SAMPLE CONTENT

NEET-UG & JEE (Main)

PHYSICS Vol - II

For all Medical and Engineering Entrance Examinations held across India.

4000+ MCQs with Hints

As per latest syllabus issued by NMC

Aurora Borealis

'Aurora Borealis' (Northern Lights) seen in the northern skies is caused due to the interaction of the Earth's magnetic field with charged particles or ions travelling down the atmosphere.

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Absolute
NEET (UG) & JEE (Main)
Physics Vol. II

Now with more study techniques

Updated as per latest syllabus for:
NEET (UG) 2024 issued by **NMC on 6th October, 2023**
JEE (Main) 2024 issued by **NTA on 1st November, 2023**

Salient Features

- Comprehensive theory for every topic
- Subtopic-wise segregation of MCQs for efficient practice
- Exhaustive coverage of questions including questions from previous years' NEET (UG), JEE (Main) and other competitive examinations **till year 2023:**
  - **4123** MCQs
  - **102** Numerical Value Type (NVT) questions
  - Solutions to the questions are provided for better understanding
- Includes **Smart Keys:** Multiple study techniques to enhance understanding and problem solving:
  - ***Time Saver***
  - ***Smart tip***
  - ***Caution***
  - ***Learning Pointers***
  - ***Think out of the box***
- Includes relevant Solved Questions from:
  - NEET (UG) 2023
  - JEE (Main) 2023 24th Jan (Shift - II)
  - NEET (UG) Manipur 2023
- Includes Question Paper and Answer Keys (Solutions through Q.R. code) of:
  - JEE (Main) 2024 31st January (Shift - I)
- Topic Test provided in each chapter for self-assessment
- Q.R. codes provide:
  - Video links for boosting conceptual retention
  - Answers & Solutions to Topic Tests

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PREFACE

'Absolute Physics Vol - II' is a complete guidebook, extremely handy for preparation of various competitive exams like NEET (UG), JEE (Main). This edition provides an unmatched comprehensive amalgamation of theory with MCQs. The chapters are aligned with the latest syllabus for **NEET (UG) and JEE (Main) 2024** examinations. Although the alignment runs parallel to NCERT curriculum, the structure of the chapters prioritizes knowledge building of the students. The book provides the students with scientifically accurate context, several study techniques and skills required to excel in these examinations.

All the questions included in a chapter have been specially created and compiled to enable students solve complex problems which require strenuous effort with promptness.

These MCQs are framed considering the importance given to every topic as per the NEET (UG) and JEE (Main) exam to form a strong foundation. They are a healthy mix of theoretical, numerical and graphical based questions.

The level of difficulty of these questions is at par with that of various competitive examinations held across India. Questions from various examinations such as NEET (UG), JEE (Main), MHT CET, K CET, WB JEE, AP EAMCET, AP EAPCET, TS EAMCET (Med. and Engg.), GUJ CET are exclusively covered.

Features in each chapter:

- Coverage of **'Theoretical Concepts'** that form a vital part of any competitive examination.
- **'Multiple Choice Questions'** are segregated topic-wise to enable easy assimilation of questions based on the specific concept.
- **'Formulae'** covers all the key formulae in the chapter, making it useful for students to glance at while solving problems and revising at the last minute.
- **'Topic Test'** has been provided at the end of each chapter to assess the level of preparation of the student on a competitive level.

All the features of this book pave the path of a student to excel in examination. The features are designed keeping the following elements in mind: Time management, easy memorization or revision and non-conventional yet simple methods for MCQ solving.

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

A book affects eternity; one can never tell where its influence stops.

Publisher

Edition: Eighth

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.

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KEY FEATURES

Formulae

'**Formulae**' cover all of the key formulae in the chapter which is useful for students while solving problems and revising at last minute at a glance.

Examples

'**Examples**' are provided to elucidate a concept using theory or MCQ or numerical question and help students hone their problem-solving skills.

Smart Keys

'**Smart Keys**' comprise a set of remarkable study techniques contrived to benefit students.

Time Saver

'**Time Saver**' illustrates quick method over lengthy conventional method of solving numerical.

Smart Tips

'**Smart Tips**' comprise important theoretical or formula based short tricks considering their usage in solving MCQ.

Caution

'**Caution**' apprises students about mistakes which are made while solving an MCQs.

Learning Pointers

'**Learning Pointers**' provide compilation of additional notes which involve fusion of two concepts from different chapters or come as indirect extensions of subtopics.

Think out of the box

'**Think out of the box**' reveals quick witted approach to crack the specific question.

To be continued...

KEY FEATURES

For your knowledge

'**For your knowledge**' includes additional information relevant to concept.

Connection

'**Connection**' enables students to interlink concepts covered in different chapters.

Gyan Guru

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

Clock symbol

'**Clock Symbol**' instructs students that given MCQ can be solved apace by applying either smart tips, Time saver, Learning Pointers or Think out of the box.

QR Code

'**QR code**' provides:

i. Access to a video/PDF in order to boost understanding of a concept or activity.
ii. Answers & Solutions to Topic Test of each chapter.
iii. Solutions to JEE (Main) 2024 31st January (Shift - 1) question paper.

Frequently Asked Questions

- **Why Absolute Series?**

  Gradually, every year the nature of competitive entrance exams is inching towards conceptual understanding of topics. Moreover, it is time to bid adieu to the stereotypical approach of solving a problem using a single conventional method.

  To be able to successfully crack the NEET(UG) /JEE (Main) examinations, it is imperative to develop skills such as data interpretation, appropriate time management, knowing various methods to solve a problem, etc. With Absolute Series, we are sure, you'd develop all the aforementioned skills and take a more holistic approach towards problem solving. The way you'd tackle advanced level MCQs with the help of Hints, Examples, Smart tips, Time Saver, Smart codes and Think out of the box would give you the necessary practice that would be a game changer in your preparation for the competitive entrance examinations.

- **What is the intention behind the launch of Absolute Series?**

  The sole objective behind the introduction of Absolute Series is to cater to needs of students across a varied background and effectively assist them to successfully crack the NEET(UG) /JEE (Main) examinations. With a healthy mix of MCQs, we intend to develop a student's MCQ solving skills within a stipulated time period.

- **What do I gain out of Absolute Series?**

  After using Absolute Series, students would be able to:

  a. assimilate the given data and apply relevant concepts with utmost ease.

  b. tackle MCQs of different pattern such as match the columns, diagram based questions, multiple concepts and assertion-reason efficiently.

  c. garner the much needed confidence to appear for competitive exams.

  d. easy and time saving methods to tackle tricky questions will help ensure that time consuming questions do not occupy more time than you can allot per question.

- **How to derive the best advantage of the book?**

  To get the maximum benefit of the book, we recommend :

  a. Go through the detailed theory and Examples solved alongwith at the beginning of a chapter for concept clarity. Commit Smart Tips and Time saver into memory and pay attention to Caution.

  b. Read through the Learning pointers section minutely.

  c. Know all the Formulae compiled at the end of theory by-heart.

  d. Using subtopic wise segregation as a leverage, complete MCQs in each subtopic at your own pace. Questions from exams such as JEE (Main), NEET(UG) are tagged and placed along the flow of subtopic. Mark these questions specially to gauge the trends of questions in various exams.

  e. Be extra receptive to Think out of the box, Alternate Method and application of Smart Tips and Time saver. Assimilate them into your thinking.

Best of luck to all the aspirants!

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Page no. to **54** are purposely left blank.

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

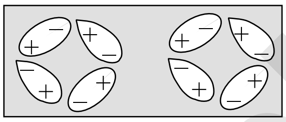
2 Electrostatics: Capacitance

- Dielectrics, Electric polarisation and Electric susceptibility
- Capacitance and Capacitors
- Combination of capacitors
- Capacitance of parallel plate capacitor with and without dielectric medium between the plates
- Energy stored in a capacitor

Dielectrics, Electric polarisation and Electric susceptibility

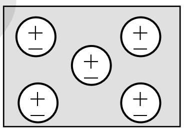
➢ **Dielectrics:**
Dielectrics are (non-conducting) materials that transmit electric effect without conducting.
There are two types of dielectrics:
i. Polar dielectrics
ii. Non-polar dielectrics

➢ **Polar dielectrics:**
i. It has permanent electric dipole moment even if the electric field is absent.
ii. Net dipole moment of polar dielectric is zero because polar molecules are randomly oriented in absence of electric field.



iii. In presence of electric field, polar molecules align themselves in the direction of the field.
Examples: Alcohol, Water, NH_3, HCl.

➢ **Non-polar dielectrics:**
i. Every non-polar molecule has zero dipole moment in its normal state.
ii. When electric field is applied, molecules become induced electric dipole.
Examples: N_2, O_2, Methane, Benzene.



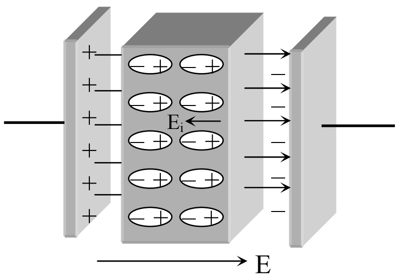
➢ **Electric polarisation:**
i. *In presence of an external electric field, a dielectric develops a net dipole moment. The dipole moment per unit volume is called polarization.*
ii. It is denoted by $\vec{P}$ and expressed in Cm^{-2}.
iii. Relation between polarisation vector and surface density of induced charges:
When a dielectric slab is placed in an electric field, the charges are induced on the surfaces of the dielectric. The negative induced surface charge is equal to the positive induced surface charge. So, dielectric as a whole remains electrically neutral. Thus, polarisation of a dielectric involves only a relative displacement of charges in it.
Let, $\pm q_p$ = induced surface charges,
$\pm \sigma_p$ = surface density of induced charges,
x = thickness of slab and A = area of the slab.
Dipole moment of slab = $q_p \times x$,
Volume of slab = A × x

Polarisation, $P = \frac{q_p x}{Ax} = \frac{q_p}{A} = \sigma_p$

So, when $\vec{P}$ is normal to the surface of the dielectric, the polarisation is numerically equal to σ_p.

$\sigma_p = \vec{P}\cdot\hat{n}$

Here, $\hat{n}$ is a unit normal vector at the surface.
iv. Electric field gets modified in presence of dielectric,
$E' = E - E_i$
Where E′ is induced field,
E is main field,
E_i is field due to dielectrics.



➢ **Dielectric constant:**
i. *Dielectric constant of dielectric medium is the ratio of the strength of the applied electric field to the strength of the reduced value of the electric field on placing dielectric between the plates of the capacitor.*

ii. Dielectric constant,

$$K = \frac{E}{E'} = \frac{\begin{pmatrix}\text{electric field between} \\ \text{the plates with air}\end{pmatrix}}{\begin{pmatrix}\text{electric field between} \\ \text{the plates with medium}\end{pmatrix}}$$

iii. K is also called as relative permittivity of the material or SIC (specific inductive capacitance).

iv. For vacuum, K = 1 and though for air its slightly greater than 1, for practical purposes, it's taken as 1.

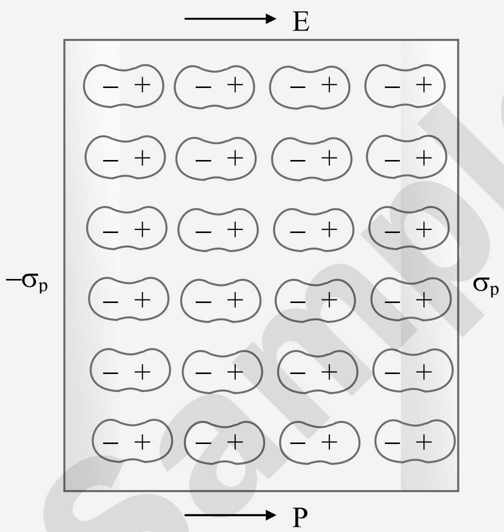
➢ **Electric susceptibility of dielectric:**

For linear isotropic dielectrics the polarisation P is directly proportional to the resultant electric field E in the dielectric.

∴ $P \propto E$ or $P = \chi\varepsilon_0 E$

χ is known as the **electric susceptibility of the dielectric**. It describes the behaviour of a dielectric. Larger the value of χ, greater will be the polarisation of the dielectric in an electric field. In the case of vacuum, the value of χ is zero because there are no molecules in vacuum.

For your knowledge



Electric Displacement:

For the slab in figure, P is along $\hat{n}$ at the right surface and opposite to $\hat{n}$ at the left surface. Thus at the right surface, induced charge density is positive and at the left surface, it is negative. Putting the equation for electric field in vector form

$$\vec{E}\cdot\hat{n} = \frac{\sigma - \sigma_P}{\varepsilon_0}$$

$$\therefore \quad \vec{E}\cdot\hat{n} = \frac{\sigma - \vec{P}\cdot\hat{n}}{\varepsilon_0} \qquad \therefore \quad \left(\varepsilon_0\vec{E} + \vec{P}\right)\cdot\hat{n} = \sigma$$

The quantity $\varepsilon_0\vec{E} + \vec{P}$ is called the *electric displacement* and is denoted by $\vec{D}$. It is a vector quantity. Thus, $\vec{D} = \varepsilon_0\vec{E} + \vec{P}$, $\vec{D}\cdot\hat{n} = \sigma$

Significance of $\vec{D}$: In vacuum, E is related to the free charge density σ.

When a dielectric medium is present, the corresponding role is taken up by $\vec{D}$. For a dielectric medium, it is $\vec{D}$ not $\vec{E}$ that is directly related to free charge density σ, as seen in above equation. Since $\vec{P}$ is in the same direction as $\vec{E}$, all the three vectors $\vec{P}$, $\vec{E}$ and $\vec{D}$ are parallel.

Ratio of the magnitudes of $\vec{D}$ and $\vec{E}$ is

$$\frac{D}{E} = \frac{\sigma\varepsilon_0}{\sigma - \sigma_P} = \varepsilon_0 K$$

Thus $\vec{D} = \varepsilon_0 K\vec{E}$ and $\vec{P} = \vec{D} - \varepsilon_0\vec{E} = \varepsilon_0(K-1)\vec{E}$

This corresponds to $\chi_e = (K-1)$

CAPACITANCE AND CAPACITORS

➢ **Capacitance:**

i. *Capacitance is defined as the amount of charge required to raise the potential difference through 1 V.*

OR

The ability of a conductor to store charge is called as capacitance of conductor.

OR

The ratio of charge on a conductor to its corresponding potential difference is called capacitance of conductor.

Formula:	$C = \frac{q}{V}$
Unit:	farad in SI system statfarad in CGS system (i.e., electrostatic unit of capacity) 1farad = 9×10^{11} statfarad 1 μF = 10^{-6} F 1 nF = 10^{-9} F 1 pF = 10^{-12} F
Dimensions:	$[M^{-1} L^{-2} T^4 A^2]$
Quantity:	scalar

ii. Capacitance of a conductor is small and limited.

iii. If a conductor is placed near a charged conductor, the potential of charged conductor decreases and hence it can store more charge i.e., nearness of a conductor increases the capacitance of a charged conductor.

➢ **Redistribution of charges and concept of common potential:**

Consider two insulated conductors P and Q of capacitances C_1 and C_2 carrying charges q_1 and q_2 respectively. Let V_1 and V_2 be their respective potentials. When the two conductors are joined by a thin metallic wire, positive charge begins to flow from a conductor of higher potential to a conductor of lower potential till their potentials are equalised. Thus, the charges are redistributed. But the total quantity of charge remains $(q_1 + q_2)$.

If we neglect the capacitance of the connecting wire and assume that the conductors are so much spaced apart that they do not electrically affect each other, then the combined capacitance of the two conductors is $C_1 + C_2$.

Common potential, $V = \dfrac{\text{Total charge}}{\text{Total capacitance}}$

or $V = \dfrac{q_1 + q_2}{C_1 + C_2}$ or $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

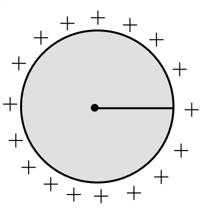
Let q_1' and q_2' be the charges on P and Q respectively after the redistribution of charges has taken place.

Then $q_1' = C_1V$ and $q_2' = C_2V$

∴ $\dfrac{q_1'}{q_2'} = \dfrac{C_1V}{C_2V}$ or $\dfrac{q_1'}{q_2'} = \dfrac{C_1}{C_2}$

➢ **Capacitance of an isolated spherical conductor:**

Consider an isolated spherical conductor of radius r placed in a medium of relative permittivity ε_r. Suppose Q is the charge on the surface of the sphere.



Potential at the surface of the sphere is given by:

$$V = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{r}$$

Let C be the capacitance, then

$$C = \frac{Q}{V} = \frac{Q}{\frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{r}}$$

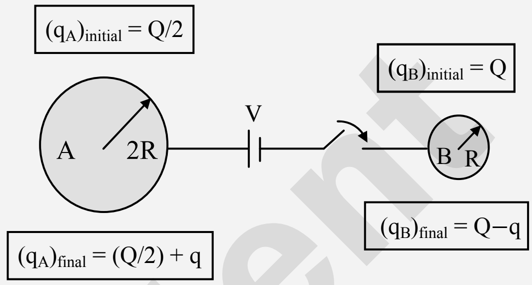
$\Rightarrow C = 4\pi\varepsilon_0\varepsilon_r r$

For vacuum, $\varepsilon_r = 1$

∴ $C = 4\pi\varepsilon_0 r$

EXAMPLE - 2.1

There are two spheres of radii R and 2R having charges Q and Q/2, respectively. These two spheres are connected with a cell of emf V volts (as shown in figure). When the switch is closed, find the final charge on each sphere.



Solution:

When the switch is closed, the potential difference between the spheres should be V. Let q charges flow from the sphere of radius R.

$$\frac{(q_A)_{final}}{C_A} - \frac{(q_B)_{final}}{C_B} = V$$

$C_A = 4\pi\varepsilon_0\,(2R)$, $C_B = 4\pi\varepsilon_0 R$

Then

$$\frac{\left(\frac{Q}{2} + q\right)}{4\pi\varepsilon_0(2R)} - \frac{(Q - q)}{4\pi\varepsilon_0(R)} = V$$

$$\frac{Q}{2} + q - 2Q + 2q = 4\pi\varepsilon_0(2R)V$$

$$\Rightarrow q = \frac{8\pi\varepsilon_0 RV}{3} + \frac{Q}{2}$$

So, the final charges on spheres B and A respectively are:

$$Q - q = \frac{Q}{2} + \frac{-8\pi\varepsilon_0 RV}{3}$$

and $\dfrac{Q}{2} + q = Q + \dfrac{8\pi\varepsilon_0 RV}{3}$

➢ **Capacitor:**

i. *Capacitor is a device which increases storing capacity of a conductor at a relatively low potential.*

OR

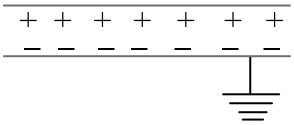
An arrangement which consists of two conductors separated by a dielectric medium such that one of the plates is positively charged and other is connected to the ground is called as capacitor.

It is also called as condenser.

ii. **Principle of a capacitor:** The capacity of a charged conductor increases if another conductor connected to earth is kept near it.

iii. Types of capacitor:

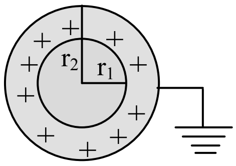
a. Parallel plate capacitor:



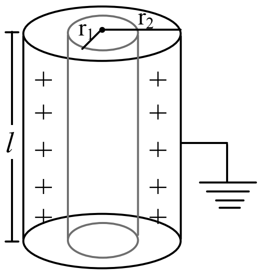
$$C = \frac{K\varepsilon_0 A}{d}$$

b. Spherical capacitor:

$$C = 4\pi K\varepsilon_0\left(\frac{r_1 r_2}{r_2 - r_1}\right)$$



c. Cylindrical capacitor:



$$C = \frac{2\pi K\varepsilon_0 l}{2.303\log\left(\frac{r_2}{r_1}\right)}$$

iv. In a capacitor, it is possible to deposit still larger charges on first plate in presence of induced negative charge on the second plate.

Smart tip - 1

i. The behaviour of a single-conductor is like a capacitor with second plate (or conductor) at infinity. Therefore, the capacitance of a single conductor is the amount of charge required to raise the potential of the conductor by a unit amount.

ii. Spherical conductor is a spherical capacitor with its outer radius as infinity.

EXAMPLE - 2.2

A spherical capacitor has an inner sphere of radius 14 cm and outer sphere of radius 15 cm. The outer sphere is earthed and the inner sphere is given a charge of 5 μC. The space between the concentric spheres is filled with a liquid of dielectric constant 30.

a. Determine the capacitance of the capacitor.

b. What is the potential of the inner sphere?

c. Compare the capacitance of this capacitor with that of an isolated sphere of radius 14 cm. Which one is smaller? Explain the reason.

Solution:

Radius of inner and outer sphere respectively,

$r_1 = 14$ cm = 0.14 m

$r_2 = 15$ cm = 0.15 m

Charge on the inner sphere,

$q = 5\ \mu C = 5 \times 10^{-6}$ C

Dielectric constant of a liquid,

K = 30

a. $C = \frac{4\pi\varepsilon_0 K r_1 r_2}{r_1 - r_2}$

$= \frac{30 \times 0.14 \times 0.15}{9 \times 10^9 \times (0.15 - 0.14)}$ F

$= 7 \times 10^{-9}$ F

b. Potential of the inner sphere is given by,

$V = \frac{q}{C} = \frac{5 \times 10^{-6}\ C}{7 \times 10^{-9}\ F} = 7.14 \times 10^2$ V

c. Radius of isolated sphere,

$r = 14 \times 10^{-2}$ m

$C' = 4\pi\varepsilon_0 r$

$= \frac{14 \times 10^{-2}\ m}{9 \times 10^9\ Nm^2\ C^{-2}}$

$= 1.56 \times 10^{-11}$ F

The capacitance of the isolated sphere is less in comparison to the concentric spheres. This is because the outer sphere of the concentric spheres is earthed, resulting in less potential difference and thus the capacitance is more than the isolated sphere.

v. Applications of capacitors:

a. For tuning in radio circuit.

b. For smoothing rectified current in power supplies.

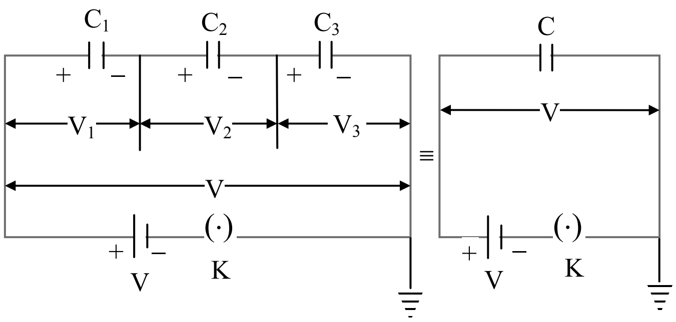
c. For eliminating sparkling of points, when they are open or close in an ignition system of automobile engine.

d. For storage of large amount of charge in nuclear reactors.

Students can scan the adjacent QR code in *Quill - The Padhai App* to understand **basics of capacitor and its uses** with the aid of a linked video.

Combination of Capacitors

➢ **Capacitors in series:**



i. In the given figure, three capacitors are connected in series with each other.

ii. Potential across capacitors are V_1, V_2 and V_3.

iii. Total potential across the capacitors is V,
$V = V_1 + V_2 + V_3$

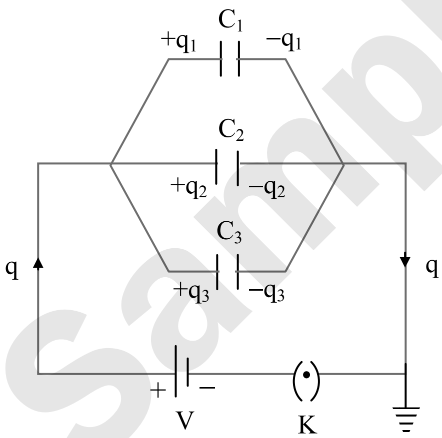
iv. $V_1 = \frac{q}{C_1}$, $V_2 = \frac{q}{C_2}$, $V_3 = \frac{q}{C_3}$, $V = \frac{q}{C_S}$

where, C_S is equivalent capacitance in series.

$$\frac{q}{C_S} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\therefore \quad \frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

➢ **Capacitors in parallel:**



i. In the given figure three capacitors are connected in parallel.

ii. Potential across each capacitor is V.

iii. Charges on each plates of capacitors are q_1, q_2, q_3.

iv. Total charge, $q = q_1 + q_2 + q_3$

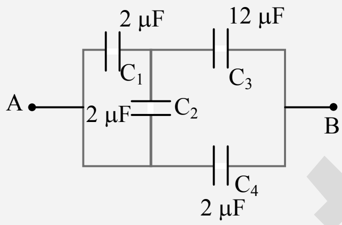
$q_1 = C_1V$, $q_2 = C_2V$, $q_3 = C_3V$ and $q = C_PV$

where, C_P is equivalent capacitor in parallel.

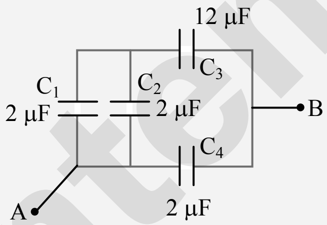
$\therefore \quad C_P = C_1 + C_2 + C_3$

EXAMPLE - 2.3

What is the effective capacitance between points A and B?

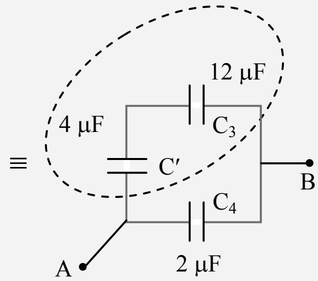


Solution:



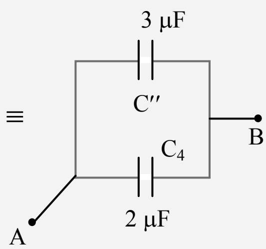
In this circuit C_1 and C_2 are parallel hence

$C' = C_1 + C_2 = 2+2 = 4$ μF



Here C′ and C_3 are in series hence

$$C'' = \frac{C' C_3}{C' + C_3} = \frac{4 \times 12}{4 + 16} = 3 \text{ μF}$$



Here C″ and C_4 are in parallel hence

$C_{eq} = C'' + C_4 = 3 + 2 = 5$ μF

Time saver - 1

When the difference in the effective capacity of two identical capacitors when joined in series and then in parallel is given as C′, then capacity of each capacitor say C is given by, $C = \frac{2C'}{3}$

Example:
The difference in the effective capacity of two similar capacitors when joined in series and then in parallel is 6 μF. The capacity of each capacitor is **[MH CET 2015]**
(A) 2 μF (B) 4 μF (C) 8 μF (D) 16 μF

Conventional Method:

$C_P = C_1 + C_2$

$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_1 + C_2}{C_1C_2}$

$\therefore \quad C_S = \frac{C_1C_2}{C_1 + C_2}$

According to given condition

$C_P - C_S = 6$ μF

$C_1 + C_2 - \frac{C_1C_2}{C_1 + C_2} = 6$

As $C_1 = C_2 = C$

$2C - \frac{C^2}{2C} = 6$

$4C^2 - C^2 = 12C$

$3C^2 = 12C$

$C = 4$ μF

Ans: (B)

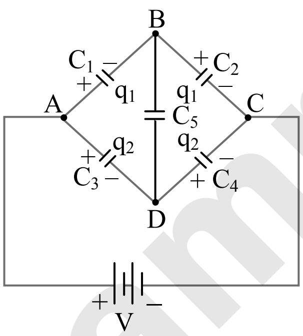
Quick method:

Capacity of each capacitor,

$C = \frac{2C'}{3} = \frac{2 \times 6}{3} = 4$ μF

Ans: (B)

➢ **Wheatstone's bridge of capacitors**



i. When potential of B is equal to potential of D, there is no flow of charge in the diagonal arm BD. So, C_5 becomes ineffective.

ii. In this situation, C_1 and C_2 are in series. Let q_1 be the charge on each capacitor C_1 and C_2. Similarly, C_3 and C_4 are in series. Let q_2 be the charge on each capacitor C_3 and C_4.

iii. Now, $V_A - V_B = \frac{q_1}{C_1}$;

$V_A - V_D = V_A - V_B \quad ....(\because V_B = V_D)$

$= \frac{q_2}{C_3}$

$V_B - V_C = \frac{q_1}{C_2}$;

$V_D - V_C = V_B - V_C = \frac{q_2}{C_4}$

Clearly, $\frac{q_1}{C_1} = \frac{q_2}{C_3}; \frac{q_1}{C_2} = \frac{q_2}{C_4}$

$\frac{q_1}{q_2} = \frac{C_1}{C_3} = \frac{C_2}{C_4}$

$\therefore \quad \frac{C_1}{C_2} = \frac{C_3}{C_4}$

CAUTION

C_5 cannot be ignored if potential at B differs from potential at D. In other words, when $\frac{C_1}{C_2} \neq \frac{C_3}{C_4}$, charge flows through C_5 and contributes into the operation of circuit.

Smart tip - 2

i. If n capacitors each of same capacitance C are connected in:
a. series, then equivalent capacitance of combination is $C_S = (C/n)$
b. parallel, then equivalent capacitance is $C_P = nC$.

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

ii. Work done by the battery is

$$W_{battery} = (\Delta q)\frac{\varepsilon}{2} = \left(-\frac{C\varepsilon}{2}\right)\frac{\varepsilon}{2} = -\frac{C\varepsilon^2}{4}$$

This means work is done on the battery.

iii. Change in the potential energy of the capacitor $= U_{final} - U_{initial}$.

$$\therefore \quad \Delta U = \frac{1}{2}C\left(\frac{\varepsilon}{2}\right)^2 - \frac{C\varepsilon^2}{2}$$

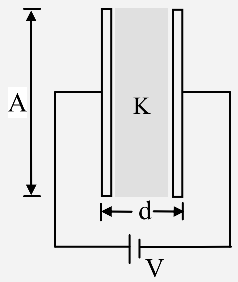
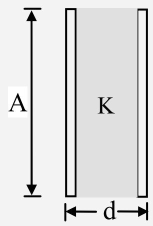
$$= \frac{1}{8}C\varepsilon^2 - \frac{1}{2}C\varepsilon^2 = -\frac{3C\varepsilon^2}{8}$$

As, work done by the battery = Change in potential energy of the capacitor + heat produced.

$\therefore$ Heat produced is

$$H = W_{battery} - \Delta U = \frac{3C\varepsilon^2}{8} - \frac{C\varepsilon^2}{4} = \frac{C\varepsilon^2}{8}$$

Smart tip - 4

i. If battery remains connected	**ii. When battery is absent/ disconnected**
	
a. Charge on plate becomes K times, i.e., $q = CV$ $= KC_0V_0 = Kq_0$, Where, q_0 is initial charge.	**a.** Charge on the plates will remain same, i.e., $q = q_0$, since in an isolated system, charge is conserved.
b. Capacitance increases, i.e., $C = KC_0$	**b.** Capacitance increases, i.e., $C = KC_0$
c. Potential difference across the plates is $V = \frac{q}{C} = \frac{Kq_0}{KC_0} = V_0$, Thus, the potential difference remains same.	**c.** Potential difference between the plates is $V = \frac{q}{C} = \frac{q_0}{KC_0} = \frac{V_0}{K}$ Thus, potential difference decreases and becomes 1/K times.
d. Electric field is $E = \left[\frac{V}{d}\right] = \frac{V_0}{d} = E_0$ Thus, electric field remains same.	**d.** Field between the plates is $E = \frac{V}{d} = \frac{V_0}{Kd} = \frac{E_0}{K}$ Thus, the electric field decreases and becomes 1/K times.
e. Energy stored in the capacitor is $U = \frac{1}{2}CV^2$ $= \frac{1}{2}(KC_0)(V_0)^2$ $= \left(K\frac{1}{2}C_0V_0^2\right) = KU_0$ Thus, energy increases and becomes K times.	**e.** Energy stored in the capacitor is $U = \frac{q^2}{2C}$ $= \frac{q_0^2}{2KC_0} = \frac{U_0}{K}$ Thus, energy decreases and becomes 1/K times.

Formulae

1. **Capacitance:** $C = \frac{q}{V}$

2. **For a parallel plate capacitor:**

i. Without dielectric, $C = \frac{\varepsilon_0 A}{d}$

ii. With dielectric, $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$

3. **Spherical capacitor:**

$$C = 4\pi K\varepsilon_0\left(\frac{r_1r_2}{r_2 - r_1}\right)$$

4. **Cylindrical capacitors:** $C = \frac{2\pi K\varepsilon_0 l}{2.303\log\left(\frac{r_2}{r_1}\right)}$

5. **Capacitors in series:** $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

6. **Capacitors in parallel:** $C_P = C_1 + C_2 + C_3$

7. **Wheatstone's bridge of capacitors:**

$$\frac{C_1}{C_2} = \frac{C_3}{C_4}$$

8. **Energy stored in capacitor:**

$$U = \frac{1}{2}CV^2 = \frac{1}{2}qV = \frac{1}{2}\frac{q^2}{C}$$

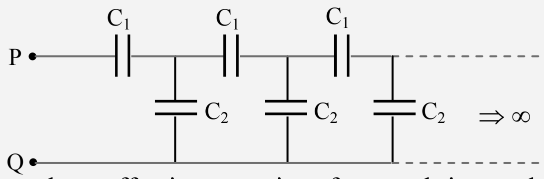
9. **Total energy stored per unit volume of the capacitor:**

$$u = \frac{U}{\text{volume}} = \frac{1}{2}\varepsilon_0E^2$$

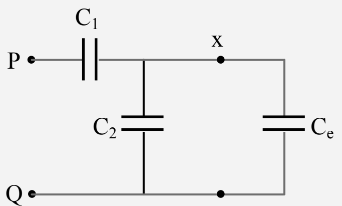
Learning Pointers

1. Dielectric strength is the maximum electric field a material can tolerate without breakdown i.e., without starting to conduct electricity through partial ionisation.

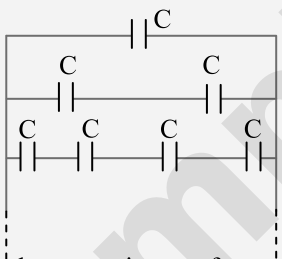
2. For a fixed distribution of charges, the effect of a dielectric is to weaken the electric field that would otherwise be present.
3. As the potential of the earth is assumed to be zero, capacity of conductor connected to earth (whatever its shape or charge on it) will be infinite.
4. For infinite network, if the effective capacitance between two points is C_e, then even if we add/remove one pair of capacitors from the chain the remaining network would still have infinite pairs of capacitors.



then, effective capacity of network is equal to effective capacity of the unit circuit of the ladder as shown below.



5. When identical capacitors each of capacitance C are connected in geometrical progession (as in figure, in parallel),



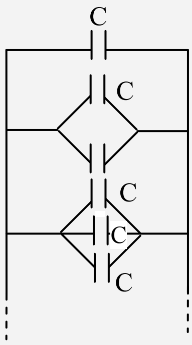
the equivalent capacitance of arrangement is

$$C' = C + \frac{C}{2} + \frac{C}{4} + \frac{C}{8} + \ldots\ldots\infty$$

$$= C\left[1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \ldots..\infty\right]$$

$$C' = \frac{C}{1 - \frac{1}{2}} = 2\,C$$

6. When a number of identical condensers each of capacity C are connected (as in figure), then equivalent capacitance is given by
$C' = C + 2C + 3C + \ldots..nC$
$= C(1 + 2 + 3 + \ldots..n)$



$$C' = \frac{n(n+1)}{2}C$$

7. If capacitance C is connected along each side of the skeleton cube, then
⇒ equivalent capacitance along the longest diagonal $= \frac{6}{5}C$
⇒ equivalent capacitance along a face diagonal $= \frac{4}{3}C$
⇒ equivalent capacitance along one side $= \frac{12}{7}C$
if one side of skeleton cube is open then equivalent capacitance between the open ends of the cube $= \frac{5}{7}C$.
8. When two charged capacitors are connected together, there is a chance of loss of energy, which can be given by equation,
$$\Delta U = U - U' = \frac{C_1C_2(V_1 - V_2)^2}{2(C_1 + C_2)}$$
This loss is usually in the form of heat.
9. Even if the current through capacitor is zero, a finite amount of energy can be stored in a capacitor.
10. When n identical liquids drops, each of radius r coalesce to form a big drop of radius R, then
$R = n^{1/3}$ r.
Also, if each small drop has a capacitanc C, a potential V, and a charge q then:
Total charge, $Q_{big} = nq_{small}$
Electric field intensity, $E_{big} = n^{1/3} E_{small}$
Electric potential, $V_{big} = n^{2/3} V_{small}$
Surface density, $\sigma_{big} = n^{1/3} \sigma_{small}$
Electric potential energy, $U_{big} = n^{5/3} U_{small}$
Electric capacitance, $C_{big} = n^{1/3} C_{small}$

Multiple Choice Questions

Dielectrics, Electric polarisation and Electric susceptibility

1. Four metal conductors having different shapes
(1) a sphere (2) cylindrical
(3) pear (4) lightning
conductor are mounted on insulating stands and charged. The one which is best suited to retain the charges for a longer time is
(A) 1 (B) 2 (C) 3 (D) 4

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

25. A fully charged capacitor has a capacitance C. It is discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity 's' and mass 'm'. If the temperature of the block is raised by ΔT, the potential difference V across the capacitance is

(A) $\sqrt{\frac{2\,mC\Delta T}{s}}$ (B) $\frac{mC\Delta T}{s}$

(C) $\frac{ma\,\Delta T}{C}$ (D) $\sqrt{\frac{2\,ms\Delta T}{C}}$

26. A pair of parallel metal plates are kept with a separation 'd'. One plate is at a potential +V and the other is at ground potential. A narrow beam of electrons enters the space between the plates with a velocity v_0 and in a direction parallel to the plates. What will be the angle of the beam with the plates after it travels an axial distance L? **[WB JEE 2020]**

(A) $\tan^{-1}\left(\frac{eVL}{mdv_0}\right)$ (B) $\tan^{-1}\left(\frac{eVL}{mdv_0^2}\right)$

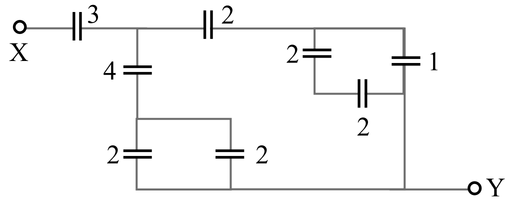
(C) $\sin^{-1}\left(\frac{eVL}{mdv_0}\right)$ (D) $\cos^{-1}\left(\frac{eVL}{mdv_0^2}\right)$

Numerical Value Type Questions

1. In a parallel plate condenser, the radius of each circular plate is 12 cm and the distance between the plates is 5 mm. There is a glass slab of 3 mm thick and of radius 12 cm with dielectric constant 6 between its plates. The capacity of the condenser in pF is_______.

2. The resultant capacitance between the points X and Y in the figure is $\frac{n}{2}$ μF. Find value of n.

(all capacitances are in μF)



3. A 5 μF capacitor is charged fully by a 220 V supply. It is then disconnected from the supply and is connected in series to another uncharged 2.5 μF capacitor. If the energy change during the charge redistribution is $\frac{X}{100}$ J then value of X to the nearest integer is _____. **[JEE (Main) Sept 2020]**

4. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 50 micro-farad is x $\times10^{-32}$ J. Find x.

5. The plates of a parallel plate capacitor are moved towards each other with small uniform velocity. For instantaneous plate separation x, rate of change of capacitance with time is proportional to x^{-n}. Find value of n.

6. N identical drops of mercury are charged simultaneously to 10 V. When combined to form one large drop, the potential is found to be 40 V. Determine the value of N.

7. A parallel plate capacitor with air between the plate has a capacitance of 15 pF. The separation between the plate becomes twice and the space between them is filled with a medium of dielectric constant 3.5. Then the capacitance becomes $\frac{x}{4}$ pF. The value of x is _______.

[JEE (Main) Jan 2023]

Topic Test

1. For corona discharge, the conductor should have a

(A) spherical end. (B) flat end.
(C) pointed end. (D) concave end.

2. The capacitance of the earth viewed as a spherical conductor of radius 6408 km is

(A) 600 μF (B) 712 μF
(C) 980 μF (D) 1424 μF

3. When two capacitors are connected in series, the equivalent capacitance is $\frac{15}{4}$ μF. When they are connected in parallel the equivalent capacitance is 16 μF. The individual capacitance are

(A) 5 μF, 11 μF (B) 6 μF, 10 μF
(C) 4 μF, 12 μF (D) 8 μF, 8 μF

4. The capacities of two conductors are C_1 and C_2 and their respective potentials are V_1 and V_2. If they are connected by a thin wire then the loss of energy will be

(A) $\frac{C_1C_2(V_1+V_2)}{2(C_1+C_2)}$ (B) $\frac{C_1C_2(V_1-V_2)}{2(C_1+C_2)}$

(C) $\frac{C_1C_2(V_1-V_2)^2}{2(C_1+C_2)}$ (D) $\frac{(C_1+C_2)\,(V_1-V_2)}{C_1C_2}$

5. With the rise in temperature, the dielectric constant of a liquid

(A) increases.
(B) decreases.
(C) remains unchanged.
(D) changes erratically.

6. **Assertion:** If the air between the plates of a charged parallel plate capacitor is replaced by a medium of dielectric constant K, then the capacitance becomes K times.
Reason: Electric capacitance of a capacitor is independent of the charge on it.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is False.

7. A conductor of capacity 10 μF is at a potential of 10 V. If the potential increases by 1 V, the increase in energy is
(A) 1 μJ (B) 210 μJ
(C) 105 μJ (D) 10.5 μJ

8. The potential of two plates of capacitor are +10 V and –10 V the charge on one of the plates is 40 C. The capacitance of the capacitor is
(A) 2 F (B) 4 F
(C) 0.5 F (D) 0.25 F

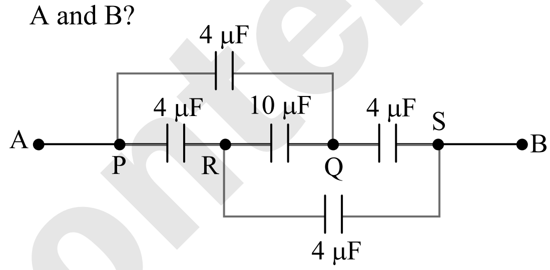
9. A parallel plate capacitor is connected to a battery. The plates are pulled apart with uniform speed v. If x is separation between plates, then the rate of change of the electrostatic energy of the condenser is proportional to
(A) x^2 (B) x
(C) $\frac{1}{x}$ (D) $\frac{1}{x^2}$

10. A 100 microfarad capacitor is to have an energy content of 50 J in order to operate a flash lamp. The voltage required to charge the capacitor is
(A) 500 V (B) 1000 V
(C) 1500 V (D) 2000 V

11. The capacitance of a parallel plate capacitor can be increased by
(A) increasing the area of the plates.
(B) decreasing the distances between the plates.
(C) using a dielectric of higher permittivity.
(D) all the above.

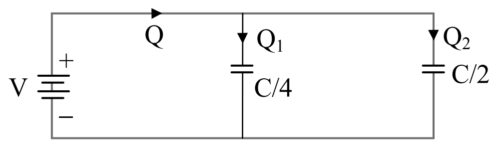
12. Voltage rating of parallel plate capacitor is 250 V. Its dielectric can withstand a maximum electric field of 10^6 V/m. The plate area is 10^{-4} m^2. What is the dielectric constant if the capacitance is 45 pF?
(given $\varepsilon_0 = 8.86 \times 10^{-12}$ C^2/Nm^2)
(A) 12.7 (B) 6.3
(C) 3.6 (D) 36.6

13. What is the effective capacitance between points A and B?



(A) 3 μF (B) 6 μF
(C) 2 μF (D) 4 μF

14. What will be the work done in completely charging both the condensers shown in the figure below?



(A) $\frac{3}{7}C^2V$ (B) $\frac{3}{4}CV^2$
(C) $\frac{3}{8}CV^2$ (D) $\frac{3}{2}CV$

Scan the adjacent Q.R. Code in *Quill - The Padhai App* to access Answers & Solutions to Topic Test.

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

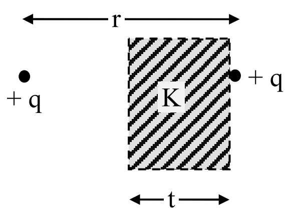
1. Electrostatics: Electric Charges, Fields and Potential

Smart Keys

Smart tip

1. When two identical conductors having charges q_1 and q_2 are kept in contact and separated later then each has charge of $\left(\frac{q_1+q_2}{2}\right)$. If charges are q_1 and $-q_2$, then, each has charge $\left(\frac{q_1-q_2}{2}\right)$.

2. When space between the two charges is partially filled with dielectrics of constant K, the thickness t of the dielectric appears to have the thickness $t\sqrt{K}$.



∴ Total distance between two charges,

$r = (r - t) + t\sqrt{K}$

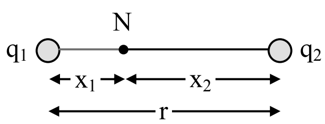
∴ Force between charges will be,

$$F' = \frac{1}{4\pi\varepsilon_0} \quad \frac{q_1 q_2}{\left[(r-t)+t\sqrt{K}\right]^2}$$

3. i. The force between any two charges is not affected by the presence or absence of other charges.

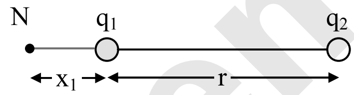
ii. The force between two charges is maximum if their magnitude is equal.

4. i. If two like charges q_1 and q_2 are separated by distance r, then distance x between charge q_1, and null point (point where net electric field due to both the charges is zero) is, $x = \frac{r}{\sqrt{\frac{q_2}{q_1}}+1}$



Null point for like charges

ii. If two unlike charges q_1 and q_2 are separated by distance r, then distance x between charge q_1, and null is, $x = \frac{r}{\sqrt{\frac{q_2}{q_1}}-1}$



Null point for unlike charges

5. The relation between the electric fields at same distances on axis as well as equator from a dipole is, $E_{axial} = 2\ E_{equator}$ i.e., $\vec{E}_{axial} = -2\ \vec{E}_{equator}$

6. For a single charge, $F \propto \frac{1}{r^2}$; $E \propto \frac{1}{r^2}$ but $V \propto \frac{1}{r}$

7. Electric potential energy of a system of N point charges is, $U = \frac{1}{2}\sum_{j=1}^{j=N}\sum_{\substack{k=1\\k\neq j}}^{k=N}\frac{1}{4\pi\varepsilon_0}\frac{q_j q_k}{r_{jk}}$

Learning Pointers

1. For + q, $\vec{F}$ and $\vec{E}$ are in same direction i.e., perpendicular to surface directing outwards. For – q, $\vec{F}$ and $\vec{E}$ are in opposite direction and $\vec{E}$ is perpendicular to surface directing inwards.

2. If an excess charge is placed on an isolated conductor, that amount of charge will move entirely to the surface of the conductor. None of the excess charge will be found within the body of the conductor

3. The atom consisting of positive and negative charges is not a dipole, as centre of positive and negative charges coincide i.e., $2l = 0$. Whereas, the atom placed in electric field becomes dipole because positive and negative centres are displaced relative to each other.

4. Two charged spheres having radii r_1 and r_2, charge densities σ_1 and σ_2 respectively, then the ratio of electric field on their surfaces will be $\frac{E_1}{E_2} = \frac{\sigma_1}{\sigma_2} = \frac{r_2^2}{r_1^2}$ $\left\{\sigma = \frac{Q}{4\pi r^2}\right\}$

5. It is interesting to note that dipole field $E \propto \frac{1}{r^3}$ decreases much rapidly as compared to the field of a point charge $\left(E \propto \frac{1}{r^2}\right)$.

6. Electric field intensity and electric potential due to a point charge q, at a distance $t_1 + t_2$ where t_1 is thickness of medium of dielectric constant K_1 and t_2 is thickness of medium of dielectric constant K_2 are:

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Q}{\left(t_1\sqrt{K_1} + t_2\sqrt{K_2}\right)^2};$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{\left(t_1\sqrt{K_1} + t_2\sqrt{K_2}\right)}$$

Answers and Solutions

Electric Charges and Their Conservation, Conductors and Insulators, Free and Bound Charges Inside a Conductor

1. **(A)** 2. **(C)** 3. **(C)**

4. **(A)**
Excess of electron gives the negative charge on body.

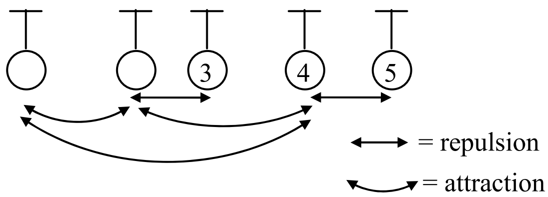
5. **(D)**
Negative charge means excess of electrons which increases the mass of sphere B. Whereas positive charge on sphere A is given by removal of electrons.

6. **(B)**
On rubbing glass rod with silk, excess electrons are transferred from glass to silk. So glass rod becomes positive and silk becomes negative.

7. **(C)**
Since both are metals so equal amount of charge will be induced in them.

8. **(B)**
When a positively charged body is connected to the earth, electrons flows from earth to body and body becomes neutral.

9. **(A)**
As 2 and 3 repel and also 4 and 5 repel; 2, 3, 4 and 5 must be charged.
As 2 and 4 attract, they must be oppositely charged.
As 1 attracts both 2 and 4, this is possible only for a neutral ball. Hence, 1 is neutral.



10. **(D)**

11. **(B)**
Charge on glass rod is positive, so charge on gold leaves will also be positive. Due to X-rays, more electrons from leaves will be emitted, so leaves become more positive and diverge further.

12. **(C)**
In case of metallic sphere either solid or hollow, the charge will reside on the surface of the sphere. Since both spheres have same surface area, they can hold equal amount of maximum charge.

13. **(C)**
For providing path to charge induced on the surface of the carriers which take inflammable material.

14. **(A)**
Number of electrons constituting 1 C,
$$n = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}} = 0.625 \times 10^{19}$$

15. **(A)**
$q = ne = 10^{14} \times 1.6 \times 10^{-19}$
$\therefore$ $q = 1.6 \times 10^{-5}$ C = 16 μC
Electrons are removed, so charge will be positive.

16. **(B)**
By using Q = ne
$Q = 10^{19} \times 1.6 \times 10^{-19}$
Q = +1.6 C

17. **(B)**
$$n = \frac{q}{e} = \frac{1 \times 10^{-9}}{1.6 \times 10^{-19}} = 6.25 \times 10^{9}$$

18. **(B)**
Q = ne
$\therefore$ $n = \frac{Q}{e}$
$$n = \frac{2 \times 10^{-6}}{2 \times 10^{22} \times 29 \times 1.6 \times 10^{-19}}$$
$\therefore$ $n = 2.16 \times 10^{-11}$

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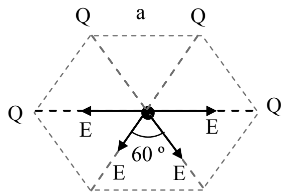
Think out of the box - Q. 23

Electric field at a point due to positive charge acts away from the charge and due to negative charge acts towards the charge. Hence, to get a non-zero electric field at the centre, the charge distribution should be asymmetric. This asymmetric distribution is found only in case (2). Hence, the only correct option here is (B).

24. **(C)**

Electric field will be maximum at the centre if, the charges are arranged as shown in figure,



$\therefore \quad E_{net} = \sqrt{E^2 + E^2 + 2E^2 \cos\theta}$

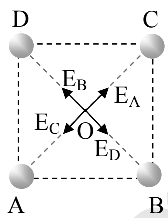
$= \sqrt{2E^2 + 2E^2 \times \frac{1}{2}}$ ….($\because \theta = 60°$)

$= \sqrt{3}\,E$

But, $E = \frac{Q}{4\pi\varepsilon_0 a^2}$

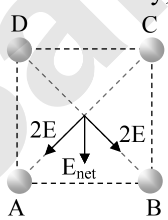
$\therefore \quad E_{net} = \frac{\sqrt{3}\,Q}{4\pi\varepsilon_0 a^2}$

25. **(B)**



$E_A = E, E_B = 2E, E_C = 3E, E_D = 4E$

Adding them vectorically,



Thus, direction of electric field at the centre of the square is along CB.

26. **(C)**

Due to deuteron, intensity of electric field at 1 Å distance,

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{9\times10^9 \times \left(1.6\times10^{-19}\right)}{\left(1\times10^{-10}\right)^2}$

$= 1.44 \times 10^{11}$ N/C

27. **(D)**

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

$= \frac{9\times10^9 \times \left(4\times10^{10}\times1.6\times10^{-19}\right)}{\left(20\times10^{-2}\right)^2} = 1440$ N/C

28. **(C)**

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

$\therefore \quad E = \frac{9\times10^9\times3\times10^{-9}}{(3\times10^{-2})^2} = 3\times10^4$ V/m

29. **(C)**

$E = \frac{1}{4\pi\varepsilon_0}.\frac{ne}{r^2}$

$\therefore \quad n = \frac{Er^2}{e}.4\pi\varepsilon_0$

$n = \frac{0.036\times0.1\times0.1}{9\times10^9\times1.6\times10^{-19}} = \frac{360}{144}\times10^5 = 2.5\times10^5$

30. **(B)**

$E = \frac{1}{4\pi\varepsilon_0}\times\frac{q}{r^2} = 9\times10^9\times\frac{q}{r^2}$

$\therefore \quad q = \frac{E\times r^2}{9\times10^9} = \frac{3\times10^6\times(2.5)^2}{9\times10^9} = 2.0833\times10^{-3}$ C

q should be less than 2.0833×10^{-3} C. In the given set of options 2×10^{-3} is the maximum charge which is smaller than 2.0833×10^{-3}.

31. **(A)**

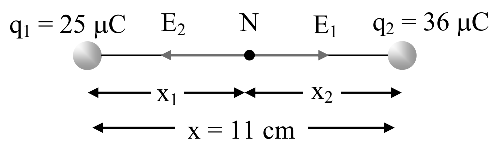
$E = \frac{kq}{r^2}$

$\therefore \quad q = \frac{Er^2}{k} = \frac{2\times(0.3)^2}{9\times10^9} = \frac{2\times9\times10^{-2}\times10^{-9}}{9}$

$\therefore \quad q = 2\times10^{-11}$ C

32. **(A)**

Suppose electric field is zero at point N in the figure then



At N, $|E_1| = |E_2|$

$\therefore$ From ***Smart tip - 4 (i)***,

$x_1 = \frac{x}{\sqrt{\frac{q_2}{q_1}}+1}$ $\quad\therefore\quad x_1 = \frac{11}{\sqrt{\frac{36}{25}}+1}$

$\therefore \quad x_1 = 5$ cm

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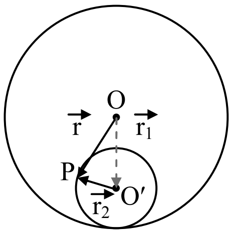
70. **(B)**

Let $\vec{OP} = \vec{r}$, $\vec{O'P} = \vec{r_2}$

And position vector of the centre of cavity from the centre of the sphere is $\vec{r_1}$.



Using Gauss' law, electric field at $\vec{r}$ is

$$E_1 \times 4\pi r^2 = \rho \times \frac{\frac{4}{3}\pi r^3}{\varepsilon_0}$$

$$\vec{E_1} = \frac{\rho}{3\varepsilon_0}\vec{r}$$

Considering the negative charge induced in cavity of same density, electric field at $\vec{r_2}$ is,

$$\vec{E}_2 = \frac{-\rho}{3\varepsilon_0}\vec{r_2}$$

By principle of superposition,

Net electric field, $\vec{E} = \vec{E}_1 + \vec{E}_2$

$$= \frac{\rho}{3\varepsilon_0}\left(\vec{r} - \vec{r_2}\right)$$

$$= \frac{\rho}{3\varepsilon_0}\left(\vec{r_1}\right) \quad (\because \vec{r_1} + \vec{r_2} = \vec{r})$$

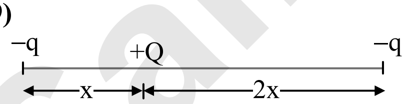
This shows that electric field in the emptied region is non-zero and uniform.

Numerical Value Type Questions

1. **(321)**

$\tau = pE \sin\theta$
$= q \times 2l \times E \sin 90°$
$= (4e)(0.8 \times 10^{-9}) \times 2 \times 3.14 \times 10^5 \times 1$
$= 4 \times 1.6 \times 10^{-19} \times 1.6 \times 3.14 \times 10^{-4}$
$= 32.15 \times 10^{-23}$
$= 3.21 \times 10^{-22}$ Nm
$= 321 \times 10^{-24}$ Nm

2. **(9)**



Total potential energy of the system is

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{(-q)(+Q)}{x} + \frac{(+Q)(-q)}{2x} + \frac{(-q)(-q)}{3x}\right]$$

U = 0 (given)

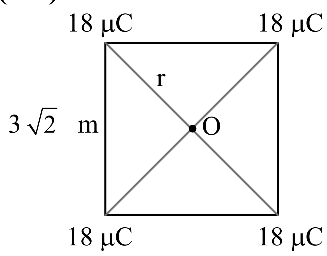
$$\therefore \quad 0 = \frac{1}{4\pi\varepsilon_0}\left[\frac{-qQ}{x} - \frac{qQ}{2x} + \frac{q^2}{3x}\right]$$

$$\therefore \quad 0 = \frac{-3}{2}\frac{qQ}{x} + \frac{q^2}{3x}$$

$$\therefore \quad \frac{3}{2}\frac{qQ}{x} = \frac{q^2}{3x}$$

$$\therefore \quad \frac{Q}{q} = \frac{1}{3} \times \frac{2}{3} = \frac{2}{9} \qquad \Rightarrow x = 9$$

3. **(216)**



The potential at point O is the addition of the potentials created by all four charges.

$\therefore$ $V = 4\,V_q$

Now, $V_q = k\frac{q}{r}$ where, $r = \frac{1}{2} \times$ Diagonal

but, Diagonal of a square = $\sqrt{2}$(side of square)

$\therefore$ Diagonal $= \sqrt{2} \times 3\sqrt{2} = 6$ m

$\therefore$ $r = \frac{1}{2} \times 6 = 3$ m

$\therefore$ $V_q = 9 \times 10^9 \times \frac{18 \times 10^{-6}}{3} = 54 \times 10^3$

$\therefore$ $V = 4\,V_q = 216 \times 10^3$ volt = 216 kV

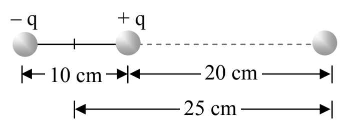
4. **(3)**

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

$$\therefore \quad E = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{(6 \times 10^{-2})^2}$$

$= 3 \times 10^4$ V/m

5. **(625)**



By using $E = 9 \times 10^9 \times \frac{2pr}{(r^2 - l^2)^2}$;

$p = (500 \times 10^{-6}) \times (10 \times 10^{-2})$
$= 5 \times 10^{-5}$ Cm

$r = 25$ cm $= 0.25$ m, $l = 5$ cm $= 0.05$ m

$$E = \frac{9 \times 10^9 \times 2 \times 5 \times 10^{-5} \times 0.25}{\{(0.25)^2 - (0.05)^2\}^2} = 6.25 \times 10^7 \text{ N/C}$$

$= 625 \times 10^5$ N/C

6. **(45)**

No. of electric field lines per unit area
= electric field at the surface

$$= \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{\rho\left(\frac{4}{3}\pi R^3\right)}{R^2} \qquad \ldots.(\because r = R)$$

$$= \frac{\rho r}{3\varepsilon_0} = \frac{2 \times 10^{-6} \times 10^6 \times 6}{3 \times 8.85 \times 10^{-12}} \approx 45.2 \times 10^{10}\ \text{NC}^{-1}$$

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JEE (Main) - 2024 QUESTION PAPER
31st January (SHIFT – I)

[Note: The following questions belong to chapters of Absolute Physics Volume - II]

Multiple Choice Questions

Electrostatics: Electric Charges, Fields and Potential

1. Two charges q and 3q are separated by a distance 'r' in air. At a distance x from charge q, the resultant electric field is zero. The value of x is:

(A) $\frac{r}{(1+\sqrt{3})}$ (B) $\frac{(1+\sqrt{3})}{r}$

(C) $r(1+\sqrt{3})$ (D) $\frac{r}{3(1+\sqrt{3})}$

Current Electricity

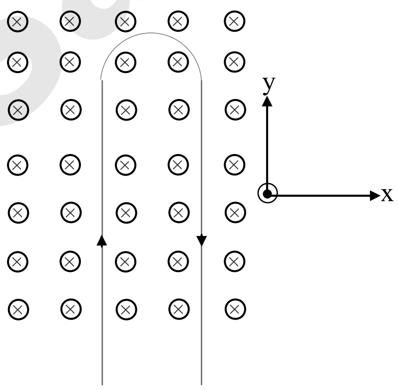
2. Two conductors have the same resistances at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients for their series and parallel combinations are:

(A) $\alpha_1 + \alpha_2, \frac{\alpha_1+\alpha_2}{2}$ (B) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$

(C) $\frac{\alpha_1+\alpha_2}{2}, \alpha_1 + \alpha_2$ (D) $\alpha_1 + \alpha_2, \frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$

Moving Charges and Magnetism

3. A rigid wire consists of a semicircular portion of radius R and two straight sections. The wire is partially immerged in a perpendicular magnetic field $B = B_0$ as shown in figure. The magnetic force on the wire if it has a current i is:



(A) –2iBR (B) 2iBR

(C) –iBR (D) iBR

Electromagnetic Induction and Alternating Current

4. A coil is placed perpendicular to a magnetic field of 5000 T. When the field is changed to 3000 T in 2 s, an induced emf of 22 V is produced in the coil. If the diameter of the coil is 0.02 m, then the number of turns in the coil is:

(A) 70 (B) 140

(C) 35 (D) 7

Electromagnetic Waves

5. In a plane EM wave, the electric field oscillates sinusoidally at a frequency of 5×10^{10} Hz and an amplitude of 50 Vm^{-1}. The total average energy density of the electromagnetic field of the wave is: [Use $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$]

(A) $1.106 \times 10^{-8}\ Jm^{-3}$

(B) $2.212 \times 10^{-10}\ Jm^{-3}$

(C) $4.425 \times 10^{-8}\ Jm^{-3}$

(D) $2.212 \times 10^{-8}\ Jm^{-3}$

Ray Optics and Optical Instruments

6. The refractive index of a prism with apex angle A is cot A/2. The angle of minimum deviation is:

(A) $\delta_m = 180° - 4A$

(B) $\delta_m = 180° - 3A$

(C) $\delta_m = 180° - 2A$

(D) $\delta_m = 180° - A$

Dual Nature of Radiation and Matter

7. When a metal surface is illuminated by light of wavelength λ, the stopping potential is 8V. When the same surface is illuminated by light of wavelength 3λ, stopping potential is 2V. The threshold wavelength for this surface is:

(A) 9λ (B) 3λ

(C) 4.5λ (D) 5λ

Atoms and Nuclei

8. If the wavelength of the first member of Lyman series of hydrogen is λ. The wavelength of the second member will be

(A) $\frac{5}{27}\lambda$ (B) $\frac{27}{32}\lambda$

(C) $\frac{32}{27}\lambda$ (D) $\frac{27}{5}\lambda$