \phi = 2EA \quad \dots(2)$$

- v. From equations (1) and (2),

$$\frac{q}{\epsilon_0} = 2EA$$

$$\therefore \frac{\sigma A}{\epsilon_0} = 2EA \quad \dots \left(\because \sigma = \frac{q}{A} \right)$$

$$\therefore E = \frac{\sigma}{2\epsilon_0}$$

This is the required expression.

- vi. Direction of electric field is outward if sheet is positively charged and inward if it is negatively charged.

READING BETWEEN THE LINES

- Points (i) to (v) of the above answer are presented as per sequence of common steps described in Q.3.

ENRICH YOUR KNOWLEDGE

- Value of permittivity of free space is $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$
 $\therefore \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$

Hence, in calculations $\frac{1}{4\pi\epsilon_0}$ is retained for easier substitutional value.

- Linear charge density, $\lambda = \frac{q}{l}$

$$\text{Surface charge density, } \sigma = \frac{q}{A}$$

$$\text{Volume charge density, } \rho = \frac{q}{V}$$

SOLVED EXAMPLES

- +Q.11. A sphere of radius 10 cm carries a charge of 1 μC . Calculate the electric field

- at a distance of 30 cm from the centre of the sphere
- at the surface of the sphere and
- at a distance of 5 cm from the centre of the sphere.

(Example 8.1 of Textbook page no. 187)

[3 Marks]

Solution:

Given: $q = 1 \mu\text{C} = 1 \times 10^{-6} \text{ C}$
 $R = 10 \text{ cm}$
 $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$

$$\therefore \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

To find: Electric Field (E)

$$\text{Formula: } E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

Calculation:

- i. For $r = 30 \text{ cm} = 0.3 \text{ m}$

From formula,

$$\begin{aligned} E &= \frac{9 \times 10^9 \times 10^{-6}}{0.3^2} \\ &= \frac{9 \times 10^9 \times 10^{-6}}{9 \times 10^{-2}} = 10^5 \text{ N/C} \end{aligned}$$

- ii. $r = R = 10 \text{ cm} = 0.10 \text{ m}$

From formula,

$$\begin{aligned} E &= \frac{9 \times 10^9 \times 10^{-6}}{0.1^2} = 9 \times 10^{9-6+2} \\ &= 9 \times 10^5 \text{ N/C} \end{aligned}$$

- iii. $r = 5 \text{ cm} = 0.05 \text{ m}$

$\therefore r < R$, electric field inside the sphere is zero
i.e., $E = 0$

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To see complete chapter buy **Target Notes** or **Target E-Notes**

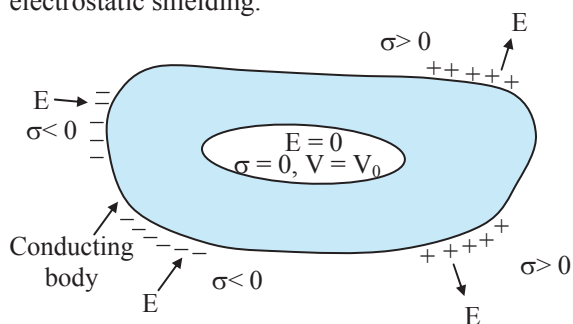


The discharging due to lightning passes to the ground through the metallic body of the car thereby keeping person sitting inside safe.

NCERT Corner

Electrostatic shielding due to cavity in conductor:

Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric influence, the field inside the cavity is always zero. This is known as electrostatic shielding.



Q.64. State reason for restricted movements of charge carriers in electrolytic conductors.

[1 Mark]

Ans: In electrolytic conductors, positive and negative ions act as charge carriers but their movements are restricted by the electrostatic force between them and the external electric field.

8.8 Dielectrics and Electric Polarisation

Q.65. Explain concept of electric polarisation.

[2 Marks]

Ans:

- i. Certain substances when are placed in an external field, their positive and negative charges get displaced in opposite directions and the molecules develop a net dipole moment. This is called polarization of the material.
- ii. The dipole moment per unit volume is called polarization and is denoted by \vec{P} . For linear isotropic dielectrics $\vec{P} = \chi_e \vec{E}$.

Where, χ_e is a constant called electric susceptibility of the dielectric medium.

- iii. **Examples:** Dielectrics substances show electric polarisation.

GG - Gyan Guru



Elevators can act as unintended Faraday cages, shielding cell phones and radios from signal from outside.

This is the precise reason why upon entering an elevator mobile phones become unfunctional



Q.63. Define free charges and bound charges.

[2 Marks]

Ans: Free charges: In metallic conductors, the electrons in the outermost shells of the atoms are loosely bound to the nucleus and hence can easily get detached and move freely inside the metal. When an external electric field is applied, they drift in a direction opposite to the direction of the applied electric field. These charges are called free charges.

Bound charges: The nucleus, which consist of the positive ions and the electrons of the inner shells, remain held in their fixed positions. These immobile charges are called bound charges.

ENRICH YOUR KNOWLEDGE



In every atom there is a positively charged nucleus and there are negatively charged electrons surrounding it. The negative charges form an electron cloud around the positive charge. These two oppositely charged regions have their own centres of charge (where the effective charge is located). The centre of negative charge is the centre of mass of negatively charged electrons and that of positive charge is the centre of mass of positively charged protons in the nucleus.

Q.66. What is electric susceptibility of dielectric medium?

[2 Marks]

Ans:

- i. A quantity that describes electrical behaviour of a dielectric is called as electric susceptibility of dielectric medium.
- ii. It is denoted by χ_e .
- iii. It is constant for a dielectric but has different values for different dielectrics.
- iv. For vacuum $\chi_e = 0$.

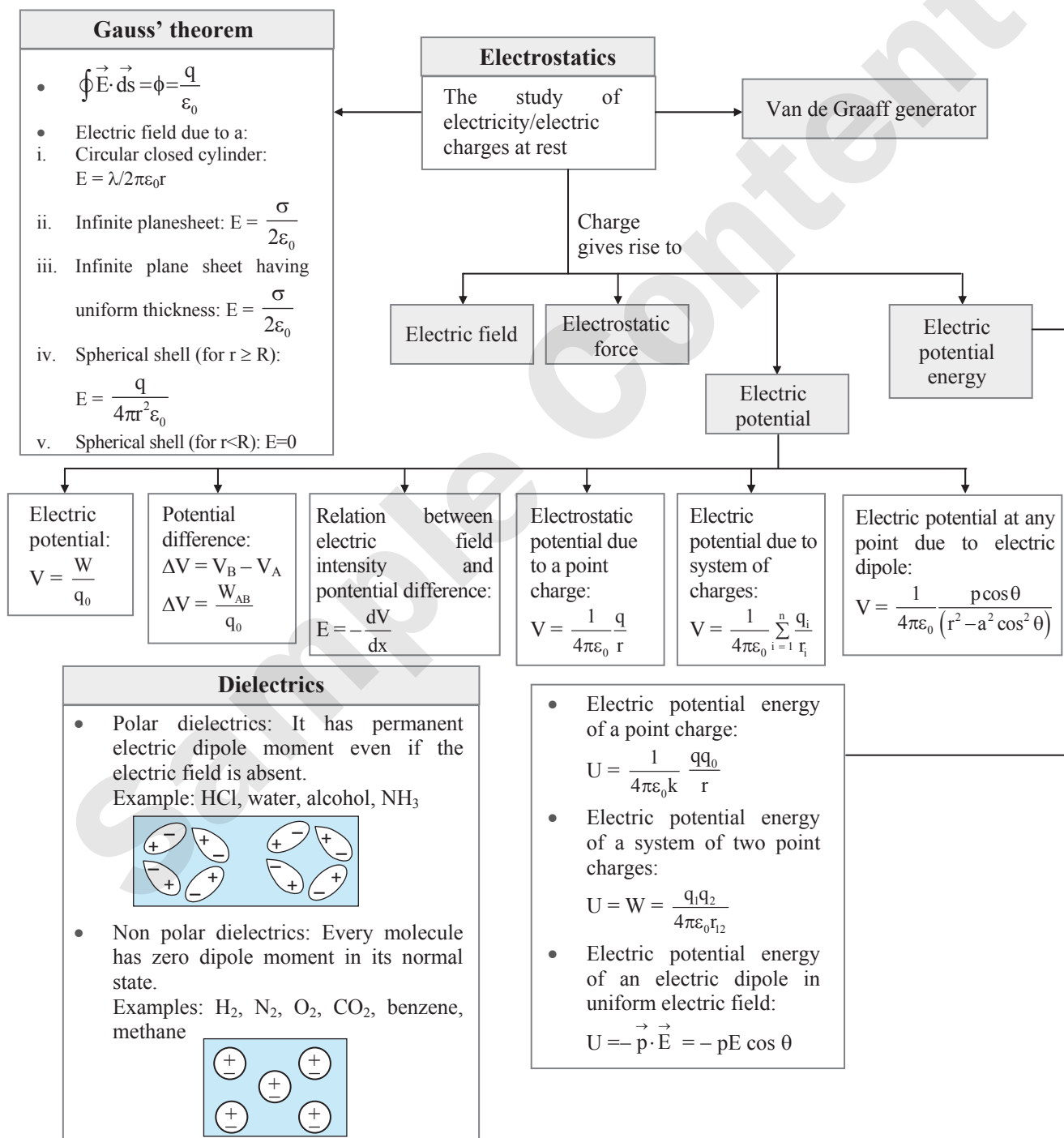
Page no. **23** to **44** are purposely left blank.

To see complete chapter buy **Target Notes** or **Target E-Notes**

**Q.125. Internet my friend.** (Textbook page no.211)

- <https://en.m.wikipedia.org/wiki/Electrostatics>
- <http://hyperphysics.phy-astr.gsu.edu/hbase/index.html>
- <https://www.britannica.com/browse/Science>
- <https://www.khanacademy.org/science/in-in-class-12th-physics-india>

[Students can use links given above as reference and collect information about Electrostatics.]

QUICK REVIEW



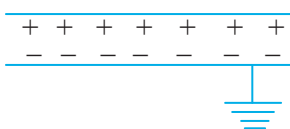
Capacitors

- **Capacitance:**
The ability of a conductor to store charge.
 $C = \frac{Q}{V}$

- **Types of capacitor:**

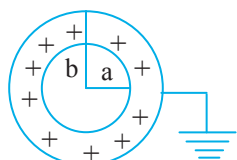
i. **Parallel plate capacitor:**

a. $C = \frac{k\epsilon_0 A}{d}$
 b. $C_m = k C_{air}$



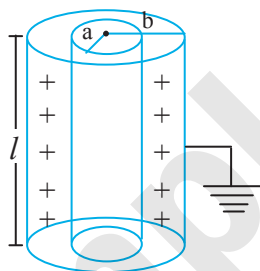
ii. **Spherical capacitor:**

$$C = 4\pi k\epsilon_0 \left(\frac{ab}{b-a} \right)$$



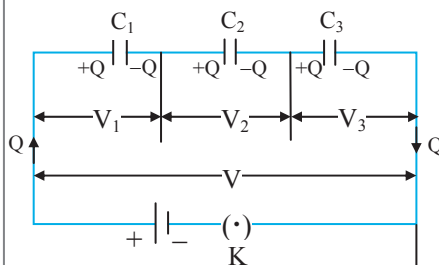
iii. **Cylindrical capacitor:**

$$C = \frac{2\pi k\epsilon_0 l}{2.303 \log \left(\frac{b}{a} \right)}$$



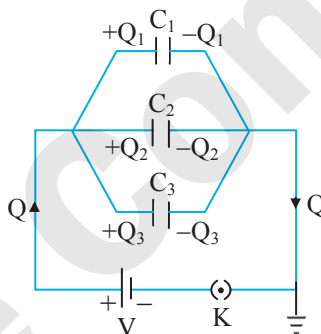
Combinations

i. **Capacitors in series:**



$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

ii. **Capacitors in parallel:**



$$C_p = C_1 + C_2 + C_3$$

Energy stored

- **Energy:**
 $U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} QV = \frac{1}{2} CV^2$

IMPORTANT FORMULAE

1. **Charge per unit length (Linear charge density):** $\lambda = \frac{q}{l}$

2. **Charge per unit surface area (Surface charge density):** $\sigma = \frac{q}{A}$

3. **Electric flux:**

i. $\phi = \int \vec{E} \cdot d\vec{s} = Eds \cos \theta$

ii. $\phi = \frac{q}{\epsilon_0}$

iii. $\phi = \frac{q}{k\epsilon_0}$

4. **Dielectric constant of a medium:** $k = \frac{\epsilon}{\epsilon_0}$

5. **Electric intensity:** $E = \frac{1}{4\pi k\epsilon_0} \frac{q}{r^2}$

6. **Electric intensity at a point outside a charged spherical conductor:**

i. $E_{medium} = \frac{q}{4\pi k\epsilon_0 r^2} = \frac{\sigma R^2}{k\epsilon_0 r^2} \dots (r > R)$

ii. $E_{vacuum} = \frac{q}{4\pi\epsilon_0 r^2} = \frac{\sigma R^2}{\epsilon_0 r^2} \dots (r > R)$

where, $\sigma = \frac{q}{4\pi R^2}$

iii. $E_{inside} = 0 \dots (r < R)$

**7. Electric intensity at a point outside a charged cylindrical conductor:**

i. Cylinder in any medium,

$$E = \frac{\lambda}{2\pi\epsilon r} = \frac{\lambda}{2\pi k\epsilon_0 r} = \frac{\sigma R}{k\epsilon_0 r} \quad \dots(r > R)$$

ii. Cylinder in free space or vacuum,

$$E = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{1}{4\pi\epsilon_0} \frac{2\lambda}{r} \quad \dots(r > R)$$

iii. $E_{\text{inside}} = 0 \quad \dots(r < R)$ **8. Electric intensity at short distance from a charged conductor of any shape:**

i. $E = \frac{\sigma}{k\epsilon_0}$

ii. Conductor in free space or air or vacuum,

$$E_0 = \frac{\sigma}{\epsilon_0} = kE$$

9. Electric intensity at a point outside a uniformly charged infinite plane sheet:

$$E = \frac{\sigma}{2\epsilon}$$

10. Work done:

i. $W = qV$ ii. $W = q(V_B - V_A)$

11. Torque on a dipole:

i. $\vec{\tau} = \vec{p} \times \vec{E}$ ii. $\tau = pE \sin \theta$

iii. For $\theta = 90^\circ$, $\tau_{\text{max}} = pE$ iv. For $\theta = 0$, $\tau_{\text{min}} = 0$

12. Work done by the external torque on dipole:

$$W = \int_{\theta_0}^{\theta} \tau_{\text{ext}}(\theta) d\theta = \int_{\theta_0}^{\theta} pE \sin \theta d\theta$$

$$= pE[\cos \theta_0 - \cos \theta]$$

13. Potential energy of electric dipole in external electric field:

$$U(\theta) - U(\theta_0) = pE(\cos \theta_0 - \cos \theta)$$

14. Capacity of condenser: $C = \frac{Q}{V}$ **15. Parallel plate condenser:**

i. Intensity between the plates,

$$E = \frac{\sigma}{\epsilon} = \frac{Q}{A\epsilon} = \frac{\sigma}{k\epsilon_0} = \frac{Q}{Ak\epsilon_0}$$

ii. Potential difference between the plates,

$$V = Ed$$

iii. Capacity between the plates,

$$C = \frac{A\epsilon}{d} = k C_0$$

iv. Capacity of vacuum, $C_0 = \frac{A\epsilon_0}{d}$ **16. Capacitance of capacitor with dielectric:**

$$C_d = C_0 \frac{E_0}{E_d}$$

where, C_0 is original capacitance E_0 is original electric field E_d is electric field with dielectric**17. Energy stored in a charged capacitor:**

$$U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$$

18. Series combination of 'n' condensers:

i. $V = V_1 + V_2 + V_3 + \dots + V_n$

ii. $Q = Q_1 = Q_2 = Q_3 = \dots = Q_n$

iii. $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$

19. Parallel combination of 'n' condensers:

i. $Q = Q_1 + Q_2 + \dots + Q_n$

ii. $V = V_1 = V_2 = V_3 = \dots = V_n$

iii. $C = C_1 + C_2 + C_3 + \dots + C_n$

EXERCISE**Theory Questions for Practice****8.1 Introduction**1. Give importance of Gauss' law. **[2 Marks]****Ans:** Refer Q.4.**8.2 Application of Gauss' law**2. What will be the electric field intensity at a point P inside a charged sphere? **[1 Mark]****Ans:** Zero3. Derive an expression for electric field intensity due to uniformly charged spherical shell or hollow sphere. **[4 Marks]****Ans:** Refer Q.6.4. State the formula for electric field intensity at a point outside an infinitely long charged cylindrical conductor. **[1 Mark] [July 18, 22]****Ans:** Formula for electric field intensity at a point outside an infinitely long charged cylindrical conductor is, $E = \frac{\lambda}{2\pi k\epsilon_0 r}$ 5. Obtain an expression for electric field intensity at a point outside uniformly charged thin plane sheet. **[4 Marks] [July 17]****Ans:** Refer Q.10.**8.3 Electric Potential and Potential Energy**6. Write a short note on electrostatic potential energy. **[2 Marks]****Ans:** Refer Q.17.

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28. Define
i. free charges ii. bound charges
[2 Marks]

Ans: Refer Q.63.

8.8 Dielectrics and Electric Polarisation

29. What is electric polarisation? [2 Marks]

Ans: Refer Q.65.

30. Write a short note on dielectrics. [2 Marks]

Ans: Refer Q.67.

31. What are polar dielectrics and non-polar dielectrics? [2 Marks] [Mar 22]

Ans: Refer Q.68.

32. Categorize the following into polar and non-polar dielectrics: [1 Mark] [July 23]

- i. H_2O ii. CO_2

- Ans. i. H_2O – polar dielectric
ii. CO_2 – non-polar dielectric

33. With the help of neat diagram, explain how non-polar dielectric material is polarised in external electric field of increasing intensity.

[3 Marks] [Oct 15]

Ans: Refer Q.69.

8.9 Capacitors and Capacitance, Combination of Capacitors in Series and Parallel

34. What is the principle of a capacitor? [3 Marks]

Ans: Refer Q.74.

35. Obtain an expression for the effective capacitance of three parallel plate capacitors connected in series. [4 Marks]

Ans: Refer Q.78.

36. Obtain an expression for effective capacitance of three capacitors connected in parallel.

[4 Marks]

Ans: Refer Q.79.

8.10 Capacitance of a Parallel Plate Capacitor Without and With Dielectric Medium Between the Plates

37. Draw neat, labelled diagram of a parallel plate capacitor with a dielectric slab between the plates. [2 Marks] [July 22]

Ans: Refer Q.94 (Diagram only)

38. Discuss the capacitance of a parallel plate capacitor when the capacitor is filled with

- i. dielectric of constant k
ii. conducting slab

[2 Marks]

Ans: Refer Q.96.

8.11 Displacement current

39. Explain origin of Displacement current.

[3 Marks]

Ans: Refer Q.106.

40. Obtain relation between conduction current and displacement current. [2 Marks]

Ans: Refer Q.107.

8.12 Energy Stored in a Capacitor

41. Obtain an expression for energy stored in a capacitor. [3 Marks]

Ans: Refer Q.109.

8.13 Van de Graaff Generator

42. What is the principle of Van de Graaff generator? [2 Marks]

Ans: Refer Q.118.

43. Explain the construction of a Van de Graaff generator. [4 Marks]

Ans: Refer Q.119. (Construction and diagram only)

44. How does a Van de Graaff generator work?

[3 Marks]

Ans: Refer Q.119 (Working only)

45. State any four applications of Van de Graaff generator. [2 Marks]

Ans: Refer Q.120. (Any four uses)

Numericals for Practice

8.1 Introduction

1. A point charge of $10 \mu C$ is situated at the centre of a sphere of radius 10 cm. Calculate the electric flux through its surface. [2 Marks]

Ans: $1.13 \times 10^6 \text{ Nm}^2/\text{C}$

2. The electric intensity on the surface of a charged conductor of area 0.5 m^2 is 200 V/m . If the electric flux is found to be $86.6 \text{ Nm}^2/\text{C}$, find the angle between the normal drawn to the surface and the electric intensity. [2 Marks]

Ans: 30°

8.2 Application of Gauss' law

3. A metal sphere of radius 10 cm is situated in air and carries a charge of $44 \mu C$. Calculate intensity of electric field at a point close to its surface. [2 Marks]

Ans: $3.96 \times 10^7 \text{ N/C}$

4. A metal cylinder of radius 10 cm has a surface charge density $2 \times 10^{-5} \text{ C/m}^2$. Find the intensity of electric field at a distance of 1 metre along a line perpendicular to its axis. [2 Marks]

Ans: $2.26 \times 10^5 \text{ N/C}$

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21. Connect three capacitors of capacity $3\ \mu\text{F}$, $3\ \mu\text{F}$ and $6\ \mu\text{F}$ such that their equivalent capacitance is $5\ \mu\text{F}$. [3 Marks]

Ans: Series combination of $3\ \mu\text{F}$ and $6\ \mu\text{F}$ is to be connected in parallel with $3\ \mu\text{F}$

22. A parallel plate capacitor has a capacity of $4\ \mu\text{F}$ and a charge of $5 \times 10^{-3}\ \text{C}$ is deposited on its plate. Find the p.d. across the capacitor. If the distance between the two plates is $1\ \text{mm}$, Find the intensity of electric field between the two plates of capacitor. [3 Marks]

Ans: $1250\ \text{V}$, $1.25 \times 10^6\ \text{N/C}$

23. Two capacitors having capacities $1\ \text{pF}$ and $2\ \text{pF}$ are connected in parallel and a battery of e.m.f $30\ \text{V}$ is connected across the combination. Calculate the resultant capacity of the combination and the charge deposited on the plate of each capacitor. [3 Marks]

Ans: $3\ \text{pF}$, $9 \times 10^{-11}\ \text{C}$

8.10 Capacitance of a Parallel Plate Capacitor Without and With Dielectric Medium Between the Plates

24. A parallel plate capacitor filled with air has an area of $6\ \text{cm}^2$ and plate separation of $3\ \text{mm}$. Calculate its capacitance. [3 Marks] [Mar 22]

Ans: $1.77\ \text{pF}$

25. A parallel plate capacitor has the area of each plate $500\ \text{cm}^2$, the distance between the plates is $0.1\ \text{mm}$. Calculate its capacity when the medium between the plates is (i) air (ii) medium of dielectric constant 4. [3 Marks]

Ans: i. $4.425 \times 10^{-3}\ \mu\text{F}$ ii. $17.7 \times 10^{-3}\ \mu\text{F}$

26. A parallel plate air condenser has a capacity of $15\ \mu\text{F}$. What will be the new capacity if a marble slab of dielectric constant 6 is introduced between the two plates such that entire space between plates is filled by marble slab? [1 Mark]

Ans: $90\ \mu\text{F}$

27. A parallel plate capacitor has two plates, each of area $100\ \text{cm}^2$. The distance between the plates is $0.5 \times 10^{-4}\ \text{cm}$ and the dielectric constant of the medium between the plates is 4. Find the capacitance of the capacitor. [2 Marks]

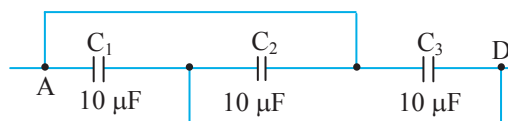
Ans: $0.708\ \mu\text{F}$

28. Calculate equivalent capacity of $2\ \mu\text{F}$, $4\ \mu\text{F}$, $6\ \mu\text{F}$ and $8\ \mu\text{F}$ in series and parallel combination. [3 Marks]

Ans: i. $0.96\ \mu\text{F}$ ii. $20\ \mu\text{F}$.

29. Find the effective capacity between A and D in the given circuit:

[2 Marks]



Ans: The effective capacity between A and D is $30\ \mu\text{F}$.

8.12 Energy Stored in a Capacitor

30. Two condensers of capacitances $C_1 = 3\ \mu\text{F}$ and $C_2 = 6\ \mu\text{F}$ arranged in series are connected in parallel with a third condenser $C_3 = 4\ \mu\text{F}$. The arrangement is connected to a $6.0\ \text{V}$ battery. Calculate the total energy stored in the condenser. [3 Marks]

Ans: $1.08 \times 10^{-4}\ \text{J}$

31. The capacity of a parallel plate air capacitor is $10\ \mu\text{F}$ and it is given a charge of $40\ \mu\text{C}$. Determine the electrical energy stored in the capacitor. [2 Marks]

Ans: $8 \times 10^{-5}\ \text{J}$

32. Two capacitors each of capacity $5\ \mu\text{F}$ and a battery of e.m.f $180\ \text{V}$ are given to you. Which combination gives the maximum energy? What is its value? Also find the charge on each capacitor of that combination. [4 Marks]

Ans: Parallel combination, $16.2 \times 10^{-2}\ \text{J}$, Charge on each capacitor of parallel arrangement = $900\ \mu\text{C}$.

Scan the given Q. R. Code in *Quill - The Padhai App* to view the solutions of the Numericals for practice.



MULTIPLE CHOICE QUESTIONS

[1 Mark Each]

- Gauss' law helps in
 - determination of electric field due to symmetric charge distribution.
 - determination of electric potential due to symmetric charge distribution.
 - determination of electric flux.
 - situations where Coulomb's law fails.
- Electric intensity at a point near a charged sphere of charge q is given by

(A) $E = \frac{1}{4\pi\epsilon_0 k} \frac{q}{r^2}$ (B) $E = \frac{1}{2\pi\epsilon_0 k} \frac{q}{r}$
 (C) $E = \frac{\sigma}{\epsilon_0 k}$ (D) $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$



3. The electric intensity due to a charged sphere at a point outside the sphere increases with increase in
 - (A) dielectric constant .
 - (B) distance from the centre of sphere.
 - (C) charge on sphere.
 - (D) square of distance from the centre of sphere.
4. Intensity of electric field at a point close and outside a charged conducting cylinder is proportional to _____.
(r is the distance of a point from the axis of cylinder) **[Mar 14]**
 - (A) $\frac{1}{r}$
 - (B) $\frac{1}{r^2}$
 - (C) $\frac{1}{r^3}$
 - (D) r^3
5. Condenser is a device used to store
 - (A) large potential at low charge.
 - (B) low potential at low charge.
 - (C) large charge at low potential.
 - (D) large charge at large potential.
6. When a capacitor is connected to a battery,
 - (A) an alternating current flows in the circuit.
 - (B) no current flows at all.
 - (C) a current flows for some time and finally it decreases to zero.
 - (D) current keeps on increasing and reaches maximum after some time.
7. If the air surrounding a charged conductor is changed by other insulating medium, its
 - (A) capacity increases.
 - (B) capacity decreases.
 - (C) capacity does not change.
 - (D) capacity becomes zero.
8. The energy of a charged capacitor resides in
 - (A) the electric field only.
 - (B) the magnetic field only.
 - (C) both the electric and magnetic fields.
 - (D) neither in the electric nor in the magnetic field.
9. The relation between electric charge, electric potential and capacity is
 - (A) $C = Q/V$
 - (B) $C = V/Q$
 - (C) $V = QC$
 - (D) all of these
10. Four coulomb charge is uniformly distributed on 2 km long wire. Its linear charge density is
 - (A) 2 C/m
 - (B) 4 C/m
 - (C) 4×10^{-3} C/m
 - (D) 2×10^{-3} C/m
11. Two capacitors of capacity C_1 and C_2 are connected in series. Their combined capacity C is given by
 - (A) $C_1 + C_2$
 - (B) $C_1 - C_2$
 - (C) $\frac{C_1 C_2}{(C_1 + C_2)}$
 - (D) $\frac{(C_1 + C_2)}{C_1 C_2}$

12. Two capacitor of capacities C_1 and C_2 are connected in parallel. Then the equivalent capacitance is
 - (A) $C_1 + C_2$
 - (B) $C_1 C_2 / C_1 + C_2$
 - (C) C_2 / C_1
 - (D) C_1 / C_2
13. Van de Graaff generator produces _____.
 - (A) zero potential
 - (B) high potential
 - (C) breakdown voltage
 - (D) low potential
14. If the charge on the condenser of 10 μ F is doubled, then the energy stored in it becomes _____. **[Mar 17]**
 - (A) zero
 - (B) twice that of initial energy
 - (C) half the initial energy
 - (D) four times the initial energy

Scan the adjacent QR Code to know more about our **“Board Questions with solution”** book for Std. XII (Sci.) and Learn about the types of questions that are asked in the XII



15. _____ of conductors and insulators can be understood on the basis of free and bound charges.
 - (A) The mechanical properties
 - (B) The electrical behaviour
 - (C) The magnetic behaviour
 - (D) The dielectric behaviour
16. The _____ dielectrics develop net dipole moment in presence of an electric field.
 - (A) polar
 - (B) non-polar
 - (C) polar and non-polar
 - (D) solid
17. Dielectric constant of metals is _____.
 - (A) 0
 - (B) 1
 - (C) -1
 - (D) ∞
18. Match the two columns in correct sequence.

	Common units of capacitance		Their values
i.	1 pF	a.	10^{-6} F
ii.	1 μ F	b.	10^{-12} F
iii.	1 nF	c.	10^{-9} F

- (A) (i – b), (ii – c), (iii – a)
- (B) (i – c), (ii – b), (iii – a)
- (C) (i – b), (ii – a), (iii – c)
- (D) (i – a), (ii – b), (iii – c)

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33. The angle at which maximum torque is exerted by the external uniform electric field on the electric dipole is _____. [Mar 22]
 (A) 0° (B) 30°
 (C) 45° (D) 90°

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. (A) 2. (A) 3. (C) 4. (A)
 5. (C) 6. (C) 7. (A) 8. (A)
 9. (A) 10. (D) 11. (C) 12. (A)
 13. (B) 14. (D) 15. (B) 16. (C)
 17. (D) 18. (C) 19. (D) 20. (D)
 21. (A) 22. (A) 23. (A) 24. (B)
 25. (D) 26. (C) 27. (C) 28. (B)
 29. (A) 30. (C) 31. (C) 32. (B)
 33. (D)

HINTS TO MULTIPLE CHOICE QUESTIONS

19. For a parallel plate capacitor:
 Charge is conserved. Hence, remains constant.

i. $C = \frac{A\epsilon_0}{d} \Rightarrow C \propto \frac{1}{d}$
 ii. $V = Ed \Rightarrow V \propto d$

20. Without slab, capacitance $C = \frac{A\epsilon_0}{d}$
 With slab capacitance, $C' = \frac{A\epsilon_0}{d - t\left(1 - \frac{1}{k}\right)}$

$$\therefore C' = \frac{A\epsilon_0}{d - \frac{3}{4}d\left(1 - \frac{1}{k}\right)} = \frac{A\epsilon_0}{\frac{d}{4} + \frac{3d}{4k}}$$

$$= \frac{A\epsilon_0}{\frac{d}{4}\left(1 + \frac{3}{k}\right)} = \frac{A\epsilon_0}{d} \left(\frac{4k}{k+3}\right)$$

22. For circular plates, $A = \pi r^2 = \pi(0.08)^2 \text{ m}^2$
 Charge $Q = CV$
 $= \frac{A\epsilon_0}{d} V$
 $= \frac{\pi(0.08)^2 \times 8.85 \times 10^{-12}}{10^{-3}} \times 100$
 $= 1.78 \times 10^{-8} \text{ C}$

23. Work done $W_{CD} = Q(V_D - V_C)$
 Where, V_D is net electric potential at D and
 V_C is net electric potential at C.
 Here, $V_C = 0$
 $\therefore W_{CD} = QV_D$

$$= Q \left[\frac{+q}{4\pi\epsilon_0 3L} + \frac{(-q)}{4\pi\epsilon_0 L} \right]$$

$$= \frac{-qQ}{6\pi\epsilon_0 L}$$

24. Dielectric constant of medium
 $k = \frac{\epsilon}{\epsilon_0} = \frac{26.55 \times 10^{-12}}{8.85 \times 10^{-12}} = 3$
27. Total flux is independent of shape and radius.
29. $E = \frac{F}{q_0} = \frac{3000}{3} = 1000 \text{ N/C}$
 $V = \frac{1}{4\pi\epsilon_0} \frac{q}{r} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \times r = E \times r$
 $= 1000 \times 0.01 \quad (\because r = 1 \text{ cm} = 0.01 \text{ m})$
 $= 10 \text{ V}$

COMPETITIVE CORNER

1. Three concentric metal shells A, B and C of respective radii a, b and c ($a < b < c$) have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is:

[JEE (Main) 2018]

(A) $\frac{\sigma}{\epsilon_0} \left[\frac{b^2 - c^2}{b} + a \right]$ (B) $\frac{\sigma}{\epsilon_0} \left[\frac{b^2 - c^2}{c} + a \right]$
 (C) $\frac{\sigma}{\epsilon_0} \left[\frac{a^2 - b^2}{a} + c \right]$ (D) $\frac{\sigma}{\epsilon_0} \left[\frac{a^2 - b^2}{b} + c \right]$

Hint: Potential of shell B will be equal to sum of potentials due to charges present on all the three shells.

$$\therefore V'_B = V_A + V_B + V_C$$

Now, as the potential is same inside the shell as that on the surface,

$$V_A = \frac{k\sigma 4\pi a^2}{b}$$

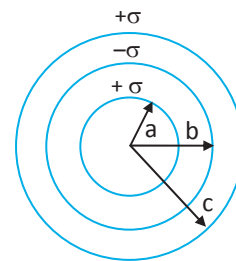
$$V_B = \frac{-k\sigma 4\pi b^2}{b}$$

$$V_C = \frac{k\sigma 4\pi c^2}{c}$$

$$\therefore V'_B = \frac{k(\sigma \times 4\pi a^2)}{b} - \frac{k(\sigma \times 4\pi b^2)}{b} + \frac{k(\sigma \times 4\pi c^2)}{c}$$

$$\therefore V'_B = \frac{\sigma}{\epsilon_0} \left(\frac{a^2}{b} - b + c \right) \quad \dots \left(\because k = \frac{1}{4\pi\epsilon_0} \right)$$

$$\therefore V'_B = \frac{\sigma}{\epsilon_0} \left(\frac{a^2 - b^2}{b} + c \right)$$



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18. A parallel plate capacitor has plate area 'A' and separation between plates is 'd'. It is charged to a potential difference of V_0 volt. The charging battery is then disconnected and plates are pulled apart three times the initial distance. The work done to increase the distance between the plates is (ϵ_0 = permittivity of free space)

[MHT CET 2023]

- (A) $\frac{3\epsilon_0 A V_0^2}{d}$ (B) $\frac{\epsilon_0 A V_0^2}{2d}$
 (C) $\frac{\epsilon_0 A V_0^2}{3d}$ (D) $\frac{\epsilon_0 A V_0^2}{d}$

Hint: Let the initial capacitance be $C_0 = \frac{\epsilon_0 A}{d}$

Let the charge on the capacitor be $Q_{\text{initial}} = C_0 V_0$

Plate separation is increased by 3 times

i.e., $d' = 3d$

$$C_{\text{final}} = \frac{\epsilon_0 A}{3d} = \frac{1}{3} \left(\frac{\epsilon_0 A}{d} \right) = \frac{C_0}{3}$$

Let Q_{final} be the final charge on the capacitor and V_{final} be the final potential on the capacitor.

$$\therefore Q_{\text{final}} = C_{\text{final}} V_{\text{final}} = \frac{1}{3} C_0 V_{\text{final}}$$

As the capacitor is isolated,

$$Q_{\text{final}} = Q_{\text{initial}},$$

$$C_0 V_0 = \frac{1}{3} C_0 V_{\text{final}}$$

$$\therefore V_{\text{final}} = 3V_0$$

Work done = Final P.E – Initial P.E

$$= \frac{1}{2} C_{\text{final}} (V_{\text{final}})^2 - \frac{1}{2} C_0 (V_0)^2$$

$$= \frac{1}{2} \frac{C_0}{3} 9V_0^2 - \frac{1}{2} C_0 V_0^2$$

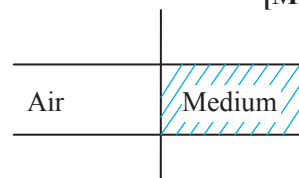
$$= C_0 V_0^2 \left(\frac{3}{2} - \frac{1}{2} \right)$$

$$= C_0 V_0^2$$

$$= \frac{\epsilon_0 A V_0^2}{d} \quad \dots (\because C_0 = \frac{\epsilon_0 A}{d})$$

19. The capacitance of a parallel plate capacitor is $2.5 \mu\text{F}$. When it is half filled with a dielectric as shown in figure, its capacitance becomes $5 \mu\text{F}$. The dielectric constant of the dielectric is

[MHT CET 2023]



- (A) 7.5 (B) 3
 (C) 4 (D) 5

Hint: Given $C = \frac{\epsilon_0 A}{d} = 2.5 \mu\text{F}$

Capacitance of air filled with area,

$$C_1 = \frac{\epsilon_0 (A/2)}{d}$$

Capacitance of dielectric filled area,

$$C_2 = \frac{k_r \epsilon_0 (A/2)}{d}$$

As, C_1 and C_2 are in parallel configuration.

$$C_{\text{eq}} = C_1 + C_2$$

Given: $C_{\text{eq}} = 5 \mu\text{F}$

$$5 = \frac{\epsilon_0 A}{2d} + \frac{k_r \epsilon_0 A}{2d}$$

$$5 = \frac{2.5}{2} + k_r \frac{2.5}{2}$$

$$\frac{3.75}{1.25} = k_r$$

$$k_r = 3$$

Time: 1 Hour 30 Min

TOPIC TEST

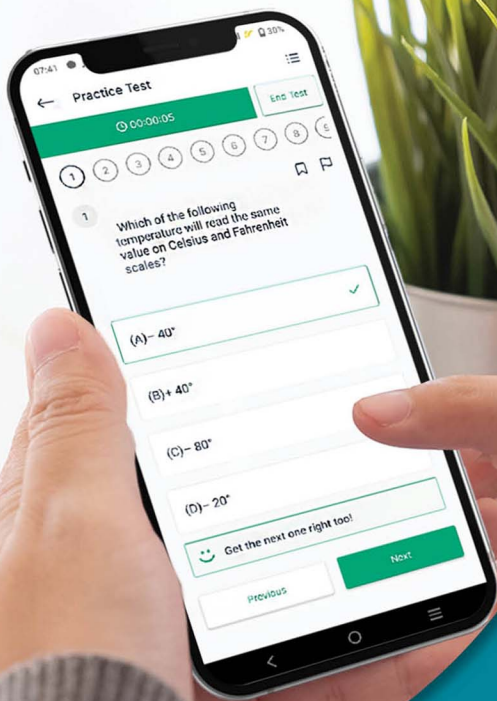
Total Marks: 25

SECTION A

Q.1. Select and write the correct answer:

[04]

- i. The dielectric constant of a conductor is _____.
- (A) unity (B) zero
 (C) infinite (D) non-negative integer
- ii. In Van de Graaff generator, electric charge deposited on the larger sphere is due to
- (A) corona discharge (pointed conductor effect). (B) friction.
 (C) both friction and corona discharge. (D) electrostatic shielding.
- iii. If the number of capacitors is connected in series then
- (A) charge on each capacitor is same and potential is different.
 (B) potential is same but charge is different.
 (C) both charge and potential are same.
 (D) both charge and potential are different.



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