## SAMPHE CONHFNH

## PERFECT

## piystics



## Based on New Paper Pattern and Latest Textbook



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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
- Includes selective and relevant Board questions from March 2013 to July 2022
- 'Quick Review' of the chapter facilitates quick revision
- 'Apply Your Knowledge' section for application of concepts
- 'Important Formulae' and 'Solved Examples' provided to cover numerical aspect of the topic in detail.
- 'Competitive Corner' presents recent questions from prominent competitive examinations - Includes features like Reading Between the Lines, Enrich Your Knowledge, Gyan Guru, Strategy, Connections, Cautions, NCERT Corner for holistic learning
- Marks provided to the Questions as per relevant weightage wherever deemed necessary
- Includes Theory questions, Numericals and MCQs for practice
- Topic Test at the end of each chapter for self-assessment
- QR Codes to access the Video/pdf links, Solutions of Numericals for Practice and Model Question Paper along with Solution.
- Includes Board Question Paper of February 2023 (Solution in pdf format through QR code)


## Printed at: India Printing Works, Mumbai

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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 designed to match the new textbook of 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.
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 chapterpreparedness. 'Model Question Paper' based on latest paper pattern is provided along with solution 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: Fifth

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.

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

iv. Model Question Paper with solution

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. Solution to Board Question Paper of February 2023
NCERT Corner covers information from NCERT textbook relevant to topic.
${ }^{\circ}$



Continue...

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

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

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


## 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:

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

[^1]| Chapter No. | Chapter Name | Marks without option | Marks with option | Page No. |
| :---: | :---: | :---: | :---: | :---: |
| 8 | Electrostatics | 4 | 6 | 1 |
| 9 | Current Electricity | 4 | 6 | 61 |
| 10 | Magnetic Fields due to Electric Current | 4 | 6 | 101 |
| 11 | Magnetic Materials | 4 | 5 | 157 |
| 12 | Electromagnetic Induction | 5 | 7 | 191 |
| 13 | AC Circuits | 4 | 6 | 231 |
| 14 | Dual Nature of Radiation and Matter | 4 | 5 | 274 |
| 15 | Structure of Atoms and Nuclei | 4 | 6 | 313 |
| 16 | Semiconductor Devices | 4 | 5 | 363 |
|  | Board Question Paper: February 2023 <br> (Solution in pdf format through QR code) |  |  | 397 |
| - | Scan the given Q.R. Code in Quill - The Padhai App to view the Model Question Paper with Solution. |  |  |  |

[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. 沉縕 symbol represents textual questions that need external reference for an answer.
5. Chapters 1 to 7 are a part of Std. XII: Perfect Physics - I

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.


## 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

### 8.1 Introduction

8.2 Application of Gauss' law
8.3 Electric Potential and Potential Energy
8.4 Electric Potential due to a Point Charge, a Dipole and a System of Charges
8.5 Equipotential Surfaces
8.6 Electrostatic Potential Energy of Two Point Charges and of a Dipole in an Electrostatic Field
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:
a. If work done by or against a force is independent of the actual path, the force is said to be a conservative force.
b. During work done by a conservative force, the mechanical energy is conserved.
c. 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 $\varepsilon_{0}$.
8.8 Dielectrics and Electric Polarisation
8.9 Capacitors and Capacitance, Combination of Capacitors in Series and Parallel
8.10 Capacitance of a Parallel Plate Capacitor Without and With Dielectric Medium Between the Plates
8.11 Displacement Current
8.12 Energy Stored in a Capacitor
8.13 Van de Graaff Generator

$$
\int \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}=\frac{\mathrm{q}}{\varepsilon_{0}}
$$

where q is the total charge within the surface.
Mathematically,
$\phi=\oint \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}=\frac{\mathrm{q}}{\varepsilon_{0}}$
where $\phi$ 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 $\phi_{E}=q / \varepsilon_{0}$. 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 $\int \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}$, 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 $\int \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}$. A Gaussian surface is purely imaginary and does not exist physically.
*Q.2. Two charges of magnitudes $-4 Q$ and $+2 Q$ are located at points $(2 a, 0)$ and $(5 a, 0)$ respectively. What is the electric flux due to these charges through a sphere of radius 4 a with its centre at the origin?
[2 Marks]
Ans:


Given: $\mathrm{d}\left(\mathrm{OX}_{1}\right)=2 \mathrm{a}$

$$
\mathrm{d}\left(\mathrm{OX}_{2}\right)=5 \mathrm{a}
$$

$$
\text { Radius, } r=4 a
$$

A Gaussian surface is of radius 4 a and contains charge -4 Q inside.
As the flux depends only upon charge enclosed by Gaussian surface, required flux according to Gauss' law would be,
$\phi=\frac{\mathrm{q}}{\varepsilon_{0}}=\frac{-4 \mathrm{Q}}{\varepsilon_{0}}$
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 $100 \mathrm{~cm}^{2}$ is placed in uniform electric field of $100 \mathrm{~N} / \mathrm{C}$ such that the angle between area vector and electric field is $60^{\circ}$. Determine the electric flux over the surface.
[2 Marks]

## Solution:

Given:

$$
\begin{aligned}
& \mathrm{ds}=100 \mathrm{~cm}^{2}=100 \times 10^{-4} \mathrm{~m}^{2}=10^{-2} \mathrm{~m}^{2} \\
& \mathrm{E}=100 \mathrm{~N} / \mathrm{C}, \theta=60^{\circ}
\end{aligned}
$$

To find: $\quad$ Electric flux $(\phi)$
Formula: $\quad \phi=$ Eds $\cos \theta$
Calculation: From formula,

$$
\begin{array}{rlrl} 
& & \phi & =100 \times 10^{-2} \times \cos 60^{\circ} \\
& \therefore & \phi & =1 \times \frac{1}{2} \\
\therefore & \phi & =\mathbf{0 . 5} \mathbf{N m}^{2} / \mathbf{C}
\end{array}
$$

Ans: The electric flux over the surface is $\mathbf{0 . 5} \mathbf{N m}^{\mathbf{2}} / \mathbf{C}$.

### 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 $\sigma$ placed in a dielectric medium of permittivity $\varepsilon\left(\varepsilon=\varepsilon_{0} \mathrm{k}\right)$. The total charge on the sphere, $\mathrm{q}=\sigma \times 4 \pi \mathrm{R}^{2}$.
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,
$\phi=\frac{\mathrm{q}}{\varepsilon_{0}}$ (for air/vacuum $\mathrm{k}=1$ )
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., $\cos \theta=1$
$\therefore \quad \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}=\mathrm{E}$ ds $\cos \theta=\mathrm{E}$ ds
$\therefore \quad$ Flux $\mathrm{d} \phi$ through the area ds, $\mathrm{d} \phi=\mathrm{E}$ ds
Total electric flux through the Gaussian surface
$\phi=\oint \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}=\oint \mathrm{Eds}=\mathrm{E} \oint \mathrm{ds}$
$\therefore \quad \phi=\mathrm{E} 4 \pi \mathrm{r}^{2}$
v. From equations (1) and (2),

$$
\begin{equation*}
\frac{\mathrm{q}}{\varepsilon_{0}}=\mathrm{E} 4 \pi \mathrm{r}^{2} \tag{3}
\end{equation*}
$$

$\therefore \quad \mathrm{E}=\frac{\mathrm{q}}{4 \pi \varepsilon_{0} \mathrm{r}^{2}}$
Substituting $q=\sigma \times 4 \pi R^{2}$ in equation (3),
$\mathrm{E}=\sigma \times \frac{4 \pi \mathrm{R}^{2}}{4 \pi \varepsilon_{0} \mathrm{r}^{2}}$
$\therefore \quad \mathrm{E}=\frac{\sigma \mathrm{R}^{2}}{\varepsilon_{0} \mathrm{r}^{2}}$
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, $r=R$
$\therefore \quad \mathrm{E}=\frac{\mathrm{q}}{4 \pi \varepsilon_{0} \mathrm{R}^{2}}=\frac{\sigma}{\varepsilon_{0}}$
Case (b): If point $P$ lies inside the sphere
Since there are no charges inside, $\sigma=0$
$\therefore \quad \mathrm{E}=0$

## READING BETWEEN THE LINES

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


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If charged object is placed in any medium other than air or vacuum, $\varepsilon_{0}$ in expression for electric field intensity will change to $\mathrm{k} \varepsilon_{0}$ 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]

## Ans:

i. Consider a uniformly charged wire of infinite length having a constant linear charge density $\lambda$ (charge per unit length), kept in a medium of permittivity $\varepsilon\left(\varepsilon=\varepsilon_{0} \mathrm{k}\right)$.
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.

iii. By Gauss' theorem, the net flux through a closed surface,
$\phi=\frac{\mathrm{q}}{\varepsilon_{0}}$ (for air/vacuum $\mathrm{k}=1$ )
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 surface of the cylinder $(\overrightarrow{\mathrm{ds}})$ is zero. Similarly the angle is $(\pi / 2)$ for the flat surface of the cylinder.
i.e., $\cos \theta=1$ (for curved surface)
or $\cos \theta=0$ (for flat surface)

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To see complete chapter buy Target Notes or Target E-Notes
iii. By Gauss' theorem, the net flux through a closed surface
$\phi=\frac{\mathrm{q}}{\varepsilon_{0}}$ (for air/vacuum $\mathrm{k}=1$ )
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 $\mathrm{P}^{\prime}$. The flux passing through the curved surface is zero as the electric field is tangential to this surface.
$\therefore \quad$ The total flux through the closed Gaussian surface is given by,

```
\(\phi=[\oint \mathrm{Eds}]_{\mathrm{P}}+[\oint \mathrm{Eds}]_{\mathrm{P}^{\prime}}+[\oint \mathrm{Eds}]_{\text {curved surface }}\)
    \(=E A+E A\)
```

        \(\ldots\binom{\because \theta=0\) for ends P and \(\mathrm{P}^{\prime} ; \cos \theta=1}{\) and \(\theta=90^{\circ}\) for curved surface; \(\cos \theta=0}\)
    $\therefore \quad \phi=2 \mathrm{EA}$
v. From equations (1) and (2),

$$
\frac{\mathrm{q}}{\varepsilon_{0}}=2 \mathrm{EA}
$$

$\therefore \quad \frac{\sigma \mathrm{A}}{\varepsilon_{0}}=2 \mathrm{EA}$
$\ldots\left(\because \sigma=\frac{q}{A}\right)$
$\therefore \quad \mathrm{E}=\frac{\sigma}{2 \varepsilon_{0}}$
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 $\varepsilon_{0}=8.85 \times 10^{-12} \mathrm{C}^{2} / \mathrm{Nm}^{2}$
$\therefore \quad \frac{1}{4 \pi \varepsilon_{0}}=9 \times 10^{9} \mathrm{Nm}^{2} / \mathrm{C}^{2}$
Hence, in calculations $\frac{1}{4 \pi \varepsilon_{0}}$ is retained for easier substitutional value.
- Linear charge density, $\lambda=\frac{\mathrm{q}}{l}$

Surface charge density, $\sigma=\frac{\mathrm{q}}{\mathrm{A}}$
Volume charge density, $\rho=\frac{\mathrm{q}}{\mathrm{V}}$

## SOLVED EXAMPLES

+ Q.11. A sphere of radius 10 cm carries a charge of $1 \mu \mathrm{C}$. Calculate the electric field
i. at a distance of $\mathbf{3 0} \mathbf{~ c m}$ from the centre of the sphere
ii. at the surface of the sphere and
iii. at a distance of 5 cm from the centre of the sphere.
(Example 8.1 of Textbook page no. 187)
[3 Marks]


## Solution:

Given:

$$
\mathrm{q}=1 \mu \mathrm{C}=1 \times 10^{-6} \mathrm{C}
$$

$$
\mathrm{R}=10 \mathrm{~cm}
$$

$$
\varepsilon_{0}=8.85 \times 10^{-12} \mathrm{C}^{2} / \mathrm{Nm}^{2}
$$

$$
\therefore \quad \frac{1}{4 \pi \varepsilon_{0}}=9 \times 10^{9} \mathrm{Nm}^{2} / \mathrm{C}^{2}
$$

To find: $\quad$ Electric Field (E)
Formula: $\quad \mathrm{E}=\frac{1}{4 \pi \varepsilon_{0}} \frac{\mathrm{q}}{\mathrm{r}^{2}}$

## Calculation.

i. For $\mathrm{r}=30 \mathrm{~cm}=0.3 \mathrm{~m}$

From formula,
$\mathrm{E}=\frac{9 \times 10^{9} \times 10^{-6}}{0.3^{2}}$
$=\frac{9 \times 10^{9-6}}{9 \times 10^{-2}}=\mathbf{1 0}^{5} \mathbf{N} / \mathrm{C}$
ii. $\quad r=R=10 \mathrm{~cm}=0.10 \mathrm{~m}$

From formula,
$\mathrm{E}=\frac{9 \times 10^{9} \times 10^{-6}}{0.1^{2}}=9 \times 10^{9-6+2}$

$$
=9 \times 10^{5} \mathrm{~N} / \mathrm{C}
$$

iii. $\quad \mathrm{r}=5 \mathrm{~cm}=0.05 \mathrm{~m}$
$\because \quad \mathrm{r}<\mathrm{R}$, electric field inside the sphere is zero
i.e., $E=0$

Ans: i. Electric field at a distance of 30 cm from the centre of the sphere is $10^{5} \mathrm{~N} / \mathrm{C}$.
ii. Electric field at surface is $\mathbf{9} \times 10^{\mathbf{5}} \mathrm{N} / \mathrm{C}$.
iii. Electric field at 5 cm from centre is $\mathbf{0}$.

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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.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.
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 $\overrightarrow{\mathrm{P}}$. For linear isotropic dielectrics $\vec{P}=\chi_{e} \overrightarrow{\mathrm{E}}$.
Where, $\chi_{\mathrm{e}}$ is a constant called electric susceptibility of the dielectric medium.
iii. Examples: Dielectrics substances show electric polarisation.


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? <br> [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 $\chi_{\mathrm{e}}$.
iii. It is constant for a dielectric but has different values for different dielectrics.
iv. For vacuum $\chi_{\mathrm{e}}=0$.

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To see complete chapter buy Target Notes or Target E-Notes
Q.125. Internet my friend. (Textbook page no.211)
i. https://en.m.wikipedia.org/wiki/Electrostatics
ii. http://hyperphysics.phy-astr.gsu.edu/hbase/index.html
iii. https://www.britannica.com/browse/Science
iv. 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

 electric field is absent.
Example: HCl , water, alcohol, $\mathrm{NH}_{3}$


- Non polar dielectrics: Every molecule has zero dipole moment in its normal state.
Examples: $\mathrm{H}_{2}, \mathrm{~N}_{2}, \mathrm{O}_{2}, \mathrm{CO}_{2}$, benzene, methane



Capacitors

- Types of capacitor:
i. Parallel plate capacitor:
a. $C=\frac{k \varepsilon_{0} A}{d}$
b. $\quad \mathrm{C}_{\mathrm{m}}=\mathrm{k} \mathrm{C}_{\text {air }}$
$+\quad+\quad+\quad+\quad+\quad+\quad+$

ii. Spherical capacitor:
$\mathrm{C}=4 \pi \mathrm{k} \varepsilon_{0}\left(\frac{\mathrm{ab}}{\mathrm{b}-\mathrm{a}}\right)$

iii. Cylindrical capacitor:
$\mathrm{C}=\frac{2 \pi \mathrm{k} \varepsilon_{0} l}{2.303 \log \left(\frac{\mathrm{~b}}{\mathrm{a}}\right)}$



## Combinations

i. Capacitors in series:

ii. Capacitors in parallel:

$\mathrm{C}_{\mathrm{P}}=\mathrm{C}_{1}+\mathrm{C}_{2}+\mathrm{C}_{3}$

## IMPORTANT FORMULAE

1. Charge per unit length (Linear charge density): $\lambda=\frac{\mathrm{q}}{l}$
2. Charge per unit surface area (Surface charge density): $\sigma=\frac{\mathrm{q}}{\mathrm{A}}$
3. Electric flux:
i. $\quad \phi=\int \overrightarrow{\mathrm{E}} \cdot \overrightarrow{\mathrm{ds}}=\mathrm{Eds} \cos \theta$
ii. $\quad \phi=\frac{\mathrm{q}}{\varepsilon_{0}}$
iii. $\quad \phi=\frac{\mathrm{q}}{\mathrm{k} \varepsilon_{0}}$
4. Dielectric constant of a medium: $\mathrm{k}=\frac{\varepsilon}{\varepsilon_{0}}$
5. Electric intensity: $E=\frac{1}{4 \pi k \varepsilon_{0}} \frac{\mathrm{q}}{\mathrm{r}^{2}}$
6. Electric intensity at a point outside a charged spherical conductor:
i. $\quad \mathrm{E}_{\text {medium }}=\frac{\mathrm{q}}{4 \pi \mathrm{k} \varepsilon_{0} \mathrm{r}^{2}}=\frac{\sigma \mathrm{R}^{2}}{\mathrm{k} \varepsilon_{0} \mathrm{r}^{2}} \ldots .(\mathrm{r}>\mathrm{R})$
ii. $\quad \mathrm{E}_{\text {vacuum }}=\frac{\mathrm{q}}{4 \pi \varepsilon_{0} \mathrm{r}^{2}}=\frac{\sigma \mathrm{R}^{2}}{\varepsilon_{0} \mathrm{r}^{2}} \quad \ldots .(\mathrm{r}>\mathrm{R})$
where, $\sigma=\frac{\mathrm{q}}{4 \pi \mathrm{R}^{2}}$
iii. $\quad E_{\text {inside }}=0$
....(r $<\mathrm{R}$ )
7. Electric intensity at a point outside a charged cylindrical conductor:
i. Cylinder in any medium,
$\mathrm{E}=\frac{\lambda}{2 \pi \varepsilon \mathrm{r}}=\frac{\lambda}{2 \pi \mathrm{k} \varepsilon_{0} \mathrm{r}}=\frac{\sigma \mathrm{R}}{\mathrm{k} \varepsilon_{0} \mathrm{r}} \quad \ldots(\mathrm{r}>\mathrm{R})$
ii. Cylinder in free space or vacuum,
$\mathrm{E}=\frac{\lambda}{2 \pi \varepsilon_{0} \mathrm{r}}=\frac{1}{4 \pi \varepsilon_{0}} \frac{2 \lambda}{\mathrm{r}}$
$\ldots .(r>R)$
iii. $\quad E_{\text {inside }}=0$
8. Electric intensity at short distance from a charged conductor of any shape:
i. $\quad \mathrm{E}=\frac{\sigma}{\mathrm{k} \varepsilon_{0}}$
ii. Conductor in free space or air or vacuum,
$\mathrm{E}_{0}=\frac{\sigma}{\varepsilon_{0}}=\mathrm{kE}$
9. Electric intensity at a point outside a uniformly charged infinite plane sheet:
$\mathrm{E}=\frac{\sigma}{2 \varepsilon}$
10. Work done:
i. $\quad \mathrm{W}=\mathrm{qV}$
ii. $\quad \mathrm{W}=\mathrm{q}\left(\mathrm{V}_{\mathrm{B}}-\mathrm{V}_{\mathrm{A}}\right)$
11. Torque on a dipole:
i. $\quad \vec{\tau}=\overrightarrow{\mathrm{p}} \times \overrightarrow{\mathrm{E}}$
ii. $\quad \tau=\mathrm{pE} \sin \theta$
iii. For $\theta=90^{\circ}, \tau_{\max }=\mathrm{pE}$ iv. For $\theta=0, \tau_{\min }=0$
12. Work done by the external torque on dipole:

$$
\begin{aligned}
\mathrm{W} & =\int_{\theta_{0}}^{\theta} \tau_{\mathrm{ext}}(\theta) \mathrm{d} \theta=\int_{\theta_{0}}^{\theta} \mathrm{pE} \sin \theta \mathrm{~d} \theta \\
& =\mathrm{pE}\left[\cos \theta_{0}-\cos \theta\right]
\end{aligned}
$$

13. Potential energy of electric dipole in external electric field:
$\mathrm{U}(\theta)-\mathrm{U}\left(\theta_{0}\right)=\mathrm{pE}\left(\cos \theta_{0}-\cos \theta\right)$
14. Capacity of condenser: $C=\frac{Q}{V}$
15. Parallel plate condenser:
i. Intensity between the plates,
$\mathrm{E}=\frac{\sigma}{\varepsilon}=\frac{\mathrm{Q}}{\mathrm{A} \varepsilon}=\frac{\sigma}{\mathrm{k} \varepsilon_{0}}=\frac{\mathrm{Q}}{\mathrm{Ak} \varepsilon_{0}}$
ii. Potential difference between the plates, V = Ed
iii. Capacity between the plates,
$\mathrm{C}=\frac{\mathrm{A} \varepsilon}{\mathrm{d}}=\mathrm{k} \mathrm{C}_{0}$
iv. Capacity of vacuum, $\mathrm{C}_{0}=\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}}$
16. Capacitance of capacitor with dielectric:
$C_{d}=C_{0} \frac{E_{0}}{E_{d}}$
where, $\mathrm{C}_{0}$ is original capacitance
$\mathrm{E}_{0}$ is original electric field
$E_{d}$ is electric field with dielectric
17. Energy stored in a charged capacitor:
$\mathrm{U}=\frac{1}{2} \frac{\mathrm{Q}^{2}}{\mathrm{C}}=\frac{1}{2} \mathrm{CV}^{2}=\frac{1}{2} \mathrm{QV}$
18. Series combination of ' $n$ ' condensers:
i. $\quad V=V_{1}+V_{2}+V_{3} \ldots \ldots+V_{n}$
ii. $\quad \mathrm{Q}=\mathrm{Q}_{1}=\mathrm{Q}_{2}=\mathrm{Q}_{3}=\ldots \ldots=\mathrm{Q}_{\mathrm{n}}$
iii. $\frac{1}{\mathrm{C}}=\frac{1}{\mathrm{C}_{1}}+\frac{1}{\mathrm{C}_{2}}+\frac{1}{\mathrm{C}_{3}}+\ldots . .+\frac{1}{\mathrm{C}_{\mathrm{n}}}$
19. Parallel combination of ' $\mathbf{n}$ ' condensers:
i. $\quad \mathrm{Q}=\mathrm{Q}_{1}+\mathrm{Q}_{2}+\ldots \ldots+\mathrm{Q}_{\mathrm{n}}$
ii. $\quad \mathrm{V}=\mathrm{V}_{1}=\mathrm{V}_{2}=\mathrm{V}_{3}=\ldots . .=\mathrm{V}_{\mathrm{n}}$
iii. $\quad \mathrm{C}=\mathrm{C}_{1}+\mathrm{C}_{2}+\mathrm{C}_{3}+\ldots \ldots+\mathrm{C}_{\mathrm{n}}$

## 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: Zero
3. 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, $\mathrm{E}=\frac{\lambda}{2 \pi \mathrm{k} \varepsilon_{0} \mathrm{r}}$
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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To see complete chapter buy Target Notes or Target E-Notes
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. 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

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

Ans: Refer Q.74.
34. Obtain an expression for the effective capacitance of three parallel plate capacitors connected in series.
[4 Marks]
Ans: Refer Q. 78.
35. 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
36. 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)
37. 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

38. Explain origin of Displacement current.
[3 Marks]
Ans: Refer Q. 106.
39. Obtain relation between conduction current and displacement current.
[2 Marks]
Ans: Refer Q.107.

### 8.12 Energy Stored in a Capacitor

40. Obtain an expression for energy stored in a capacitor.
[3 Marks]
Ans: Refer Q. 109.

### 8.13 Van de Graaff Generator

41. What is the principle of Van de Graaff generator?
[2 Marks]
Ans: Refer Q. 118.
42. Explain the construction of a Van de Graaff generator.
[4 Marks]
Ans: Refer Q.119.(Construction and diagram only)
43. How does a Van de Graaff generator work?
[3 Marks]
Ans: Refer Q. 119 (Working only)
44. 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 $10 \mu \mathrm{C}$ is situated at the centre of a sphere of radius 10 cm . Calculate the electric flux through its surface. [2 Marks]
Ans: $1.13 \times 10^{6} \mathrm{Nm}^{2} / \mathrm{C}$
2. The electric intensity on the surface of a charged conductor of area $0.5 \mathrm{~m}^{2}$ is $200 \mathrm{~V} / \mathrm{m}$. If the electric flux is found to be $86.6 \mathrm{Nm}^{2} / \mathrm{C}$, find the angle between the normal drawn to the surface and the electric intensity.
[2 Marks]
Ans: $30^{\circ}$

### 8.2 Application of Gauss' law

3. A metal sphere of radius 10 cm is situated in air and carries a charge of $44 \mu \mathrm{C}$. Calculate intensity of electric field at a point close to its surface.
[2 Marks]
Ans: $3.96 \times 10^{7} \mathrm{~N} / \mathrm{C}$
4. A metal cylinder of radius 10 cm has a surface charge density $2 \times 10^{-5} \mathrm{C} / \mathrm{m}^{2}$. Find the intensity of electric field at a distance of 1 metre along a line perpendicular to its axis.
[2 Marks]
Ans: $2.26 \times 10^{5} \mathrm{~N} / \mathrm{C}$

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To see complete chapter buy Target Notes or Target E-Notes
21. Connect three capacitors of capacity $3 \mu \mathrm{~F}, 3 \mu \mathrm{~F}$ and $6 \mu \mathrm{~F}$ such that their equivalent capacitance is $5 \mu \mathrm{~F}$.
[3 Marks]
Ans: Series combination of $3 \mu \mathrm{~F}$ and $6 \mu \mathrm{~F}$ is to be connected in parallel with $3 \mu \mathrm{~F}$
22. A parallel plate capacitor has a capacity of $4 \mu \mathrm{~F}$ and a charge of $5 \times 10^{-3} \mathrm{C}$ is deposited on its plate. Find the p.d. across the capacitor. If the distance between the two plates is 1 mm , Find the intensity of electric field between the two plates of capacitor.
[3 Marks]
Ans: $1250 \mathrm{~V}, 1.25 \times 10^{6} \mathrm{~N} / \mathrm{C}$
23. Two capacitors having capacities 1 pF and 2 pF are connected in parallel and a battery of e.m.f 30 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: $3 \mathrm{pF}, 9 \times 10^{-11} \mathrm{C}$

### 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 $6 \mathrm{~cm}^{2}$ and plate separation of a 3 mm . Calculate its capacitance. [3 Marks] [Mar 22]
Ans: 1.77 pF
25. A parallel plate capacitor has the area of each plate $500 \mathrm{~cm}^{2}$, the distance between the plates is 0.1 mm . Calculate its capacity when the medium between the plates is (i) air (ii) medium of dielectric constant 4.
[3 Marks]
Ans: i. $\quad 4.425 \times 10^{-3} \mu \mathrm{~F} \quad$ ii. $\quad 17.7 \times 10^{-3} \mu \mathrm{~F}$
26. A parallel plate air condenser has a capacity of $15 \mu \mathrm{~F}$. 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: $90 \mu \mathrm{~F}$
27. A parallel plate capacitor has two plates, each of area $100 \mathrm{~cm}^{2}$. The distance between the plates is $0.5 \times 10^{-4} \mathrm{~cm}$ and the dielectric constant of the medium between the plates is 4 . Find the capacitance of the capacitor.
[2 Marks]
Ans: $0.708 \mu \mathrm{~F}$

### 8.12 Energy Stored in a Capacitor

28. Two condensers of capacitances $\mathrm{C}_{1}=3 \mu \mathrm{~F}$ and $\mathrm{C}_{2}=6 \mu \mathrm{~F}$ arranged in series are connected in parallel with a third condenser $\mathrm{C}_{3}=4 \mu \mathrm{~F}$. The arrangement is connected to a 6.0 V battery. Calculate the total energy stored in the condenser.
[3 Marks]
29. The capacity of a parallel plate air capacitor is $10 \mu \mathrm{~F}$ and it is given a charge of $40 \mu \mathrm{C}$. Determine the electrical energy stored in the capacitor.
[2 Marks]
Ans: $8 \times 10^{-5} \mathrm{~J}$
30. Two capacitors each of capacity $5 \mu \mathrm{~F}$ and a battery of e.m.f 180 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, $16.2 \times 10^{-2} \mathrm{~J}$, Charge on each capacitor of parallel arrangement $=900 \mu \mathrm{C}$.
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]

1. Gauss' law helps in
(A) determination of electric field due to symmetric charge distribution.
(B) determination of electric potential due to symmetric charge distribution.
(C) determination of electric flux.
(D) situations where Coulomb's law fails.
2. Electric intensity at a point near a charged sphere of charge $q$ is given by
(A) $\mathrm{E}=\frac{1}{4 \pi \varepsilon_{0} \mathrm{k}} \frac{\mathrm{q}}{\mathrm{r}^{2}}$
(B) $\mathrm{E}=\frac{1}{2 \pi \varepsilon_{0} \mathrm{k}} \frac{\mathrm{q}}{\mathrm{r}}$
(C) $\mathrm{E}=\frac{\sigma}{\varepsilon_{0} \mathrm{k}}$
(D) $\mathrm{E}=\frac{1}{4 \pi \varepsilon_{0}} \frac{\mathrm{q}}{\mathrm{r}}$
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 $\qquad$ .
( $r$ is the distance of a point from the axis of cylinder)
[Mar 14]
(A) $\frac{1}{r}$
(B) $\frac{1}{\mathrm{r}^{2}}$
(C) $\frac{1}{\mathrm{r}^{3}}$
(D) $\mathrm{r}^{3}$
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) $\mathrm{C}=\mathrm{Q} / \mathrm{V}$
(B) $\mathrm{C}=\mathrm{V} / \mathrm{Q}$
(C) $\mathrm{V}=\mathrm{QC}$
(D) all of these
10. Four coulomb charge is uniformly distributed on 2 km long wire. Its linear charge density is
(A) $2 \mathrm{C} / \mathrm{m}$
(B) $4 \mathrm{C} / \mathrm{m}$
(C) $4 \times 10^{-3} \mathrm{C} / \mathrm{m}$
(D) $2 \times 10^{-3} \mathrm{C} / \mathrm{m}$
11. Two capacitors of capacity $\mathrm{C}_{1}$ and $\mathrm{C}_{2}$ are connected in series. Their combined capacity C is given by
(A) $\mathrm{C}_{1}+\mathrm{C}_{2}$
(B) $\mathrm{C}_{1}-\mathrm{C}_{2}$
(C) $\frac{\mathrm{C}_{1} \mathrm{C}_{2}}{\left(\mathrm{C}_{1}+\mathrm{C}_{2}\right)}$
(D) $\frac{\left(\mathrm{C}_{1}+\mathrm{C}_{2}\right)}{\mathrm{C}_{1} \mathrm{C}_{2}}$
12. Two capacitor of capacities $\mathrm{C}_{1}$ and $\mathrm{C}_{2}$ are connected in parallel. Then the equivalent capacitance is
(A) $\mathrm{C}_{1}+\mathrm{C}_{2}$
(B) $\mathrm{C}_{1} \mathrm{C}_{2} / \mathrm{C}_{1}+\mathrm{C}_{2}$
(C) $\mathrm{C}_{2} / \mathrm{C}_{1}$
(D) $\mathrm{C}_{1} / \mathrm{C}_{2}$
13. Van de Graaff generator produces $\qquad$ -
(A) zero potential
(B) high potential
(C) breakdown voltage
(D) low potential
14. If the charge on the condenser of $10 \mu \mathrm{~F}$ is doubled, then the energy stored in it becomes
$\qquad$ .
[Mar 17]
(A) zero
(B) twice that of initial energy
(C) half the initial energy
(D) four times the initial energy

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15. $\qquad$ 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 $\qquad$ 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 $\qquad$ .
(A) 0
(B) 1
(C) -1
(D) $\infty$
18. Match the two columns in correct sequence.

|  | Common units of <br> capacitance |  | Their values |
| :---: | :--- | :--- | :--- |
| i. | 1 pF | a. | $10^{-6} \mathrm{~F}$ |
| ii. | $1 \mu \mathrm{~F}$ | b. | $10^{-12} \mathrm{~F}$ |
| iii. | 1 nF | c. | $10^{-9} \mathrm{~F}$ |

(A) ( $\mathrm{i}-\mathrm{b}$ ), ( $\mathrm{ii}-\mathrm{c}$ ), ( $\mathrm{iii}-\mathrm{a}$ )
(B) $(\mathrm{i}-\mathrm{c}),(\mathrm{ii}-\mathrm{b}),(\mathrm{iii}-\mathrm{a})$
(C) $(\mathrm{i}-\mathrm{b}),(\mathrm{ii}-\mathrm{a}),(\mathrm{iii}-\mathrm{c})$
(D) $(\mathrm{i}-\mathrm{a}),(\mathrm{ii}-\mathrm{b}),(\mathrm{iii}-\mathrm{c})$
*19. A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential, capacitance respectively is
(A) Constant, decreases, decreases
(B) Increases, decreases, decreases
(C) Constant, decreases, increases
(D) Constant, increases, decreases

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To see complete chapter buy Target Notes or Target E-Notes
33. The angle at which maximum torque is exerted by the external uniform electric field on the electric dipole is $\qquad$ -
[Mar 22]
(A) $0^{\circ}$
(B) $30^{\circ}$
(C) $45^{\circ}$
(D) $90^{\circ}$

## 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. $\mathrm{C}=\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}} \Rightarrow \mathrm{C} \propto \frac{1}{\mathrm{~d}}$
ii. $\quad V=E d \Rightarrow V \propto d$
20. Without slab, capacitance $\mathrm{C}=\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}}$

With slab capacitance, $\mathrm{C}^{\prime}=\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}-\mathrm{t}\left(1-\frac{1}{\mathrm{k}}\right)}$

$$
\begin{aligned}
\therefore \quad \mathrm{C}^{\prime} & =\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}-\frac{3}{4} \mathrm{~d}\left(1-\frac{1}{\mathrm{k}}\right)}=\frac{\mathrm{A} \varepsilon_{0}}{\frac{\mathrm{~d}}{4}+\frac{3 \mathrm{~d}}{4 \mathrm{k}}} \\
& =\frac{\mathrm{A} \varepsilon_{0}}{\frac{\mathrm{~d}}{4}\left(1+\frac{3}{\mathrm{k}}\right)}=\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}}\left(\frac{4 \mathrm{k}}{\mathrm{k}+3}\right)
\end{aligned}
$$

22. For circular plates, $\mathrm{A}=\pi \mathrm{r}^{2}=\pi(0.08)^{2} \mathrm{~m}^{2}$

Charge $\mathrm{Q}=\mathrm{CV}$

$$
\begin{aligned}
& =\frac{\mathrm{A} \varepsilon_{0}}{\mathrm{~d}} \mathrm{~V} \\
& =\frac{\pi(0.08)^{2} \times 8.85 \times 10^{-12}}{10^{-3}} \times 100 \\
& =1.78 \times 10^{-8} \mathrm{C}
\end{aligned}
$$

23. Work done $\mathrm{W}_{\mathrm{CD}}=\mathrm{Q}\left(\mathrm{V}_{\mathrm{D}}-\mathrm{V}_{\mathrm{C}}\right)$

Where, $\mathrm{V}_{\mathrm{D}}$ is net electric potential at D and $\mathrm{V}_{\mathrm{C}}$ is net electric potential at C .
Here, $\mathrm{V}_{\mathrm{C}}=0$
$\therefore \quad \mathrm{W}_{\mathrm{CD}}=\mathrm{QV}_{\mathrm{D}}$

$$
\begin{aligned}
& =\mathrm{Q}\left[\frac{+\mathrm{q}}{4 \pi \varepsilon_{0} 3 \mathrm{~L}}+\frac{(-\mathrm{q})}{4 \pi \varepsilon_{0} \mathrm{~L}}\right] \\
& =\frac{-\mathrm{qQ}}{6 \pi \varepsilon_{0} \mathrm{~L}}
\end{aligned}
$$

24. Dielectric constant of medium

$$
\mathrm{k}=\frac{\varepsilon}{\varepsilon_{0}}=\frac{26.55 \times 10^{-12}}{8.85 \times 10^{-12}}=3
$$

27. Total flux is independent of shape and radius.
28. $\mathrm{E}=\frac{\mathrm{F}}{\mathrm{q}_{0}}=\frac{3000}{3}=1000 \mathrm{~N} / \mathrm{C}$

$$
\begin{aligned}
\mathrm{V} & =\frac{1}{4 \pi \varepsilon_{0}} \frac{\mathrm{q}}{\mathrm{r}}=\frac{1}{4 \pi \varepsilon_{0}} \frac{\mathrm{q}}{\mathrm{r}^{2}} \times \mathrm{r}=\mathrm{E} \times \mathrm{r} \\
& =1000 \times 0.01 \quad(\because \mathrm{r}=1 \mathrm{~cm}=0.01 \mathrm{~m}) \\
& =10 \mathrm{~V}
\end{aligned}
$$

## COMPETITIVE CORNER

1. Three concentric metal shells $\mathrm{A}, \mathrm{B}$ and C of respective radii a , b and $\mathrm{c}(\mathrm{a}<\mathrm{b}<\mathrm{c})$ have surface charge densities $+\sigma,-\sigma$ and $+\sigma$ respectively. The potential of shell B is:
[JEE (Main) 2018]
(A) $\frac{\sigma}{\varepsilon_{0}}\left[\frac{\mathrm{~b}^{2}-\mathrm{c}^{2}}{\mathrm{~b}}+\mathrm{a}\right]$
(B) $\frac{\sigma}{\varepsilon_{0}}\left[\frac{b^{2}-c^{2}}{c}+a\right]$
(C) $\frac{\sigma}{\varepsilon_{0}}\left[\frac{\mathrm{a}^{2}-\mathrm{b}^{2}}{\mathrm{a}}+\mathrm{c}\right]$
(D) $\frac{\sigma}{\varepsilon_{0}}\left[\frac{\mathbf{a}^{2}-\mathbf{b}^{2}}{\mathbf{b}}+\mathbf{c}\right]$

Hint: Potential of shell $B$ will be equal to sum of potentials due to charges present on all the three shells.
$\therefore \quad \mathrm{V}_{\mathrm{B}}^{\prime}=\mathrm{V}_{\mathrm{A}}+\mathrm{V}_{\mathrm{B}}+\mathrm{V}_{\mathrm{C}}$
Now, as the potential is same inside the shell as that on the surface,
$\mathrm{V}_{\mathrm{A}}=\frac{\mathrm{k} \sigma 4 \pi \mathrm{a}^{2}}{\mathrm{~b}}$
$\mathrm{V}_{\mathrm{B}}=\frac{-\mathrm{k} \sigma 4 \pi \mathrm{~b}^{2}}{\mathrm{~b}}$

$\mathrm{V}_{\mathrm{C}}=\frac{\mathrm{k} \sigma 4 \pi \mathrm{c}^{2}}{\mathrm{c}}$
$\therefore \quad \mathrm{V}_{\mathrm{B}}^{\prime}=\frac{\mathrm{k}\left(\sigma \times 4 \pi \mathrm{a}^{2}\right)}{\mathrm{b}}-\frac{\mathrm{k}\left(\sigma \times 4 \pi \mathrm{~b}^{2}\right)}{\mathrm{b}}+\frac{\mathrm{k}\left(\sigma \times 4 \pi \mathrm{c}^{2}\right)}{\mathrm{c}}$
$\therefore \quad \mathrm{V}_{\mathrm{B}}^{\prime}=\frac{\sigma}{\varepsilon_{0}}\left(\frac{\mathrm{a}^{2}}{\mathrm{~b}}-\mathrm{b}+\mathrm{c}\right) \quad \ldots .\left(\because \mathrm{k}=\frac{1}{4 \pi \varepsilon_{0}}\right)$
$\therefore \quad \mathrm{V}_{\mathrm{B}}^{\prime}=\frac{\sigma}{\varepsilon_{0}}\left(\frac{\mathrm{a}^{2}-\mathrm{b}^{2}}{\mathrm{~b}}+\mathrm{c}\right)$

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(C) towards the right as its potential energy will increase.
(D) towards the left as its potential energy will increase.
Hint: Electric field lines in this case are closer to +q , hence net force on the dipole will act towards right side. A system always moves to decrease its potential energy.
17. A capacitor of capacitance ' C ', is connected across an ac source of voltage V , given by $\mathrm{V}=$ $\mathrm{V}_{0} \sin \omega \mathrm{t}$. The displacement current between the plates of the capacitor, would then be given by:
[NEET (UG) 2021]
(A) $\mathrm{I}_{\mathrm{d}}=\frac{\mathrm{V}_{0}}{\omega \mathrm{C}} \cos \omega \mathrm{t}$
(B) $\mathrm{I}_{\mathrm{d}}=\frac{\mathrm{V}_{0}}{\omega \mathrm{C}} \sin \omega \mathrm{t}$
(C) $\mathrm{I}_{\mathrm{d}}=\mathrm{V}_{0} \omega C \sin \omega \mathrm{t}$
(D) $I_{d}=V_{0} \omega C \cos \omega t$

Hint: $q=C V$
$\therefore \quad \frac{\mathrm{dq}}{\mathrm{dt}}=\mathrm{C} \frac{\mathrm{dV}}{\mathrm{dt}}$
$\therefore \quad \mathrm{I}_{\mathrm{d}}=\mathrm{C}\left(\mathrm{V}_{0} \omega \mathrm{C} \cos \omega \mathrm{t}\right)=\mathrm{V}_{0} \omega \mathrm{C} \cos \omega \mathrm{t}$
18. A capacitor of capacity ' C ' has charge ' Q ' and energy stored is ' $E$ '. If the charge is increased to $3 Q$, the energy stored is ' $E_{1}$ ', the relation between ' $E_{1}$ ' and ' $E$ ' is
[MHT CET 2021]
(A) $\quad E_{1}=\frac{E}{6}$
(B) $\quad \mathrm{E}_{1}=3 \mathrm{E}$
(C) $\quad E_{1}=\frac{E}{3}$
(D) $\quad \mathrm{E}_{1}=9 \mathrm{E}$

Hint: $\mathrm{E}=\frac{1}{2} \frac{\mathrm{Q}^{2}}{\mathrm{C}}$ and $\mathrm{E}_{1}=\frac{1}{2} \frac{(3 \mathrm{Q})^{2}}{2}$
$\therefore \quad \frac{\mathrm{E}_{1}}{\mathrm{E}}=9$
$\therefore \quad \mathrm{E}_{1}=9 \mathrm{E}$
19. Three isolated metal spheres $\mathrm{A}, \mathrm{B}, \mathrm{C}$ have radius $R, 2 R, 3 R$ respectively, and same charge $Q . U_{A}$, $U_{B}$ and $U_{C}$ be the energy density just outside the surface of the spheres. The relation between $U_{A}$, $\mathrm{U}_{\mathrm{B}}$ and $\mathrm{U}_{\mathrm{C}}$ is
[MHT CET 2022]
(A) $\mathrm{U}_{\mathrm{A}}>\mathrm{U}_{\mathrm{B}}<\mathrm{U}_{\mathrm{C}}$
(B) $\mathrm{U}_{\mathrm{A}}>\mathrm{U}_{\mathrm{B}}>\mathrm{U}_{\mathrm{C}}$
(C) $\mathrm{U}_{\mathrm{A}}<\mathrm{U}_{\mathrm{B}}<\mathrm{U}_{\mathrm{C}}$
(D) $\mathrm{U}_{\mathrm{A}}<\mathrm{U}_{\mathrm{B}}>\mathrm{U}_{\mathrm{C}}$

Hint: Energy of a charged sphere
$\mathrm{U}=\frac{1}{2} \frac{\mathrm{Q}^{2}}{4 \pi \varepsilon_{0} \mathrm{a}}$, where, a is radius of sphere
For sphere $A: U_{A}=\frac{1}{2} \frac{Q^{2}}{4 \pi \varepsilon_{0} R}$
For sphere B:
$\mathrm{U}_{\mathrm{B}}=\frac{1}{2} \frac{\mathrm{Q}^{2}}{4 \pi \varepsilon_{0}(2 \mathrm{R})}=\frac{1}{2}\left(\frac{1}{2} \frac{\mathrm{Q}^{2}}{4 \pi \varepsilon_{0} \mathrm{R}}\right)=\frac{\mathrm{U}_{\mathrm{A}}}{2}$
For sphere C:

$$
\mathrm{U}_{\mathrm{C}}=\frac{1}{2} \frac{\mathrm{Q}^{2}}{4 \pi \varepsilon_{0}(3 \mathrm{R})}=\frac{1}{3}\left(\frac{1}{2} \frac{\mathrm{Q}^{2}}{4 \pi \varepsilon_{0} \mathrm{R}}\right)=\frac{\mathrm{U}_{\mathrm{A}}}{3}
$$

$\therefore \quad \mathrm{U}_{\mathrm{A}}>\mathrm{U}_{\mathrm{B}}>\mathrm{U}_{\mathrm{C}}$

## SECTION A

Q.1. Select and write the correct answer:
i. The dielectric constant of a conductor is $\qquad$ .
(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.
iv. Electric intensity due to a charged sphere at a point outside the sphere decreases with $\qquad$ .
(A) increase in charge on sphere.
(B) increase in dielectric constant.
(C) decrease in the distance from the centre of sphere.
(D) decrease in square of distance from the centre of sphere.

## Q.2. Answer the following:

i. State formula for work done against electrostatic force while displacing charge $+q_{0}$ at distance $r_{1}$ towards charge $+Q$ at distance $r_{2}$.
ii. Define equipotential surface.
iii. Give two examples each of polar and non-polar molecules

## SECTION B

## Attempt any Four:

Q.3. What is electrostatic potential energy?
Q.4. Show graphical variation of electric field (or electric force) and electric potential due to a single charge at a distance $r$.
Q.5. Explain why no work is done to move a charge anywhere in the equatorial plane of electric dipole.
Q.6. An infinite line charge produces a field of $2 \times 10^{4} \mathrm{~N} / \mathrm{C}$ at a distance of 9 cm . Calculate the linear charge density.
Q.7. Two identical parallel plate air capacitors are connected in series to a battery of e.m.f. 'V'. If one of the capacitor is completely filled with dielectric material of constant ' $k$ ', then determine the value of potential difference of the other capacitor.
Q.8. Three capacitors of capacities $8 \mu \mathrm{~F}, 8 \mu \mathrm{~F}$ and $4 \mu \mathrm{~F}$ are connected in a series and potential difference of 100 volt is maintained across the combination. Calculate the charge on capacitor of capacity $4 \mu \mathrm{~F}$.

## SECTION C

## Attempt any Two:

Q.9. Derive an expression for electric potential due to a point charge.
Q.10. Derive an expression for potential energy of a system of two-point charges.
Q.11. A parallel plate air capacitor has rectangular plates, each of area $40 \mathrm{~cm}^{2}$ separated by a distance of 4 mm . The potential difference between the plates is 800 volt. Calculate
i. its capacitance ii. the charge on each plate
iii. the electric field intensity between the two plates.

## SECTION D

## Attempt any One:

Q.12. i. Draw neat labelled diagram of a Van de Graaff generator.
ii. Electrostatic energy of $5 \times 10^{-4} \mathrm{~J}$ is stored in a capacitor at 1000 V . What is the charge on the capacitor?
Q.13. i. Derive relation between conduction current and displacement current.
ii. What will happen if a parallel plate capacitor is filled with (a) dielectric of constant k (b) conducting slab?

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