SURA'S

Physics

VOLUME - I

12th Standard

Based on the New Syllabus and New Textbook (Volume - I) for the year 2019-20

Salient Features :

- Complete Solutions to Textbook Exercises.
- Exhaustive Additional Questions in all Units.
- NEET based questions with Answers are also given.

SURA PUBLICATIONS
Chennai

2019-20 *Edition*

ISBN : 978-81-8449-804-2

Code No : SG 96

Authors

Ms. A. Subhabarathi, M.Sc., M.Ed. M.Phil., Chennai
Mr. P. Charles Xavier, M.Sc, M.Ed. PGT-Physics, Chennai

Edited by

Mr. S. Murugan, M.Sc., B.Ed., Chennai

Reviewed by

Dr. B. Rajendran M.Sc., M.Phil., Ph.D.
Head of the Department
Chennai

Head Office:

1620, 'J' Block, 16th Main Road,
Anna Nagar, **Chennai - 600 040.**
Phones : 044-26161088, 26161099.
Mobile : 96001 75757 / 81242 01000 / 81243 01000
Whatsapp : 81242 01000
e-mail : orders@surabooks.com
website : www.surabooks.com

PREFACE

" The woods are lovely, dark and deep. "

But I have promises to keep, and

miles to go before I sleep

\- Robert Frost

Respected Principals, Correspondents, Head Masters / Head Mistresses, Teachers,

From the bottom of our heart, we at SURA Publications sincerely thank you for the support and patronage that you have extended to us for more than a decade.

It is in our sincerest effort we take the pride of releasing **SURA'S Physics Guide (Volume - I)** for +2 Standard – Edition 2019. This guide has been authored and edited by qualified teachers having teaching experience for over a decade in their respective subject fields. This Guide has been reviewed by reputed Professors who are currently serving as Head of the Department in esteemed Universities and Colleges.

With due respect to Teachers, I would like to mention that this guide will serve as a teaching companion to qualified teachers. Also, this guide will be an excellent learning companion to students with exhaustive exercises and in-text questions in addition to precise answers for textual questions.

In complete cognizance of the dedicated role of Teachers, I completely believe that our students will learn the subject effectively with this guide and prove their excellence in Board Examinations.

I once again sincerely thank the Teachers, Parents and Students for supporting and valuing our efforts.

God Bless all.

Subash Raj, B.E., M.S.
- Publisher
Sura Publications

All the Best

TO ORDER WITH US

SCHOOLS and TEACHERS:

We are grateful for your support and patronage to **'SURA PUBLICATIONS'**
Kindly prepare your order in your School letterhead and send it to us.
For Orders contact: 81242 01000 / 81243 01000

DIRECT DEPOSIT

A/c Name	: **Sura Publications**	A/c Name	: **Sura Publications**
Our A/c No.	: **36550290536**	Our A/c No.	: **21000210001240**
Bank Name	: **STATE BANK OF INDIA**	Bank Name	: **UCO BANK**
Bank Branch	: PADI	Bank Branch	: Anna Nagar West
IFSC	: SBIN0005083	IFSC	: UCBA0002100
A/c Name	: **Sura Publications**	A/c Name	: **Sura Publications**
Our A/c No.	: **6502699356**	Our A/c No.	: **1154135000017684**
Bank Name	: **INDIAN BANK**	Bank Name	: **KVB BANK**
Bank Branch	: ASIAD COLONY	Bank Branch	: Anna Nagar
IFSC	: IDIB000A098	IFSC	: KVBL0001154

After Deposit, please send challan and order to our address.
email : orders@surabooks.com / Whatsapp : 81242 01000.

DEMAND DRAFT / CHEQUE

Please send Demand Draft / cheque in favour of **'SURA PUBLICATIONS'** payable at **Chennai**.

The Demand Draft / cheque should be sent with your order in School letterhead.

STUDENTS :

Order via Money Order (M/O) to

SURA PUBLICATIONS
1620, 'J' Block, 16th Main Road, Anna Nagar,
Chennai - 600 040.
Phones : 044-26162173, 26161099.
Mobile : 96001 75757/ 81242 01000/81243 01000.
email : orders@surabooks.com Website : www.surabooks.com

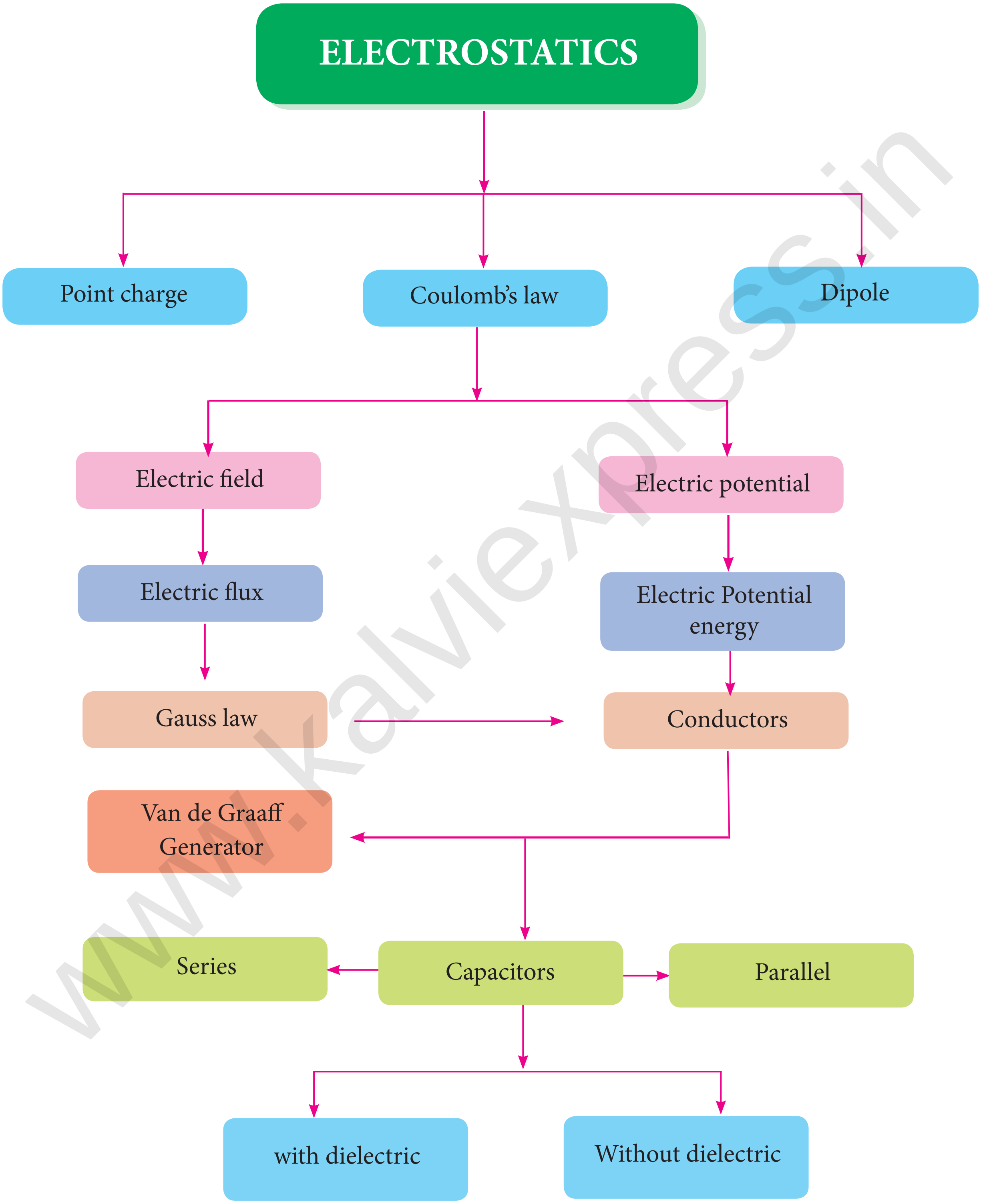
CONTENTS


SURA'S
2019-20 EDITION
SCHOOL GUIDES
40 YEARS SERVICE TO EDUCATION
For Class
12th Standard
100 Marks Pattern
English & Tamil Medium
SMART ENGLISH
SMART ENGLISH Tamil Translation
SMART ENGLISH Practice Workbook
SMART ENGLISH KEY BOOK For Practice Workbook
தமிழ் உரைநூல்
MATHEMATICS
PHYSICS
CHEMISTRY
BOTANY
ZOOLOGY
COMPUTER SCIENCE
Business Mathematics and Statistics
ACCOUNTANCY
COMMERCE
ECONOMICS
SURA PUBLICATIONS
1620, 'J' Block, 16th Main Road, Anna Nagar,
Chennai - 600 040. INDIA. Phones : 044-26162173, 26161099.
Mobile : 96001 75757, 81242 01000, 81243 01000
email : enquiry@surabooks.com
orders@surabooks.com
Buy online @ surabooks.com

UNIT 1 ELECTROSTATICS

CHAPTER SNAPSHOT

CONCEPT MAP



Unit 1

MUST KNOW DEFINITIONS

Electrostatics : Study of electric charges at rest or stationary charged bodies.

Electric charge : A basic property of some substances due to which they can exert a force of electrostatic attraction or repulsion on other charged bodies at a distance.

Frictional electricity :

600 B.C. Thales, a Greek Philosopher - amber with fur - electrification

17th century William Gilbert - glass, ebonite exhibit charging by rubbing.

Elektron (Greek word) - means amber

Positive charge	Negative charge
Glass rod	Silk cloth
Fur cap	Ebonite rod
Woollen cloth	Plastic object

Superposition principle : In an isolated system, the total force on a given charge is the vector sum of the individual forces exerted on it by all other charges, each individual force calculated by Coulomb's law.

$$\vec{F}_1^{tot} = k\left[\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21} + \frac{q_1 q_3}{r_{31}^2}\hat{r}_{31} + \ldots\ldots + \frac{q_1 q_n}{r_{n1}^2}\hat{r}_{nl}\right]$$

Properties of charges :

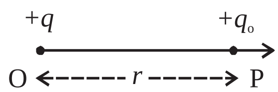
Quantisation of charge $q = ne$ [n = 0, ±1, ±2, ±3,....]

Charges are additive $Q = \Sigma Q_n$

Conservation of charges Q = Constant

A point charge : The dimension of the charged object is very small and neglected in comparison with the distances involved.

Electric field due to a point charge :



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

Direction of E is along line joining OP : Points outward for $+q$ at O

Points inward for $-q$ at O

Definition of Coulomb : It is defined as the quantity of charge which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge experiences a repulsive force of 9×10^9 N.

Test charge : A charge which, on introduction in an existing field, does not alter the field.

Electric field : It is the space or the region around the source charge in which the effect of the charge can be felt.

Electric field intensity : Force experienced by a unit positive charge kept at that point in the field.

Electrostatics

Electric lines of force	:	Imaginary straight or curved line along which a unit positive charge tends to move in an electric field. Each unit positive charge gives rise to $\frac{1}{\varepsilon_o}$ lines of force in free space.
Electric dipole	:	Two equal and opposite charges separated by a very small vector distance.
Importance of dipole	:	Any complicated array of a complex arrangement of charges, can be simplified as a number dipoles and analysed.
Potential difference	:	It is defined as the amount of work done in moving a unit positive charge from one point to the other in an electric field.
Volt	:	If 1 joule of work is done in moving 1 coulomb of charge from one point to another in an electric field.
Electric potential	:	It is defined as the amount of work done in moving a unit positive charge from infinity to that point.
Equipotential surface	:	If the potential at all points on a surface is the same, it is said to be an equipotential surface.
Electric flux	:	The total number of electric lines of force crossing a given area. $d\phi = \vec{E}.\vec{ds} = E ds \cos\theta$
Gauss' law	:	It states that the total flux of the electric field E over any closed surface is equal to $\frac{1}{\varepsilon_o}$ times the net charge enclosed by the surface, $\phi = \frac{q}{\varepsilon_o}$.
Gaussian surface	:	The closed imaginary surface over an enclosed net charge.
Electrostatic shielding	:	Process of isolating a certain region of space from external field. It is based on the fact that electric field inside a conductor is zero.
Electrostatic induction	:	It is the method of obtaining charges without any contact with another charge. They are called induced charges and the phenomenon of producing induced charges is called electrostatic induction. It is used in electrostatic machines like Van de Graaff generators and capacitors.
Capacitance	:	It is defined as the ratio of charge given to the conductor to the potential developed in the conductor. Its unit is farad (F). A conductor has a capacitance of one farad if a charge of 1 coulomb given to it raises its potential by 1 volt.
Dielectric	:	A dielectric is an insulating material in which all electrons are tightly bound to the nucleus of the atom. The electrons are not free to move under the influence of an external field. Hence, there are no free electrons to carry current.
Polar molecule	:	It is one in which the centre of gravity (mass) of the positive charges is separated from the centre of gravity of the negative charges by a finite distance. **e.g :** N_2O, H_2O, HC*l*, NH_3. These molecules have a permanent dipole moment.

Non-polar molecules : A non-polar molecule is one is which centers of positive and negative charges coincide. It has no permanent dipole moment, e.g: H_2, O_2, CO_2 etc.

Electric polarisation : The alignment of electric dipole moments of the permanent or induced dipoles in the direction of the external applied field.

Corona discharge : The leakage of electric charges from the sharp points on the charged conductor is called action of points or corona discharge. It is used in machines like Van de Graaff generators and lightning arrestors (conductors).

Force - Displacing vector

Torque - Rotating vectors; it is the moment of force

Hint:

1. In a uniform electric field when equal and opposite forces act at the ends of the dipole, the net force is zero.
2. The forces act at different points. Hence, the moment of the force is non-zero and the torque is non-zero.
3. The non-zero torque, always tends to align the dipole in the direction of the field.
4. The direction of torque vector is along the axis of rotation.
5. Charges outside the Gaussian surface will not contribute to the flux inside.
6. Field outside the charged parallel sheets is zero.

Conduction	Induction
Charges are obtained in contact with other charged body.	Charges are obtained without any contact with other charged body.
Produces similar or one type of charge.	Both positive and negative charges are produced.
Only limited amount of charges are obtained.	Large quantity of charges can be induced.

	Capacitors in series	Capacitors in parallel
Total Charge	q is same for C_1 and C_2 and C_3	$q = q_1 + q_2 + q_3$ $q_1 = C_1V$; $q_2 = C_2V$ $q_3 = C_3V$
Total potential	$V = V_1 + V_2 + V_3$ $V_1 = \frac{q}{C_1}$; $V_2 = \frac{q}{C_2}$; $V_3 = \frac{q}{C_3}$	V is same for C_1, C_2 and C_3
Expression for equivalent capacitance	$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	$C_p = C_1 + C_2 + C_3$

Electrostatics

Charge (q)	Mass(m)
Can be zero, +ve or –ve	Can never be zero, only +ve
Force between two charges can be positive or negative	Force between any two masses is always attractive in nature
Value of constant depends upon $\varepsilon, \varepsilon_r, \varepsilon_0$	Value of constant G is always fixed.

FORMULAE

(1) Electrostatic force between charges q_1 and q_2, $F = \vec{F}_{12} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}$

(2) Value of $k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9\ \text{Nm}^2\text{C}^{-2}$

(3) Value of $\varepsilon = 8.854 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$

(5) Total charge $q = n \times e$; Number of electrons × Charge of an electron

(6) Components of force F, $F_1 = F\cos\theta$; $F_2 = F\sin\theta$; $|F| = \sqrt{F_1^2 + F_2^2}$

(7) Relative permittivity or Dielectric constant $\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$

(8) Force between charges in medium $F_m = \frac{F_{air}}{\varepsilon_r}$

(9) Electrostatic field, $E = \frac{\text{force}}{\text{charge}} = \frac{F}{q} \Rightarrow F = qE$

(10) Electric field due to a point charge $E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$

(11) Electric dipole moment, $\vec{p} = q \times 2a\hat{i}$

(12) (i) Electric field due to a dipole at a point on the axial line, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ $(r >> a)$

(ii) Electric field due to a dipole at a point on the equatorial line $E = \vec{E}_{tot} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$ $(r >> a)$

(13) Magnitude of torque $\tau = \vec{p} \times \vec{E} = pE\sin\theta$ $(p = q\,2a)$

(14) Electric potential at a point due to a point charge, $V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$

(15) Electric potential energy of dipole $U = -pE\cos\theta = -\vec{p}.\vec{E}$

(16) Electric potential at a point due to an electric dipole $V = \frac{p}{4\pi\varepsilon_o}\frac{\cos\theta}{r^2}$

(17) Electric flux $= \frac{q}{\varepsilon_o} \Rightarrow \phi_E = \vec{E}.\vec{A} = EA\cos\theta$

(18) Electric field due to infinite long straight charged wire, $E = \frac{\lambda}{2\pi\varepsilon_o r}$

(19) Electric field due to plane sheet of charge $E = \frac{\sigma}{2\varepsilon_o} = \frac{q}{A}\frac{1}{2\varepsilon_o}$ Vector form, $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

(20) Electric field at a point between two parallel sheets of charge $E = \frac{\sigma}{\varepsilon_o}$

(21) Electric field due to a uniformly charged sphere -

(i) at a point on the surface of the sphere, $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{R^2}\hat{r}$ $\because [r = R]$

(ii) at a point outside the sphere $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}\hat{r}$

(iii) at a point inside the sphere $E = 0$ $[r < R]$

(22) Capacitance of a conductor $C = \frac{q}{V}$

(23) Work done by a charge $W = qV$

(24) Charge density, $\sigma = \frac{q}{A}$

(25) Capacitance of a parallel plate capacitor $C = \frac{\varepsilon_o A}{d}$

(i) With a dielectric slab, $C = \frac{\varepsilon_o A}{\left[(d-t)+\frac{t}{\varepsilon_r}\right]}$

(ii) With the dielectric completely filled capacitor $C^1 = \frac{\varepsilon_o \varepsilon_r A}{d} = C \times \varepsilon_r$

(26) Energy stored in a capacitor $E = \frac{1}{2}CV^2$

(27) Capacitance of a spherical capacitor, $C = 4\pi\varepsilon_0 A$ or $C = \frac{A}{9\times10^9}$

(28) Equivalent capacitance

(i) C_1 and C_2 in series $C_s = \frac{C_1C_2}{C_1+C_2}$; $C_s = \frac{1}{C_S} = \frac{1}{C_1}+\frac{1}{C_2}$

(ii) C_1 and C_2 in parallel $C_P = C_1 + C_2$

(29) Polarisation, $\vec{p} = \chi_e \vec{E}_{ext}$ (χ_e - electric susceptibility)

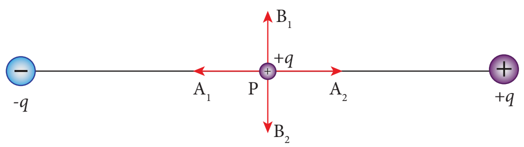
Values And Units

(1)	Permittivity of free space ε_o	=	8.854×10^{-12} $C^2N^{-1}m^{-2}$
(2)	$\frac{1}{4\pi\varepsilon_o}$	=	9×10^9 Nm^2C^{-2}
(3)	Charge of an electron, e	=	1.6×10^{-19} C
(4)	1 micro farad	=	10^{-6} farad
(5)	1 pico farad	=	10^{-12} farad
(6)	Permittivity of medium, ε	=	$C^2N^{-1}m^{-2}$
(7)	Electric charge (q)	=	Coulomb (C)
(8)	Electric field (E)	=	NC^{-1} or $V\,m^{-1}$
(9)	Electric potential (V)	=	JC^{-1} or volt
(10)	Electric dipole moment (p)	=	Coulomb metre
(11)	Electric potential energy (U)	=	Joule
(12)	Capacitance (C)	=	farad
(13)	Electric flux	=	Nm^2C^{-1}
(14)	Torque	=	Nm
(15)	Relative permittivity of air	=	1 (no unit)

Evaluation

Choose the Correct Answer:

1. **Two identical point charges of magnitude $-q$ are fixed as shown in the figure below. A third charge $+q$ is placed midway between the two charges at the point P. Suppose this charge $+q$ is displaced a small distance from the point P in the directions indicated by the arrows, in which direction(s) will $+q$ be stable with respect to the displacement?**



(a) A_1 and A_2 (b) B_1 and B_2
(c) both directions (d) No stable

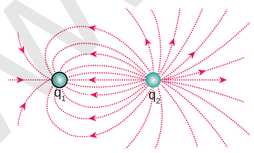
[*Ans.* (b) B_1 and B_2]

2. **Which charge configuration produces a uniform electric field?**

(a) point Charge
(b) infinite uniform line charge
(c) uniformly charged infinite plane
(d) uniformly charged spherical shell

[*Ans.* (c) uniformly charged infinite plane]

3. **What is the ratio of the charges $\left|\frac{q_1}{q_2}\right|$ for the following electric field line pattern?**



(a) $\frac{1}{5}$ (b) $\frac{25}{11}$
(c) 5 (d) $\frac{11}{25}$

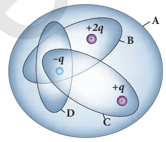
[*Ans.* (d) $\frac{11}{25}$]

4. **An electric dipole is placed at an alignment angle of 30° with an electric field of 2×10^5 N C^{-1}. It experiences a torque equal to 8 N m. The charge on the dipole if the dipole length is 1 cm is**

(a) 4 mC (b) 8 mC
(c) 5 mC (d) 7 mC

[*Ans.* (b) 8 mC]

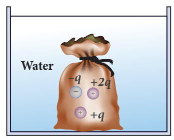
5. **Four Gaussian surfaces are given below with charges inside each Gaussian surface. Rank the electric flux through each Gaussian surface in increasing order.**



(a) D < C < B < A (b) A < B = C < D
(c) C < A = B < D (d) D > C > B > A

[*Ans.* (a) D < C < B <A]

6. **The total electric flux for the following closed surface which is kept inside water**



(a) $\frac{80q}{\varepsilon_o}$ (b) $\frac{q}{40\varepsilon_o}$
(c) $\frac{q}{80\varepsilon_o}$ (d) $\frac{q}{160\varepsilon_o}$

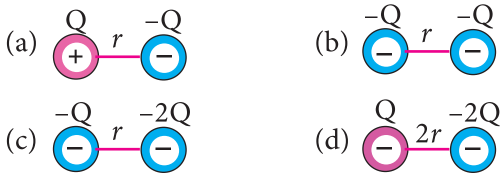
[*Ans.* (b) $\frac{q}{40\varepsilon_o}$]

7. **Two identical conducting balls having positive charges q_1 and q_2 are separated by a center to center distance r. If they are made to touch each other and then separated to the same distance, the force between them will be** *(NSEP 04-05)*

(a) less than before (b) same as before
(c) more than before (d) zero

[*Ans.* (c) more than before]

8. Rank the electrostatic potential energies for the given system of charges in increasing order.



(a) 1 = 4 < 2 < 3 (b) 2 = 4 < 3 < 1
(c) 2 = 3 < 1 < 4 (d) 3 < 1 < 2 < 4

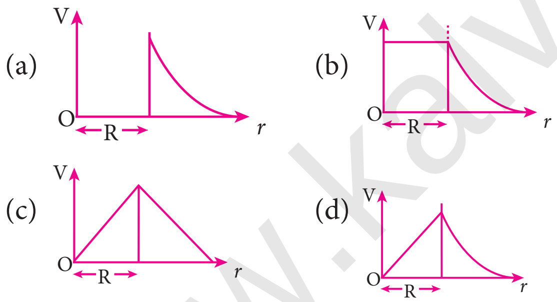
[Ans. (a) 1 = 4 < 2 < 3]

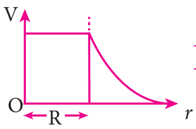
9. An electric field $\vec{E} = 10\,x\,\hat{i}$ exists in a certain region of space. Then the potential difference $V = V_0 - V_A$, where V_0 is the potential at the origin and V_A is the potential at $x = 2$ m is:

(a) 10 J (b) – 20 J
(c) +20 J (d) -10J

[Ans. (b) – 20 J]

10. A thin conducting spherical shell of radius R has a charge Q which is uniformly distributed on its surface. The correct plot for electrostatic potential due to this spherical shell is



[Ans. (b)  **]**

11. Two points A and B are maintained at a potential of 7 V and –4 V respectively. The work done in moving 50 electrons from A to B is

(a) 8.80×10^{-17} J (b) -8.80×10^{-17} J
(c) 4.40×10^{-17} J (d) 5.80×10^{-17} J

[Ans. (a) 8.80×10^{-17} J]

12. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion.

(a) Q remains the same, C is doubled
(b) Q is doubled, C doubled
(c) C remains same, Q doubled
(d) Both Q and C remain same

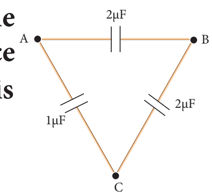
[Ans. (c) C remains same, Q doubled]

13. A parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the parallel plate capacitor and the distance between the plates are each doubled then which is the quantity that will change?

(a) Capacitance (b) Charge
(c) Voltage (d) Energy density

[Ans. (d) Energy density]

14. Three capacitors are connected in triangle as shown in the figure. The equivalent capacitance between the points A and C is



(a) 1μF
(b) 2 μF
(c) 3 μF
(d) $\frac{1}{4}$ μF

[Ans. (b) 2 μF]

15. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2} C and 5×10^{-2} C respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is

(AIIPMT -2012)

(a) 3×10^{-2} C (b) 4×10^{-2} C
(c) 1×10^{-2} C (d) 2×10^{-2} C

[Ans. (a) 3×10^{-2} C]

II. Short Answer Questions :

1. What is meant by quantisation of charges?

Ans. (i) The charge q on any object is equal to an integral multiple of this fundamental unit of charge e.

$$q = ne$$

(ii) Here n is any integer (0, ±1, ±2, ±3, ±4..........). This is called Quantisation of electric charge.

Electrostatics

2. Write down Coulomb's law in vector form and mention what each term represents.

Ans. (i) According to Coulomb, the force on the point charge q_2 exerted by another point charge q_1 is

$$\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

where $\hat{r}_{12}$ is the unit vector directed from charge q_1 to charge q_2 and k is the proportionality constant.

(ii) $k = \frac{1}{4\pi\varepsilon_0}$ and its value is $k = 9 \times 10^9$ Nm^2C^{-2} Here ε_0 is the permittivity of free space or vacuum and the value of $\frac{1}{4\pi k} = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

3. What are the differences between Coulomb force and gravitational force?

Ans.

	Coulomb	Gravitational
i)	It may be attractive or repulsive.	It is always attractive in nature.
ii)	It depends upon medium	It does not depend upon the medium
iii)	It is always greater in magnitude because of high value of $K = 9 \times 10^9\ Nm^2\ C^{-2}$	It is lesser than coulomb force because value of G is $6.62 \times 10^{-11}\ Nm^2\ kg^{-2}$
iv)	The force between the charges will not be same during motion or rest.	It is always same whether the two masses are rest or motion

4. Write a short note on superposition principle.

Ans. When a number of charges are interacting the total force of a given charge is the vector sum of the individual forces exerted on the given charge by all the other charges.

5. Define 'Electric field'.

Ans. (i) The electric field at the point P at a distance r from the point charge q is the force experienced by a unit charge and is given by

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

(ii) Here $\hat{r}$ is the unit vector pointing from q to the point of interest P. The electric field is a vector quantity and its SI unit is Newton per Coulomb (NC^{-1}).

6. What is mean by 'Electric field lines'?

Ans. Electric field vectors are visualized by the concept of electric field lines. They form a set of continuous lines which represent the electric field in some region of space visually.

7. The electric field lines never intersect. Justify.

Ans. If some charge is placed in the intersection point, then it has to move in two different directions at the same time, which is physically impossible. Hence, electric field lines do not intersect.

8. Define 'Electric dipole'.

Ans. Two equal and opposite charges separated by a small distance constitute an electric dipole.

9. What is the general definition of electric dipole moment?

Ans. The magnitude of the electric dipole moment is equal to the product of the magnitude of one of the charges and the distance between them, $|\vec{p}| = 2qa$.

10. Define 'electrostatic potential''.

Ans. The electric potential at a point P is equal to the work done by an external force to bring a unit positive charge with constant velocity from infinity to the point P in the region of the external electric field $\vec{E}$.

11. What is an equipotential surface?

Ans. An equipotential surface is a surface on which all the points are at the same potential.

12. What are the properties of an equipotential surface?

Ans. (i) The work done to move a charge q between any two points A and B, $W = q\,(V_B - V_A)$.

(ii) If the points A and B lie on the same equipotential surface, work done is zero because $V_B = V_A$.

(iii) The electric field is normal to an equipotential surface.

Unit 1

13. Give the relation between electric field and electric potential.

Ans. Consider a positive charge q kept fixed at the origin. To move a unit positive charge by a small distance dx in the electric field E, the work done is given by $dW = -E\, dx$. The minus sign implies that work is done against the electric field. This work done is equal to electric potential difference. Therefore,

$$dW = dV$$

$$(\text{or}) \quad dV = -E\, dx$$

$$\text{Hence } E = -\frac{dV}{dx}$$

The electric field is the negative gradient of the electric potential.

14. Define 'electrostatic potential energy'.

Ans. Electric potential energy is defined as the work done in bringing the various charges to their respective positions from infinitely large mutual separation.

15. Define 'electric flux'

Ans. The number of electric field lines crossing a given area kept normal to the electric field lines is called electric flux.

16. What is meant by electrostatic energy density?

Ans. The energy stored per unit volume of space is defined as energy density $u_E = \frac{U}{\text{Volume}}$.

17. Write a short note on 'electrostatic shielding'.

Ans. (i) The phenomenon of protecting a region of space from any external electric field is called electrostatic shielding.

(ii) Consider a cavity inside the conductor. Whatever the charges at the surfaces and whatever the electrical disturbances outside, the electric field inside the cavity is zero.

18. What is Polarisation?

Ans. (i) Polarisation $\vec{p}$ is defined as the total dipole moment per unit volume of the dielectric.

$$\vec{p} = \chi_e \vec{E}_{ext}$$

(ii) where χ_e is a constant called the electric susceptibility which is a characteristic of each dielectric.

19. What is dielectric strength?

Ans. The maximum electric field the dielectric can withstand before it gets breakdown is called dielectric strength.

20. Define 'capacitance'. Give its unit.

Ans. The capacitance C of a capacitor is defined as the ratio of the magnitude of charge on either of the conductor plates to the potential difference existing between the conductors.

21. What is Corona discharge?

Ans. The electric field near the edge of conductor is very high and it ionizes the surrounding air. The positive ions are repelled at the sharp edge and negative ions are attracted towards the sharper edge. This reduces the total charge of the conductor near the sharp edge. This is called action at points or corona discharge.

III. Long Answer Questions :

1. Discuss the basic properties of electric charges.

Ans. (i) **Electric charge :** The electric charge is another intrinsic and fundamental property of particles.

(ii) **Conservation of charges :** Charges are neither created or nor be destroyed but can only be transferred from one object to the other. This is called conservation of total charges.

(iii) **Quantisation of charges :** The charge q on any object is equal to an integral multiple of this fundamental unit of charge e. $q = ne$. Here n is any integer (0, ±1, ±2, ±3, ±4..........). This is called Quantisation of electric charge.

2. Explain in detail Coulomb's law and its various aspects.

Ans. Various aspects of Coulomb's law :

(i) Coulomb's law states that electrostatic force is directly proportional to the product of the magnitude of the two point charges and is inversely proportional to the square of the distance between them.

(ii) The force on the charge q_2 exerted by the q_1 always lies along the line joining the two charges. $\hat{r}_{12}$ is the unit vector from charge q_1 to q_2. $\vec{F}_{21} = k\frac{q_1 q_2}{r^2}\vec{r}_{21}$. The force on the charge q_1 exerted by q_2 is along $-\hat{r}_{12}$ (i.e., in opposite direction).

$\vec{F}_{21} = k.\frac{q_1 q_2}{r^2}.\hat{r}_{21}$ i.e. $\vec{F}_{12} = -\vec{F}_{21}$

(iii) $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

ε_0-permittivity of free space or vacuum

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

(iv) If $q_1 = q_2 = 1C$; $r = 1m$, then

$|F| = \frac{9\times10^9 \times 1\times1}{1^2} = 9\times10^9 \text{ N}$

(v) In vacuum $\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{12}$.

In a medium $\vec{F}_{21} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}\hat{r}_{12}$ $\quad \varepsilon > \varepsilon_0$

$\therefore \varepsilon = \varepsilon_0 . \varepsilon_r$ (ε_r-relative permittivity)

For air or vacuum $\varepsilon_r = 1$ and for all other media $\varepsilon_r > 1$.

(vi) It has same structure as Newton's law of gravitation, $F = G\frac{M_1 M_2}{r^2}$

(vii) The expression for Coulomb force is true only for point charges.

3. Define 'Electric field' and discuss its various aspects.

Ans. **Electric Field :**

Electric Field at the point P at a distance r from the point charge q is the force experienced by a unit charge. $\vec{E} = \frac{\vec{F}}{q_0}$ i.e. $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ ...(1)

Important aspects of the Electric field :

(i) If q is positive, electric field points away from source charge q. If q is negative, electric field points towards the source charge q.

(ii) Force experienced by the test charge q_0 at P

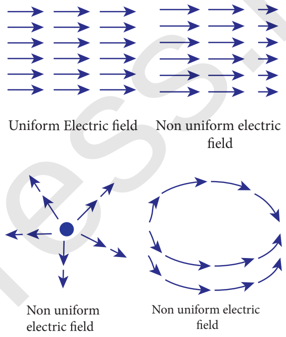
$\vec{F} = q_0\vec{E}$

(iii) From equation (1) electric field is independent of q_0 (test charge) and depends on q (source charge).

(iv) It is a vector quantity, which has unique direction and magnitude, as distance increases, electric field decreases.

(v) Test charge is considered as very small.

(vi) Equation (1) is only for point charges.



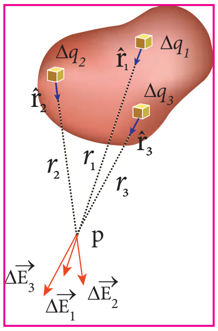
(vii) There are uniform and non-uniform electric fields.

Uniform electric field : It has same direction and constant magnitude at all points.

Non-uniform electric field : Different directions or different magnitudes or both at different points.

4. How do we determine the electric field due to a continuous charge distribution? Explain.

Ans. Electric filed due to continuous charge distribution : consider the charged object of irregular shape. It is divided into large number of charge elements.



Δq_1, $\rightarrow$ 1st charge element; r_{1p} - distance of the point P from Ist charge

Δq_2, $\rightarrow$ Second charge element; r_{2p} - distance of the point P from 2nd charge

Δq_n, $\rightarrow n^{th}$ charge element; r_{np} - distance of the point P from nth charge

Then.

$$\vec{E} \approx \frac{1}{4\pi\varepsilon_0}\left(\frac{\Delta q_1}{r_{1P}^2}\hat{r}_{1P} + \frac{\Delta q_2}{r_{2P}^2}\hat{r}_{2P} + \ldots\ldots + \frac{\Delta q_n}{r_{nP}^2}\hat{r}_{nP}\right)$$

$$\approx \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{\Delta q_i}{r_{iP}^2}\hat{r}_{iP} \qquad (1)$$

For continuous distribution of charge,

Lt $\Delta q \to 0\ (= dq)$

$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0}\cdot\int\frac{dq}{r^2}\hat{r}$$

$r \to$ distance of point P from infinitesimal charge dq.

$\hat{r}$ Unit vector from dq to point P.

(i) For linear charge distribution :

Linear density $\lambda = \frac{Q}{L}$ C m^{-1}.

i.e. charge per unit length. where Q is uniformly distributed charge along the wire of length L for infinitesimal length $dq = \lambda\, dl$.

(ii) Surface charge distribution :

$\sigma = \frac{Q}{A}$ C m^{-2}.

$\sigma \to$ surface charge density (charge per unit area)

Q $\to$ uniformly distributed charge on surface of area A.

For infinitesimal area, $dq = \sigma dA$.

(iii) Volume charge distribution :

$\rho = \frac{Q}{V}$ C m^{-3}.

$\rho \to$ Volume charge density (charge per unit volume)

Q $\to$ uniformly distribution of charge in a volume V.

5. Calculate the electric field due to a dipole on its axial line and equatorial plane.

Ans. **Electric field due to an electric dipole at points on the axial line :**

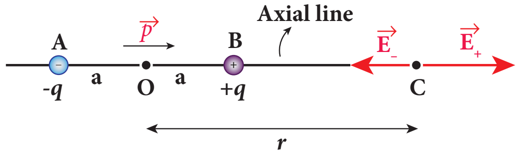
AB - Electric dipole

C - point along axial line.

r - Distance from mid point to point C.

Electric field at point C due to $+q$

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} \text{ along BC}$$



Electric filed at C due to $-q$

$$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p} \text{ along CA}$$

where $\vec{p}$ electric dipole moment unit vector from $-q$ to $+q$ ($\vec{E}_+ > \vec{E}_-$)

Total Electric field at point C

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

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}q\left(\frac{4ra}{(r^2-a^2)^2}\right)\hat{p} \text{ along BC}$$

r >> a i.e. point C is far away from dipole.

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\cdot\left(\frac{4aq}{r^3}\right)\hat{p}$$

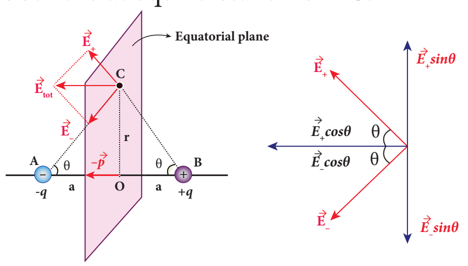
$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2\vec{p}}{r^3} \quad \text{since } 2aq\ \hat{P} = \vec{P}$$

$\vec{E}_{tot}$ is in the direction of $\vec{p}$

Electric field to dipole at a point on equatorial line :

C - point at a distance r from midpoint O on the equatorial plane.

Electric filed at C due to $+q$ and $-q$ are same $\therefore$ both are at equi-distant from C.



Electric field due to a dipole at a point on the equatorial plane

So it is resolved into two components. The perpendicular components $|\vec{E}_+|\sin\theta$ and $|\vec{E}_-|\sin\theta$ are equal and opposite so they cancel each other. Total Electric Field at C is sum of parallel components.

Electrostatics

$$\vec{E}_{tot} = -\left|\vec{E}_+\right|\cos\theta\,\hat{p} - \left|\vec{E}_-\right|\cos\theta\,\hat{p} \qquad ...(1)$$

The magnitudes $\vec{E}_+$ and $\vec{E}_-$ are same.

$$\left|\vec{E}_+\right| = \left|\vec{E}_-\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)} \qquad ...(2)$$

substituting equation (2) in (1),

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_0}\frac{2q\cos\theta}{(r^2+a^2)}\hat{p}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_0}\cdot\frac{2qa}{(r^2+a^2)^{\frac{3}{2}}}\hat{p}$$

$$[\cos\theta = \frac{a}{\sqrt{r^2+a^2}}]$$

$r >> a$ and $\vec{p} = 2qa\,\hat{p}$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3} \qquad (r >> a)$$

$\vec{E}$ is opposite to the direction of $\vec{p}$

Important inferences :

(i) For very large distance : The magnitude of 'E' along axial line is twice the magnitide of 'E' along Equatorial plank.

(ii) Electric field due to a dipole varies as $\frac{1}{r^3}$

Electric field to point charge varies as $\frac{1}{r^2}$

i.e. two charges appear to be close to each other and reutralize.

(iii) Distance $2a = 0$ and $q = \infty$ (infinity).

Then $2aq = p$ is finite. This dipole is called a point dipole.

6. Derive an expression for the torque experienced by a dipole due to a uniform electric field.

Ans. **Electric dipole in uniform electric field :**

AB - an electrical dipole ; $\vec{p}$ dipole moment.

$\vec{E}$ - uniform electric filed : θ-angle made by $\vec{p}$ with $\vec{E}$

$qE \rightarrow$ force experienced by $+q$; $-qE \rightarrow$ force experienced by - q. Both the forces are equal and acting in opposite direction. Total force acting on dipole is zero.

These two force acting at different points will constitute a couple and dipole experience a torque. Torque tends to rotate the dipole.

Total torque on dipole

$$\vec{\tau} = \vec{OA} \times \left|-q\vec{E}\right| + \vec{OB} \times q\vec{E}$$

τ is parallel to the plane of the paper and directed in to it (By right hand cork screw rule)

$$\therefore \tau = \left|\vec{OA}\right|\left|\left(-q\vec{E}\right)\right|\sin\theta + \left|\vec{OB}\right|\left|q\vec{E}\right|\sin\theta$$

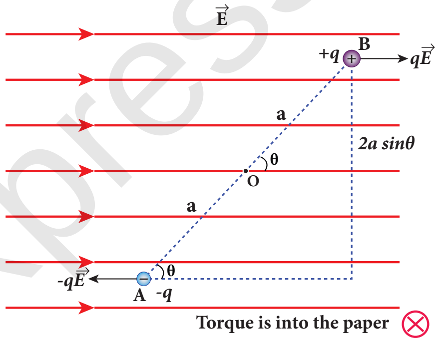
$\tau = qE \,.\, 2a\sin\theta$

$p = 2aq$

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

When $\theta = 90^\circ$ τ is maximum. i.e. $\tau = PE$

$\theta = 0^\circ$ $\tau = 0$ i.e. dipole align with the electric field E.



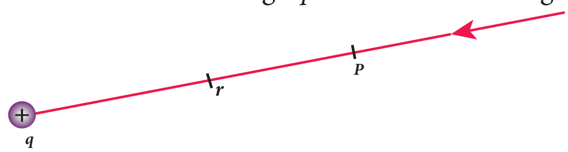
For Non-uniform electric field :

Force experienced by $+q$ is different from that experienced by $-q$. So there is net force.

∴ Dipole experience both torque and net force

7. Derive an expression for electrostatic potential due to a point charge.

Ans. **(i)** Consider a positive charge q kept fixed at the origin. Let P be a point at distance r from the charge q. This is shown in Figure.



Electrostatic potential at a point P

(ii) The electric potential at the point P is

$$V = \int_\infty^r \left(-\vec{E}\right)\cdot d\vec{r} = -\int_\infty^r \vec{E}\cdot d\vec{r} \qquad ...(1)$$

Electric field due to positive point charge q is

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

$$V = \frac{-1}{4\pi\varepsilon_0}\int_\infty^r \frac{q}{r^2}\hat{r}.d\vec{r}$$

Unit 1

The infinitesimal displacement vector, $d\vec{r} = dr\hat{r}$ and using $\hat{r}.\hat{r} = 1$, we have

$$V = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r}.dr\hat{r} = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}dr$$

After the integration,

$$V = -\frac{1}{4\pi\varepsilon_0}q\left\{-\frac{1}{r}\right\}_{\infty}^{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

Hence the electric potential due to a point charge q at a distance r is

$$V = \frac{-1}{4\pi\varepsilon_0}\frac{q}{r} \quad ...(2)$$

Important points :

(i) If the source charge q is positive, V > 0. If q is negative, then V is negative and equal to

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

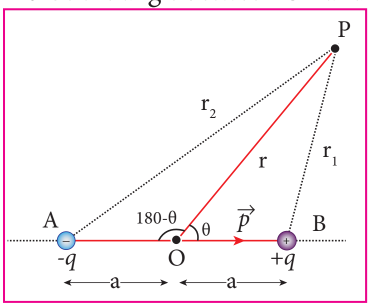
(ii) It is clear that the potential due to positive charge decreases as the distance increases, but for a negative charge the potential increases as the distance is increased. At infinity, $(r = \infty)$ electrostatic potential is zero (V = 0).

(iii) A positive charge moves from a point of higher electrostatic potential to lower electrostatic potential, a negative charge moves from lower electrostatic potential to higher electrostatic potential.

(iv) The electric potential at a point P due to a collection of charges $q_1, q_2, q_3.....q_n$ is equal to sum of the electric potentials due to individual charges.

8. Derive an expression for electrostatic potential due to an electric dipole.

Ans. **(i)**
- ➢ AB be the electric dipole ($-q$ at A and $+q$ at B).
- ➢ 2a be the distance between $-q$ and $+q$.
- ➢ 'r' be the distance between the point 'P' and mid point 'O' of AB.
- ➢ 'θ' be the angle between OP and OB.



Potential due to electric dipole

(ii) Let r_1 be the distance of point P from $+q$ and r_2 be the distance of point P from $-q$.

Potential at P due to charge $+q = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1}$

Potential at P due to charge $-q = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r_2}$

Total potential at the point P,

$$V = \frac{1}{4\pi\varepsilon_0}q\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad ...(1)$$

(iii) By the cosine law for triangle BOP,

$$r_1^2 = r^2 + a^2 - 2ra\cos\theta$$

$$r_1^2 = r^2\left(1 + \frac{a^2}{r^2} - \frac{2a}{r}\cos\theta\right)$$

Since a<<r, the term $\frac{a^2}{r^2}$ is very small and can be neglected. Therefore

$$r_1^2 = r^2\left(1 - 2a\frac{\cos\theta}{r}\right)$$

$$\text{(or) } r_1 = r\left(1 - \frac{2a}{r}\cos\theta\right)^{\frac{1}{2}}$$

$$\frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2a}{r}\cos\theta\right)^{\frac{1}{2}}$$

(iv) Using binomial theorem we get.

$$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) \quad ...(2)$$

Similarly applying the cosine law for triangle AOP,

$$r_2^2 = r^2 + a^2 - 2ra\cos(180-\theta)$$

Since $\cos(180 - \theta) = -\cos\theta$ we get

$$r_2^2 = r^2 + a^2 + 2ra\cos\theta$$

Neglecting $\frac{a^2}{r^2}$ (because $r>>a$)

$$r_2^2 = r^2\left(1 + \frac{2a\cos\theta}{r}\right)$$

$$r_2 = r\left(1 + \frac{2a\cos\theta}{r}\right)^{\frac{1}{2}}$$

Using Binomial theorem, we get

$$\frac{1}{r_2} = \frac{1}{r}\left(1 - a\frac{\cos\theta}{r}\right) \quad ...(3)$$

Substituting equation (3) and (2) in equation (1),

Electrostatics

$$V=\frac{1}{4\pi\varepsilon_0}q\left(\frac{1}{r}\left(1+a\frac{\cos\theta}{r}\right)-\frac{1}{r}\left(1-a\frac{\cos\theta}{r}\right)\right)$$

$$V=\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r}\left(1+a\frac{\cos\theta}{r}-1+a\frac{\cos\theta}{r}\right)\right)$$

$$V=\frac{1}{4\pi\varepsilon_0}\frac{2aq}{r^2}\cos\theta$$

(v) But the electric dipole moment $p = 2qa$ and we get,

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{p\cos\theta}{r^2}\right)$$

If $p\cos\theta = \vec{p}\cdot\hat{r}$, where $\hat{r}$ is the unit vector from the point O to point P. then

$$V=\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2} \quad (r>>a) \qquad ...(4)$$

Special cases

Case (i) If the point P lies on the axial line then $\theta = 0$, then

$$V=\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2} \qquad ...(5)$$

Case (ii) If the point P lies on the axial line then $\theta = 180°$, then

$$V=-\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2} \qquad ...(6)$$

Case (iii) If the point P lies on the equatorial line, then $\theta = 90°$. Hence

$$V = 0 \qquad ...(7)$$

9. Obtain an expression for potential energy due to a collection of three point charges which are separated by finite distances.

Ans. **(i)** The electric potential at a point at a distance r from point charge q_1 is given by

$$V=\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r}$$

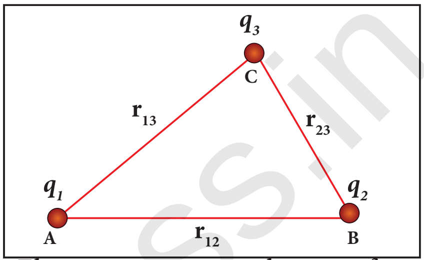
(ii) This potential V is the work done to bring a unit positive charge from infinity to the point. Now if the charge q_2 is brought from infinity to that point at distance r from q_1, the work done is the product of q_2 and the electric potential at that point. Thus we have

$$W = q_2 V$$

(iii) This work done is stored as the electrostatic potential energy U of a system of charges q_1 and q_2 separated by a distance r. Thus we have

$$U=q_2V=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r} \qquad ...(1)$$

(iv) Three charges are arranged in the following configuration as shown in Figure.



Electrostatic potential energy for Collection of point charges

(a) Bringing a charge q_1 from infinity to the point A requires no work, because there are no other charges already present in the vicinity of charge q_1.

(b) To bring the second charge q_2 to the point B, work must be done against the electric field at B created by the charge q_1. So the work done on the charge q_2 is $W = q_2 V_{1B}$. Here V_{1B} is the electrostatic potential due to the charge q_1 at point B.

$$U=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}} \qquad ...(2)$$

(c) Similarly to bring the charge q_3 to the point C, work has to be done against the total electric field due to both the charges q_1 and q_2. So the work done to bring the charge q_3 is $= q_3 (V_{1C} + V_{2C})$. Here V_{1C} is the electrostatic potential due to charge q_1 at point C and V_{2C} is the electrostatic potential due to charge q_2 at point C.

The electrostatic potential is

$$U=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_3}{r_{13}}+\frac{q_2q_3}{r_{23}}\right) \qquad ...(3)$$

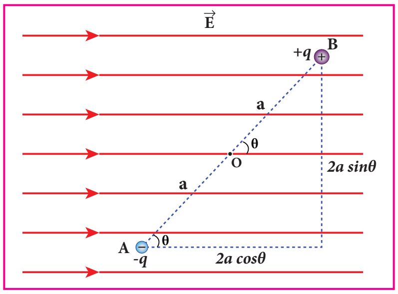
(d) Adding equations (2) and (3), the total electrostatic potential energy for the system of three charges q_1, q_2 and q_3 is

$$U=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}}+\frac{q_1q_3}{r_{13}}+\frac{q_2q_3}{r_{23}}\right) \qquad ...(4)$$

This stored potential energy U is equal to the total external work done to assemble the three charges at the given locations.

10. Derive an expression for electrostatic potential energy of the dipole in a uniform electric field.

Ans. (i) Consider a dipole placed in the uniform electric field $\vec{E}$. This dipole experiences a torque which rotates the dipole to align it with the direction of the electric field. To rotate the dipole (at constant angular velocity) from its initial angle θ′ to another angle θ, an equal and opposite external torque must be applied on the dipole.



The dipole in a uniform electric field

(ii) The work done by the external torque to rotate the dipole at constant angular velocity is

$$W = \int_{\theta'}^{\theta} \tau_{ext}\, d\theta \quad ...(1)$$

(iii) Since $\vec{\tau}_{ext}$ is equal and opposite to $\vec{\tau}_E = \vec{p} \times \vec{E}$

We have

$$\left|\vec{\tau}_{ext}\right| = \left|\vec{\tau}_E\right| = \left|\vec{p}\times\vec{E}\right| \quad ...(2)$$

$\Rightarrow p_E \sin\theta = \tau_{ext}$

Substituting equation (2) in equation (1), we get

$$W = \int_{\theta'}^{\theta} pE\sin\theta\, d\theta$$

$W = pE\,(\cos\theta' - \cos\theta)$

(iv) This work done is equal to the potential energy difference.

$\Delta U = -\,pE\cos\theta + pE\cos\theta'$

If the initial angle is θ′ = 90°, then U (θ′) = pE cos 90° = 0 .

$$U = -\,pE\cos\theta = -\,\vec{p}\,.\,\vec{E} \quad ...(3)$$

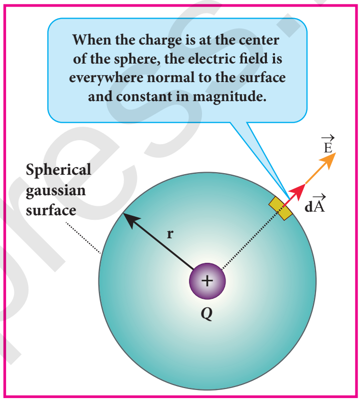
(v) The potential energy is maximum when the dipole is aligned anti-parallel (θ = π) and minimum when the dipole is aligned parallel (θ = 0) to the external field.

11. Obtain Gauss law from Coulomb's law.

Ans. (i) A positive point charge Q is surrounded by an imaginary sphere of radius *r* electric flux through the closed surface of the sphere

$$\Phi_E = \oint \vec{E}.d\vec{A} = \oint E\,dA\cos\theta$$

(ii) Since the electric field of the point charge is directed radially outward both $d\vec{A}$ and $\vec{E}$ are along the same direction therefore θ = 0°.



$\therefore \Phi_E = \oint E\,dA$ since cos0° = 1

E is uniform on the surface of the sphere,

$\because \oint dA = 4\pi r^2$

$\therefore \varphi_E = 4\pi r^2 E$

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

$$\Phi_E = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2}\times 4\pi r^2 = 4\pi\frac{1}{4\pi\varepsilon_0}Q$$

$$\Phi_E = \frac{Q}{\varepsilon_0}$$

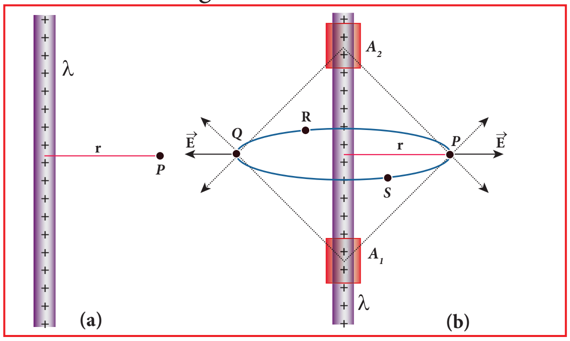
The equation is called as Gauss's law.

12. Obtain the expression for electric field due to an infinitely long charged wire.

Ans. (i)
- ➢ λ be the Linear charge density of an infinitily long, uniformly charged wire, *r* be the distance between the wire and point '*p*'.
- ➢ To find Electric filed (E) at the point 'p' consider two charge elements A_1 and A_2.
- ➢ The resultant 'E' due to A_1 and A_2, act redially outward.

Electrostatics

➢ The charged wire is assumed to form a cylindrical Gaussian surface of radius 'r' and length 'L'.



Electric field due to infinite long charged wire

(ii) The total electric flux in this closed surface E.

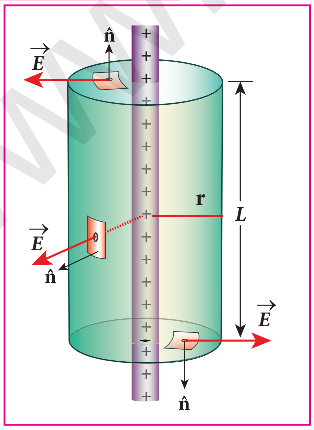
$$\Phi_E = \oint \vec{E}\cdot d\vec{A}$$

$$\oint_{\text{Curved surface}} \vec{E}\cdot d\vec{A} + \oint_{\text{top surface}} \vec{E}\cdot d\vec{A} + \oint_{\text{bottom surface}} \vec{E}\cdot d\vec{A} \quad ...(1)$$

(iii) for the curved surface, $\vec{E}$ is parallel to $\vec{A}$ and $\vec{E}\cdot d\vec{A}$ = E dA. For the top and bottom surfaces, $\vec{E}$ is perpendicular to $\vec{A}$ and $\vec{E}\cdot d\vec{A} = 0$

Applying Gauss law to the cylindrical surface,

$$\phi_E = \int_{\text{Curved surface}} E\cdot dA = \frac{Q_{encl}}{\varepsilon_0} \quad ...(2)$$



Cylindrical Gaussian surface

(vi) Since the magnitude of the electric field for the entire curved surface is constant, Q_{encl} is given by $Q_{encl} = \lambda L$.

$$E\int_{\text{Curved surface}} dA = \frac{\lambda L}{\varepsilon_0} \quad ...(3)$$

Here $\int_{\text{Curved surface}} dA$ be the total area of the curved surface $2\pi rl$. therefore equation (3), becomes

$$E\,.\,2\pi r L = \frac{\lambda L}{\varepsilon_0}$$

$$E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r} \quad ...(4)$$

In vector form $\vec{E} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}\hat{r}$ ...(5)

(vi) The electric field due to the infinite charged wire depends on $\frac{1}{r}$ for a point charge.

(vii) The equation (5) is true only for an infinitely long charged wire. For a charged wire of finite length, the electric field need not be radial at all points.

13. Obtain the expression for electric field due to an charged infinite plane sheet.

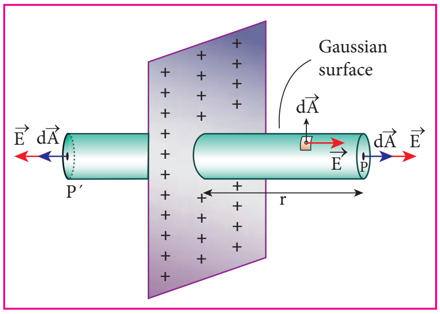
Ans. **Electric field due to charged infinite plane sheet :**

(i) σ be the surface charge density of an uniformly charged infinite plane sheet.

(ii) A cylindrical shaped Gaussian surface of length 2r and area A of the flat surfaces is chosen such that the infinite plane sheet passes perpendicularly through the middle part of the Gaussian surface. Applying Gauss law for this cylindrical surface,

$$\phi_E = \oint \vec{E}\cdot d\vec{A}$$

$$= \int_{\text{Curved surface}} \vec{E}\cdot d\vec{A} + \int_{P} \vec{E}\cdot d\vec{A} + \int_{P'} \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} \quad ...(1)$$



Electric field due to charged infinite planar sheet

(iii) The electric field is perpendicular to the area element on the curved surface and is parallel to the surface areas at P and P′. Then,

$$\phi_E = \int_P E\, dA + \int_{P'} E\, dA = \frac{Q_{encl}}{\varepsilon_0} \qquad ...(2)$$

(iv) The magnitude of the electric field at these two equal surfaces is uniform, $Q_{encl} = \sigma A$, substituting in (2) Here,

We get, $2E\int_P dA = \frac{\sigma A}{\varepsilon_0}$

The total area of surface either at P or P′

$$\int_P dA = A$$

$$\text{Hence } 2EA = \frac{\sigma A}{\varepsilon_0} \quad \text{or } E = \frac{\sigma}{2\varepsilon_0} \qquad ...(3)$$

$$\text{In vector } \vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n} \qquad ...(4)$$

(v) The electric field due to an infinite plane sheet of charge depends on the surface charge density and is independent of the distance *r*.

(vi) For a finite charged plane sheet, equation (4) is approximately true only in the middle region of the plane and at points far away from both ends.

14. Obtain the expression for electric field due to an uniformly charged spherical shell.

Ans. **Electric Field due to a uniform charged spherical shell :**

Consider a uniformly charged spherical shell.

Radius - R

Total charge - Q

(a) At a point outside the shell (r > R) :

P is a point outside the shell at a distance *r* from the centre. The charge is uniformly distributed on the surface of the sphere.

(i) If Q > 0, field point radially outward.

If Q < 0, field point readially inward.

Applying Gauss law

$$\oint_{\text{Gaussian surface}} \vec{E}.\vec{dA} = \frac{Q}{\varepsilon_0} \qquad ...(1)$$

$\vec{E}$ and $\vec{dA}$ are in the same direction.

Hence $E\oint dA = \frac{Q}{\varepsilon_0}$

But $\oint dA$ = total area of Gaussian surface $= 4\pi r^2$

Substituting in (1)

$$E.\,4\pi r^2 = \frac{Q}{\varepsilon_0} \quad \text{(or)} \quad E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

In vector from $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}.\hat{r}$

(b) At a point on the surface of the spherical shell (r = R). Electric field at points on the spherical shell, is *r* = R

$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 R^2}.\hat{r}$$

(c) At a point inside the shell (r < R) :

Consider a point P inside the shell at a distance r from the center.

$$\oint_{\text{Gaussian surface}} \vec{E}.\vec{dA} = \frac{Q}{\varepsilon_0}$$

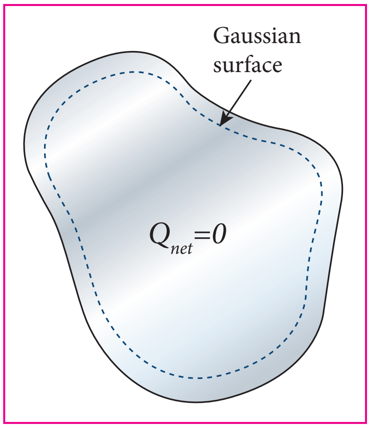
$$E\,.\,4\pi r^2 = \frac{Q}{\varepsilon_0}$$

Since Gaussian surface encloses no charge, so Q = 0.

$\therefore$ E = 0

15. Discuss the various properties of conductors in electrostatic equilibrium.

Ans. **(i)** The Electric Field is zero everywhere inside the conductors whether the conductor is solid or hallow.



No net charge inside the conductor

(ii) There is no net charge inside the conductors. The charges must reside only on the surface of the conductors.

(iii) The Electric Field outside the conductor is perpendicular to the surface of the conductor and has a magnitude of $\frac{\sigma}{\varepsilon_0}$ where σ is the surface charge density at the point (i.e. $E \propto \sigma$)

(iv) The electrostatic potential has the same value on the surface and inside of the conductor.

Potential is constant within and on the surface of a conductor.

16. Explain the process of electrostatic induction.

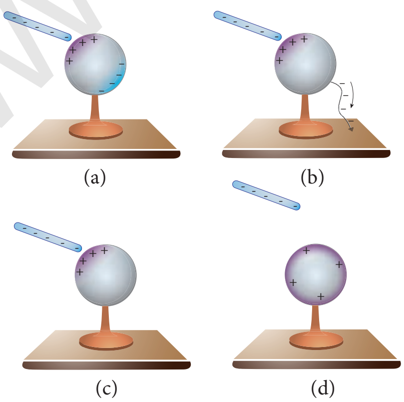
Ans. Charging without actual contact is called electrostatic induction.

(i) Consider an uncharged (neutral) conducting sphere at rest on an insulating stand. Suppose a negatively charged rod is brought near the conductor without touching it, as shown in Figure (a).

The negative charge of the rod repels the electrons in the conductor to the opposite side. As a result, positive charges are induced near the region of the charged rod while negative charges on the farther side.

Before introducing the charged rod, the free electrons were distributed uniformly on the surface of the conductor and the net charge is zero.

Once the charged rod is brought near the conductor, the distribution is no longer uniform with more electrons located on the farther side of the rod and positive charges are located closer to the rod. But the total charge is zero.



Various steps in electrostatic induction

(ii) Now the conducting sphere is connected to the ground through a conducting wire. This is called grounding. Since the ground can always receive any amount of electrons, grounding removes the electron from the conducting sphere.

Note that positive charges will not flow to the ground because they are attracted by the negative charges of the rod (Figure (b)).

(iii) When the grounding wire is removed from the conductor, the positive charges remain near the charged rod (Figure (c))

(iv) Now the charged rod is taken away from the conductor. As soon as the charged rod is removed, the positive charge gets distributed uniformly on the surface of the conductor (Figure (d)). By this process, the neutral conducting sphere becomes positively charged.

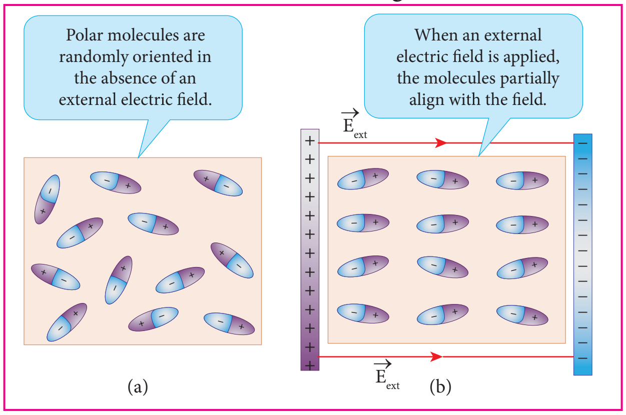
17. Explain dielectrics in detail and how an electric field is induced inside a dielectric.

Ans. (i) When an external electric field is applied on a conductor, the charges are aligned in such a way that an internal electric field is created which cancels the external electric field. But in the case of a dielectric, which has no free electrons, the external electric field only realigns the charges so that an internal electric field is produced.

(ii) The magnitude of the internal electric field is smaller than that of external electric field. Therefore the net electric field inside the dielectric is not zero but is parallel to an external electric field with magnitude less than that of the external electric field. Let us consider a rectangular dielectric slab placed between two oppositely charged plates (capacitor) as shown in the Figure (b).

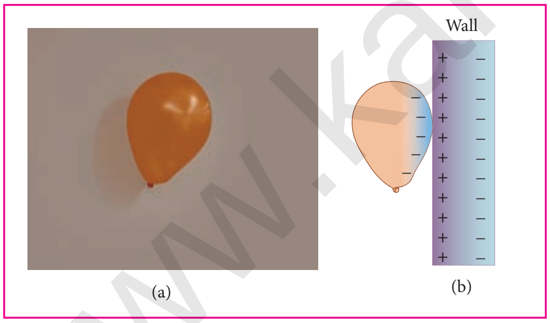
(iii) The uniform electric field between the plates acts as an external electric field $\vec{E}_{ext}$ which polarizes the dielectric placed between plates. The positive charges are induced on one side surface and negative charges are induced on the other side of surface.

(iv) But inside the dielectric, the net charge is zero even in a small volume. So the dielectric in the external field is equivalent to two oppositely charged sheets with the surface charge densities $+\sigma_b$ and $-\sigma_b$. These charges are called bound charges. They are not free to move like free electrons in conductors. This is shown in the Figure (b).



Induced electric field lines inside the dielectric

(v) For example, the charged balloon after rubbing sticks onto a wall. The reason is that the negatively charged balloon is brought near the wall, it polarizes (induces) opposite charges on the surface of the wall, which attracts the balloon.



(a) Balloon sticks to the wall (b) Polarisation of wall due to the electric field due to the balloon

18. Obtain the expression for capacitance for a parallel plate capacitor.

***Ans.* Capacitance of a parallel plate capacitor**

Consider a capacitor with two parallel plates,
A - Area of each plate
d - Distance between the plates
σ - surface charge density on the plates

$$\sigma = \frac{Q}{A}$$

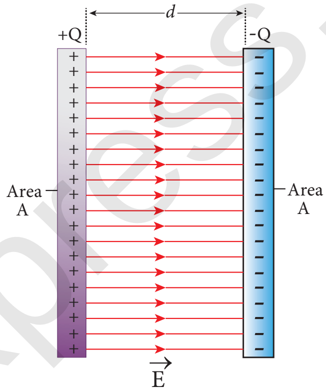
The Electric Field between the plates is

$$E = \frac{Q}{A\varepsilon_0}$$

Since the Electric Field is uniform, the electrical potential between the plates $V = Ed = \frac{Qd}{A\varepsilon_0}$

∴ Capacitance of the capacitor

$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$$



Capacitance is directly proportional to the area of cross section and is inversely proportional to the distance between the plates.

(i) 'A' is increased, capacitance is increased therefore more charges can be distributed.

(ii) Distance '*d*' is reduced, V decreases, charges flow from battery to plates. Distance 'd' is increased, capacitor voltage increases, charges flow from plates to battery.

19. Obtain the expression for energy stored in the parallel plate capacitor.

Ans. The capacitor stores not only charge but also it stores energy.

When battery is connected to the capacitor, electrons of total charge - Q are transferred from one plate to another.

To transfer charge, work is done by the battery. This work done is stored as Electrostatic Potential energy in the capacitor.

dQ - Infinitesimal charge

V - potential difference

Work done $dW = V.dQ$

where $V = \frac{Q}{C}$

The total work done to charge the capacitor

$$W = \int_0^Q \frac{Q}{C}.dQ = \frac{Q^2}{2C}$$

This work done is stored as Electrostatic Potential Energy

$$U_E = \frac{Q^2}{2C} = \frac{1}{2}.CV^2 \qquad [\because Q = CV]$$

For parallel capacitor, capacitance $C = \frac{\varepsilon_0 A}{d}$ and $V = Ed$

$$U_E = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2 = \frac{1}{2}.\varepsilon_0.(Ad)E^2$$

Ad - volume of the space between the capacitor plates.

Energy density, $u_E = \frac{U}{\text{Volume}}$

$$u_E = \frac{1}{2}\varepsilon_0 E^2$$

20. Explain in detail the effect of a dielectric placed in a parallel plate capacitor.

Ans. (i) A dielectric is an insulating material in which all the electrons are bound to the nucleus of the atom. In this material no free electrons to carry current.

(ii) When dielectric is introduced between the two plates of parallel plate capacitor, the capacitance of the capacitor increases.

Capacitance of a parallel plate capacitor with a dielectric medium:

(i) Consider a parallel plate capacitor having two conducting plates X and Y each of area A, separated by a distance d apart. X is given a positive charge so that the surface charge density on it is σ and Y is earthed.

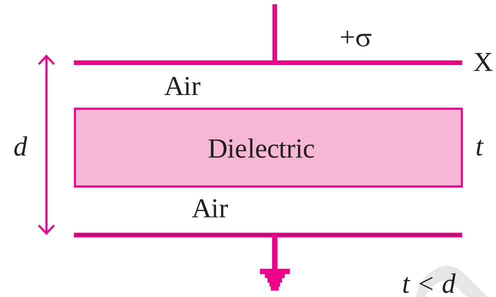
(ii) Let a dielectric slab of thickness t and relative permittivity ε_r be introduced between the plates figure.

Thickness of dielectric slab = t

(iii) Thickness of air gap = $(d - t)$. Electric field at any point in the air between the plates,

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

(iv) Electric field at any point, in the dielectric slab $E' = \frac{\sigma}{\varepsilon_o}$



Dielectric in capacitor

(v) The total potential difference between the plates, is the work done in crossing unit positive charge from one plate to another in the field E over a distance (*d*-*t*) and in the field E' over a distance t, then

$$V = E(d - t) + E't$$

$$V = \frac{\sigma}{\varepsilon_o}(d-t) + \frac{\sigma t}{\varepsilon_o \varepsilon_r}$$

$$= \frac{\sigma}{\varepsilon_o}\left[(d-t) + \frac{t}{\varepsilon_r}\right]$$

(vi) The charge on the plate X, $q = \sigma A$

Hence the capacitance of the capacitor is,

$$C = \frac{q}{V} = \frac{\sigma A}{\frac{\sigma}{\varepsilon_o}\left[(d-t)+\frac{t}{\varepsilon_r}\right]} = \frac{\varepsilon_o A}{(d-t)+\frac{t}{\varepsilon_r}}$$

Effect of dielectric: In capacitors, the region between the two plates is filled with dielectric like mica or oil.

(i) The capacitance of the air filled capacitor, $C = \frac{\varepsilon_o A}{d}$

(ii) The capacitance of the dielectric filled capacitor, $C' = \frac{\varepsilon_r \varepsilon_o A}{d} \therefore \frac{C'}{C} = \varepsilon_r$

or $C' = \varepsilon_r C$

since, $\varepsilon_r > 1$ for any dielectric medium other than air, the capacitance increases, when dielectric is placed.

21. Derive the expression for resultant capacitance, when capacitors are connected in series and in parallel.

Ans. **Capacitors in series :**

C_1, C_2. C_3 - capacitances of capacitors connected in series.

V - battery voltage

Q - charge on each capacitor is same.

V_1, V_2, V_3 - potential difference across C_1, C_2, C_3.

Total voltage across each capacitor = Voltage of the battery.

$V = V_1 + V_2 + V_3$.

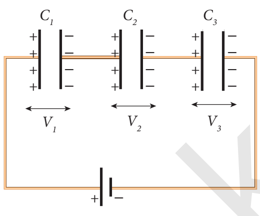
Since $Q = CV$; $V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

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

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

The inverse of the equivalent capacitance in series is equal to the sum of the inverses of each capacitance.

C_s is always less than the smallest individual capacitance in series.



(a)

(a) Capacitors connected in series

Capacitor in parallel :

C_1. C_2, C_3 - capacitances of capacitors connected in parallel connection.

V - Applied parallel potential.

Potential difference across each capacitor is same. Q_1, Q_2, Q_3 - charge stored in C_1, C_2, C_3.

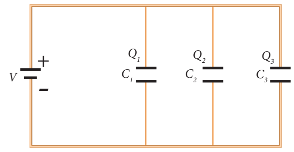
Total charge $Q = Q_1 + Q_2 + Q_3$

$Q = C_pV$;

$Q = C_1V + C_2V + C_3V$

$C_pV = (C_1 + C_2 + C_3)V$

$C_p = C_1 + C_2 + C_3$



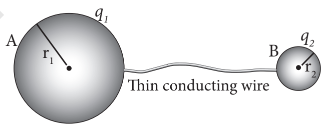
(a)

(a) capacitors in parallel

The equivalent capacitance of capacitors connected in parallel is equal to the sum of the individual capacitance. C_p is always greater than the largest individual capacitance.

22. Explain in detail how charges are distributed in a conductor, and the principle behind the lightning conductor.

Ans. **(i)** Consider two conducting spheres A and B of radii r_1 and r_2 respectively connected to each other by a thin conducting wire as shown in the Figure. The distance between the spheres is much greater than the radii of either spheres.



Two conductors are connected through conducting wire

(ii) If a charge Q is introduced into any one of the spheres, this charge Q is redistributed into both the spheres such that the electrostatic potential is same in both the spheres. They are now uniformly charged and attain electrostatic equilibrium. Let q1 be the charge residing on the surface of sphere A and q_2 is the charge residing on the surface of sphere B such that $Q = q_1 + q_2$. The charges are distributed only on the surface and there is no net charge inside the conductor.

The electrostatic potential at the surface of the sphere A is given by

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} \quad ...(1)$$

(iii) The electrostatic potential at the surface of the sphere B is given by

$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2} \quad ...(2)$$

(iv) The surface of the conductor is an equipotential. Since the spheres are connected by the conducting wire, the surfaces of both the spheres together form an equipotential surface. This implies that

$$V_A = V_B$$

or $$\frac{q_1}{r_1} = \frac{q_2}{r_2} \quad ...(3)$$

(v) Let us take the charge density on the surface of sphere A is σ1 and charge density on the surface of sphere B is σ_2. This implies that $q_1 = 4\pi r_1^2 \sigma_1$ and $q_2 = 4\pi r_2^2 \sigma_2$ Substituting these values into equation (3), we get

$$\sigma_1 r_1 = \sigma_2 r_2 \quad ...(4)$$

from which we conclude that

$$\sigma r = \text{constant} \quad ...(5)$$

(vi) Thus the surface charge density σ is inversely proportional to the radius of the sphere. For a smaller radius, the charge density will be larger and vice versa.

23. Explain in detail the construction and working of a Van de Graaff generator.

Ans. It is a machine which produces large electrostatic potential difference of the order of 10^7 V.

Principle:

Electrostatic induction and action at points.

Construction:

(i) It consists of a hollow metallic sphere (A) mounted on insulating pillars.

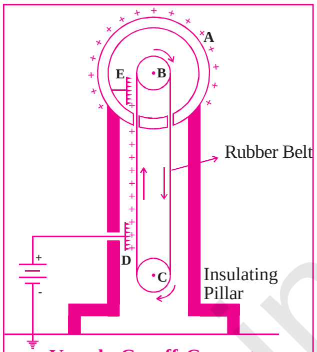
(ii) A pulley B is mounted at the centre of the sphere and another pulley C is mounted near the bottom.

(iii) A belt made of silk moves over the pulleys.

(iv) Two comb-shaped conductors D and E are mounted near the pulleys.

(v) The comb D is maintained at a positive potential of the order of 10^4 volt.

(vi) The upper comb E is connected to the inner side of the hollow metal sphere.



Van de Graaff Generator

Working:

(i) Because of the high electric field near the comb D, the air gets ionized.

(ii) The negative charges in air move towards the needles and positive charges are repelled towards the belt due to action of points.

(iii) The +ve charges stick to the belt moves up end reaches near the comb E.

(iv) E acquires negative charge and the sphere acquires positive charge due to electrostatic induction.

(v) The acquired +ve charge is distributed on the outer surface of the sphere.

(vi) Thus the machine, continuously transfers the positive charge to the sphere.

(vii) The leakage of charges from the sphere can be reduced by enclosing it in a gas filled steel chamber at a very high pressure.

(viii) The high voltage can be used to accelerate positive ions for the purpose of nuclear disintegration.

EXERCISES :

1. When two objects are rubbed with each other, approximately a charge of 50 nC can be produced in each object. Calculate the number of electrons that must be transferred to produce this charge.

Ans. **Given:** Charge produced $q = 50$ nC $= 50 \times 10^{-9}$ C;

To find:

No. of electrons n = ?

$q = ne$ magnitude of electrons $= 1.6 \times 10^{-19}$ C

Solution:

$$\frac{q}{e} = \frac{50\times10^{-9}}{1.6\times10^{-19}} = 31.25 \times 10^{10} \text{ electrons.}$$

2. The total number of electrons in the human body is typically in the order of 10^{28}. Suppose, due to some reason, you and your friend lost 1% of this number of electrons. Calculate the electrostatic force between you and your friend separated at a distance of 1m. Compare this with your weight. Assume mass of each person is 60 kg and use point charge approximation.

Ans. **Given:**

Total no. of electrons in the human body = 10^{28}

Total no of electrons in me and my friend

$= 10^{28} \times 1\%$

$10^{28} \times 1\% = 10^{28} \times \frac{1}{100} = 10^{28} \times 10^{-2} = 10^{26}$

Distance = 1m

The electrostatic force $F = \frac{1}{4\pi\varepsilon_0}.\frac{q_1 q_2}{r_2}$

Solution:

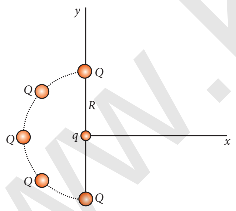
$$F = \frac{1}{4\pi\varepsilon_0}.\frac{10^{26}\times10^{26}}{1} = 9 \times 10^9 \times 10^{52}$$

$$F = 9 \times 10^{61}\text{ N}$$

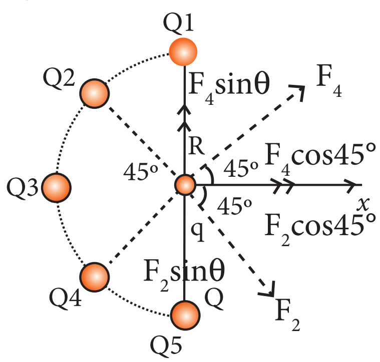
mass of the person m = 60 kg; weight = ?

Weight = mg = 60 × 9.8 = 588 N.

3. Five identical charges Q are placed equidistant on a semicircle as shown in the figure. Another point charge *q* is kept at the center of the circle of radius R. Calculate the electrostatic force experienced by the charge *q*.



Ans. The forces acting on q, due to Q_1 and Q_2 are F_1 and F_2.



These forces are equal and opposite.

Forces due to Q_2 and Q_4 on q is resolved into components.

$F_2 \sin\theta$ and $F_4 \sin\theta$ i.e $F_1 \sin 45°$ and $F_2 \sin 45°$ are equal and opposite. So they get cancel.

Total force acting on q is due to Q_3 (i.e F_3)

$F_4 \cos\theta, F_2 \cos\theta \quad F = F_3 + F_2 \cos\theta + F_4 \cos\theta$

$$\text{Total force F} = k.\frac{qQ}{R^2} + k.\frac{qQ}{R^2}.\cos 45° + \frac{kqQ}{R^2}.\cos 45°$$

$$= \frac{kqQ}{R^2}\left[1+\frac{2}{\sqrt{2}}\right]$$

$$\text{Total F} = \frac{kqQ}{R^2}\left[1+\sqrt{2}\right]\hat{i}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{qQ}{R^2}\left[1+\sqrt{2}\right]\hat{i}$$

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

4. Suppose a charge +*q* on Earth's surface and another +*q* charge is placed on the surface of the Moon. (a) Calculate the value of q required to balance the gravitational attraction between Earth and Moon (b) Suppose the distance between the Moon and Earth is halved, would the charge *q* change? (Take $m_E = 5.9 \times 10^{24}$ kg, $m_M = 7.9 \times 10^{22}$ kg)

Ans. **Given:**

(a) Mass of the earth $m_E = 5.9 \times 10^{24}$ kg

Mass of the moon $m_M = 7.9 \times 10^{22}$ kg

Charge placed on earth and moon is q

To find: The amount of charge required to balance to gravitational attraction between earth & moon = ?

If q is the charge placed on the moon & earth, then

Formula : $\frac{1}{4\pi\varepsilon_0}.\frac{q\times q}{r^2} = G.\frac{m_E \times m_M}{r^2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$

$G = 6.6 \times 10^{-11}\text{ Nm}^{-2}\text{ kg}^{-2}$

$4\pi\varepsilon_0 = 0.11 \times 10^{-9}$

(or)

$$q = \sqrt{4\pi\varepsilon_0\, Gm_E\,.m_M}$$

$$= \sqrt{0.11\times10^{-9}\times6.6\times10^{-11}\times5.9\times10^{24}\times7.9\times10^{22}}$$

$$q = \sqrt{33.84\times10^{26}}$$

$q = 5.82 \times 10^{13}$ C.

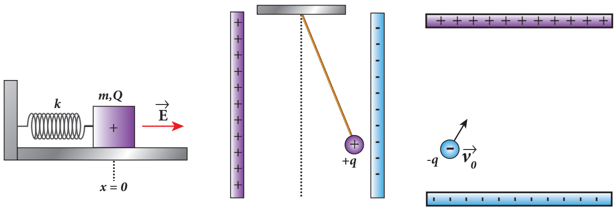
Electrostatics

(b) The distance between moon & earth is halved, the charge q = ?

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{\left(\frac{r}{2}\right)^2} = G.\frac{m_E.m_M}{\left(\frac{r}{2}\right)^2}$$

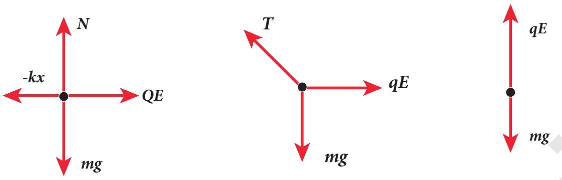
There will not be any change in the charge q.

5. Draw the free body diagram for the following charges as shown in the figure (a), (b) and (c).



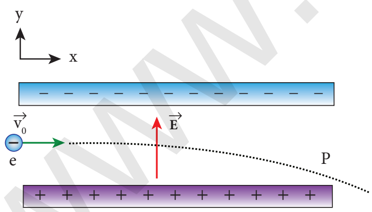
(a) (b) (c)

Ans.



(a) (b) (c)

6. Consider an electron travelling with a speed v_o and entering into a uniform electric field $\vec{E}$ which is perpendicular to $\vec{v}$ as shown in the Figure. Ignoring gravity, obtain the electron's acceleration, velocity and position as functions of time.



Ans. The speed of the electrons $= v_0$

Electric field strength $= \vec{E}$

Acceleration of the electrons a = ?

Velocity of the electrons v = ?

Position of the electrons r = ?

According to Newton's II law F = ma

The force on the electrons in an uniform electric field.

F = Ee

The e^- s acceleration due to electric field

$$a = \frac{F}{m} = \frac{Ee}{m}$$

The acceleration of the electrons $\left[a = \frac{Ee}{m}\right]$ is in the down direction. The horizontal velocity remains v_0 as there is no acceleration in this direction.

$$\vec{a} = -\frac{eE}{m}.\hat{j}$$

The downward component of the velocity of the electrons as it emerges from the field region is

$$v = v_x\,\hat{i} + v_y\,\hat{j}$$

The horizontal component of the velocity remains $v_x = v_0$. The vertical component (downward) velocity as it emerges from the field region is

$$v_y = \vec{a}\,t = -\frac{eE}{m}t.\hat{j}$$

The velocity of the e^- $= v_0\,\hat{i} - \frac{eE}{m}.t.\hat{j}$

The electrons starts with a velocity v_0.

From equation of motion, $s = ut + \frac{1}{2}at^2$

The position of the electrons $s = r$ = ?

Initial velocity of the electrons $\vec{u} = v_0$

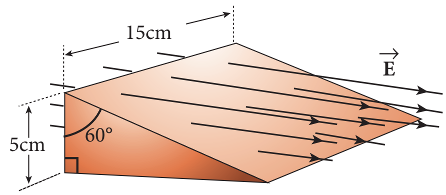
Acceleration of the electrons $\vec{a} = \left(-\frac{eE}{m}\right)t.\hat{j}$

$$\therefore \vec{r} = v_0 t\,\hat{i} + \frac{1}{2}.\left(-\frac{Ee}{m}t\right).\hat{j}$$

$$= v_0 t\,\hat{i} - \frac{1}{2}.\frac{Ee}{m}.t^2\,\hat{j}$$

$$\vec{r} = v_0 t\,\hat{i} - \frac{1}{2}.\frac{Ee}{m}.t^2\,\hat{j}$$

7. A closed triangular box is kept in an electric field of magnitude E = 2×10^3 N C^{-1} as shown in the figure.



Calculate the electric flux through the (a) vertical rectangular surface (b) slanted surface and (c) entire surface.

Ans. **Given:**

The magnitude of electric field $E = 2 \times 10^3\ NC^{-1}$

Area of the surface $A = 0.15 \times 0.05$

[From the diagram l = 15 cm = 0.15 m, b = 5 cm = 0.05m]

The electric flux through

To find:

a) Vertical rectangular surface $\phi_{vert} = ?$

Solution:

According to Gauss law $\phi = E A \cos\theta$

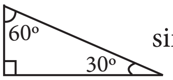
$$\phi_{\text{vertical surface}} = 2 \times 10^3 \times 0.15 \times 0.05 \times \cos 0^\circ$$
$$= 0.015 \times 10^3 = 15\ Nm^2\ C^{-1}$$

b) Electric flux through slanted surface

$\phi_{\text{slanted surface}} = ?$

$\phi_{\text{slanted surface}} = E A \cos\theta$

$\theta = 60^\circ \Rightarrow \cos 60^\circ = \frac{1}{2}$

Scm 

$\sin 30 = \frac{\text{opposite}}{\text{hyp}}$

Opposite = 5 cm. $\text{hyp} = \frac{\text{opposite}}{\sin 30^\circ}$

$$\text{hyp.} = \frac{5 \times 10^{-2}}{\frac{1}{2}} = 2 \times .05$$
$$= 0.10\ m$$

Area of the slanted surface

$$A = (0.10 \times 0.15)\ m^2$$
$$\phi_{\text{slanted surface}} = EA\cos\theta$$
$$\phi_{\text{slanted surface}} = 2 \times 10^3 \times (0.10 \times 0.15) \times \cos 60^\circ$$
$$= 0.015 \times 10^3$$
$$= -15\ Nm^2 C^{-1}$$

c) Entire surface $\phi_{tot} = ?$

$\phi_{tot} = \phi_{vs} + \phi_{s.s} + \phi_{ends}$

$\phi_{ends} = EA\cos\theta$

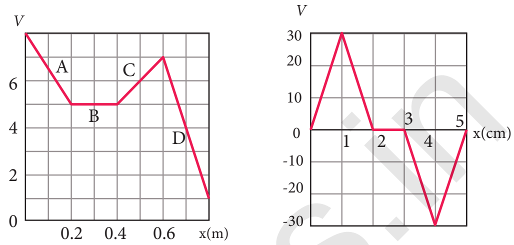
$\theta = 90^\circ$; $\cos 90^\circ = 0$

$\phi_{ends} = 0$

$= -15 + 15 + 0$

$\phi_{tot} = 0.$

8. **The electrostatic potential is given as a function of x in figure (a) and (b). Calculate the corresponding electric fields in regions A, B, C and D. Plot the electric field as a function of x for the figure (b).**



(a) (b)

Ans.

(a) $E = -\frac{dV}{dx}$

(i) Region A

$$\frac{dV}{dx} = \frac{-3}{0.2} = -15V_i,\ E = \frac{dV}{dx}$$
$$\therefore\ E = -(-15) = 15\ Vm^{-1}$$

(ii) Region B

$$\frac{dV}{dx} = \frac{0}{0.2} = 0$$

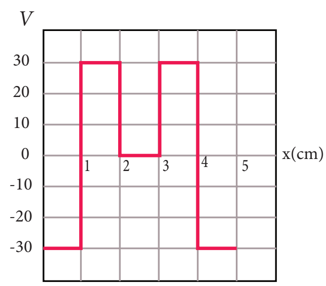
(iii) Region C

$$\frac{dV}{dx} = \frac{2}{0.2} = 10$$
$$E = -\frac{dV}{dx} = (-10)Vm^{-1}$$

(iv) Region D

$$\frac{dV}{dx} = \frac{-6}{0.2} = -30$$
$$E = -\frac{dV}{dx} = -(-30) = 30Vm^{-1}.$$

(b)



9. A spark plug in a bike or a car is used to ignite the air-fuel mixture in the engine. It consists of two electrodes separated by a gap of around 0.6 mm gap as shown in the figure.

To create the spark, an electric field of magnitude 3 × 10⁶ Vm⁻¹ is required. (a) What potential difference must be applied to produce the spark? (b) If the gap is increased, does the potential difference increase, decrease or remains the same? (c) find the potential difference if the gap is 1 mm.

Ans. **Given:**

(a) The distance between two electrodes d = 0.6mm $= 0.6 \times 10^{-3}$ m

The magnitude of electric filed $E = 3 \times 10^{6}\ Vm^{-1}$

To find:

Potential difference need to produce spark V = ?

Formula: $E = \dfrac{V}{d}$

Solution: $\therefore V = E . d$

$= 0.6 \times 10^{-3} \times 3 \times 10^{6}$

$= 1800$ V.

(b) From the above, we come to know when the gap is increased. potential also increase.

(c) The distance, $d = 1\text{ mm} = 1 \times 10^{-3}$ m

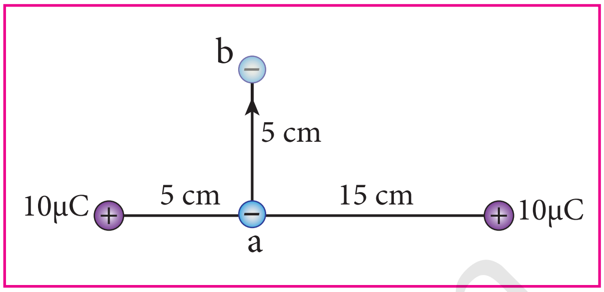
Electric field, $E = 3 \times 10^{6}\ Vm^{-1}$

New potential difference due to increase in the gap.

$V = E.\ d = 3 \times 10^{6} \times 1 \times 10^{-3}$

$= 3000$ V.

10. A point charge of +10 μC is placed at a distance of 20 cm from another identical point charge of +10 μC. A point charge of -2 μC is moved from point a to b as shown in the figure. Calculate the change in potential energy of the system? Interpret your result.



Ans. Given : $q_1 = 10 \times 10^{-6}$ C, $q_2 = -2 \times 10^{-6}$ C

$r = 5 \times 10^{-2}$ m

Solution: Change in potential energy

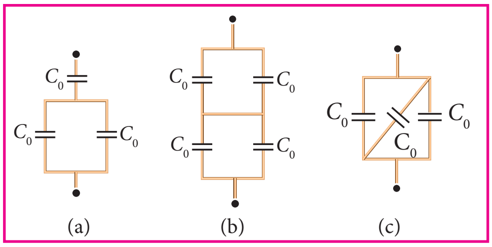
$$\Delta U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = \frac{9\times10^{9}\times(10)(-2)\times10^{-12}}{5\times10^{-2}}$$

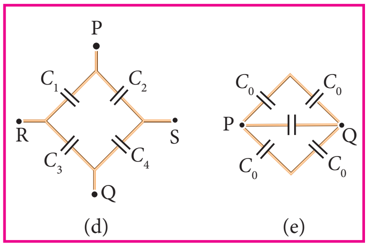
$$= \frac{-9\times10^{9}\times \overset{4}{\cancel{20}}\times10^{-12}\times10^{2}}{\cancel{5}}$$

$= -36 \times 10^{-1} = -3.6$ J

ΔU = -3.6 J, negative sign implies that to move the charge -2μC no external work is required. System spends its stored energy to move the charge from point a to point b.

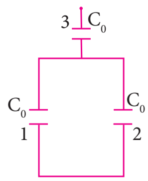
11. Calculate the resultant capacitances for each of the following combinations of capacitors.





Ans.

a.



Capacitor 1 & 2 are connected in parallel

$C_p = C_0 + C_0 = 2C_0$

Capacitor C_p and C_3 are in series.

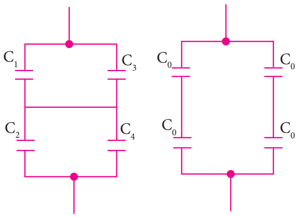
$$\frac{1}{C_s} = \frac{1}{C_p}+\frac{1}{C_3} \Rightarrow \frac{1}{C_s} = \frac{1}{2C_0}+\frac{1}{C_0}$$

$$= \frac{1+2}{2C_0} = \frac{3}{2C_0}$$

$$\therefore C_s = \frac{2}{3}.C_0$$

The resultant capacitance = $\frac{2}{3}C_0$

b.



C_1 & C_2 are in series $\frac{1}{Cs_1} = \frac{1}{C_0}+\frac{1}{C_0} = \frac{2}{C_0}$

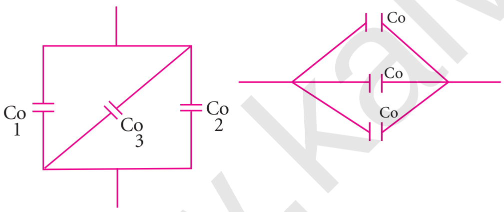
C_3 & C_4 are in series $\frac{1}{Cs_2} = \frac{2}{C_0}$

Cs_1 & Cs_2 are in parallel.

$\therefore C_p = Cs_1 + Cs_2 = \frac{C_0}{2}+\frac{C_0}{2} = C_0$

Resultant capacitance = C_0

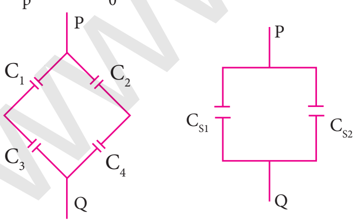
c.



Resultant capacitance $C_p = C_0 + C_0 + C_0$

$C_p = 3\,C_0$

d.



C_1 and C_3 are in series $\frac{1}{Cs_1} = \frac{1}{C_1}+\frac{1}{C_3} = \frac{C_1+C_3}{C_1C_3}$

$$Cs_1 = \frac{C_1C_3}{C_1+C_3}$$

C_2 and C_4 are in series

$$\frac{1}{Cs_2} = \frac{1}{C_2}+\frac{1}{C_4}$$

$$Cs_2 = \frac{C_2+C_4}{C_2C_4} = \frac{C_2C_4}{C_2+C_4}$$

Now Cs_1 and Cs_2 are parallel

$$Cp = Cs_1+Cs_2$$

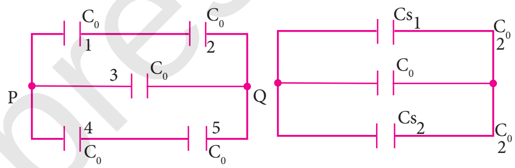
$$= \frac{C_1C_3}{C_1+C_3}+\frac{C_2C_4}{C_2+C_4}$$

$$= \frac{(C_1C_3)(C_2+C_4)+(C_2C_4)(C_1+C_3)}{(C_1+C_3)(C_2+C_4)}$$

The resultant capacitance

$$= \frac{C_1C_2C_3+C_1C_3C_4+C_1C_2C_4+C_3C_2C_4}{(C_1+C_3)(C_2+C_4)}$$

e.



Capacitors 1 and 2 are in series

$$\frac{1}{Cs_1} = \frac{1}{C_0}+\frac{1}{C_0} = \frac{2}{C_0}$$

$$Cs_1 = \frac{C_0}{2}$$

Parallerly 4 and 5 are in series

$$Cs_2 = \frac{C_0}{2}$$

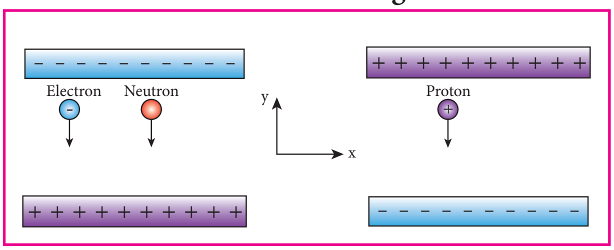
Cs_1, Cs_2, 3 are in parallel

$$\therefore C_p = \frac{C_0}{2}+\frac{C_0}{2}+C_0$$

$$= C_0 + C_0$$

Resultant capacitance = 2C

12. An electron and a proton are allowed to fall through the separation between the plates of a parallel plate capacitor of voltage 5 V and separation distance h = 1 mm as shown in the figure.



Unit 1

(a) Calculate the time of flight for both electron and proton (b) Suppose if a neutron is allowed to fall, what is the time of flight? (c) Among the three, which one will reach the bottom first?

(Take $m_p = 1.6 \times 10^{-27}$ kg, $m_e = 9.1 \times 10^{-31}$ kg and $g = 10$ m s^{-2})

Ans. **Given:** Potential difference between the plates of Parallel plate capacitor = E = 5V

Distance between the plates of

$h = 1 \text{ mm} = 1 \times 10^{-3}$ m

Mass of proton $m_p = 1.6 \times 10^{-27}$ kg

Mass of electron $m_e = 9.1 \times 10^{-31}$ kg

Charge of proton, $e = 1.6 \times 10^{-19}$ C

To find:

a. Time of flight of an electron t_e = ?

$s = ut + \frac{1}{2}at^2$, initial velocity $(u) = 0$

Solution:

$$s = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2s}{a}}$$

$a = \frac{F}{m}$ (according to Newton's II law) [F = ma]

F - force due to electric field

$$F = Ee, \; E = \frac{\Delta V}{\Delta d} = \frac{5}{10^{-3}}$$

$$\therefore a = \frac{Ee}{m} \qquad \therefore t = \sqrt{\frac{2sm}{Ee}}$$

s = h distance of separation = 1×10^{-3} m

$$\therefore t_e^2 = \frac{2hm_e}{\frac{\Delta V}{\Delta d}.e}$$

$$t_e^2 = \frac{2hm_e}{Ee} = \frac{2\times10^{-3}\times9.1\times10^{-31}\times10^{-3}}{5\times1.6\times10^{-19}}$$

$$t_e = \sqrt{\frac{2\times10^{-3}\times9.1\times10^{-31}\times10^{-3}}{5\times1.6\times10^{-19}}}$$

$$= \sqrt{2.275\times10^{-18}} = 1.5 \times 10^{-9} \text{ s (or) } 1.5 \text{ ns}$$

$$t_p = \sqrt{\frac{2\times10^{-3}\times1.6\times10^{-27}\times10^{-3}}{5\times1.6\times10^{-19}}}$$

$$= \sqrt{\frac{2}{5}\times10^{-33}\times10^{19}} = \sqrt{0.4\times10^{-14}}$$

$t_p = 0.63 \times 10^{-7}$ s (or) 63×10^{-9}s (or) 63 ns

b. Neutron falls, it is a neutral charge so it does not experience any electric filed. (It is like a force fall)

$$t^2 = \frac{2h}{g} \qquad \left[\text{i.e. } t = \frac{2s}{a}\right] a = g, s = h$$

$$t = \sqrt{\frac{2\times10^{-3}}{10}} = \sqrt{2\times10^{-4}}$$

$t = 1.414 \times 10^{-2}$ sec.

c. Electron will reach first

∵ the time to reach the bottom first by electron is 1.5 ns.

13. During a thunder storm, the movement of water molecules within the clouds creates friction, partially causing the bottom part of the clouds to become negatively charged. This implies that the bottom of the cloud and the ground act as a parallel plate capacitor. If the electric field between the cloud and ground exceeds the dielectric breakdown of the air (3×10^6 Vm^{-1}), lightning will occur.

(a) If the bottom part of the cloud is 1000 m above the ground, determine the electric potential difference that exists between the cloud and ground.

(b) In a typical lightning phenomenon, around 25 C of electrons are transferred from cloud to ground. How much electrostatic potential energy is transferred to the ground?

Ans. **Given:**

a. Electric field between ground and cloud

$E = 3 \times 10^6$ Vm^{-1}

Distance between ground and the cloud

$d = 1000$m

To find: Electric potential between ground and the cloud V = ?

Formula: $E = \frac{V}{d} \Rightarrow V = E.d.$

$E = 3 \times 10^6 \times 10^3 = 3 \times 10^9$ V

b. The amount of electrons transfered from cloud to ground $q = 25$ C

Electrostatic P.E. transfered from cloud to ground U = ?

Solution:

$$U = \frac{1}{2} CV^2$$

$$C = \frac{q}{V} \qquad \therefore U = \frac{1}{2} q.V$$

$$U = \frac{1}{2} \times 25 \times 3 \times 10^9 = \frac{75}{2} \times 10^9$$

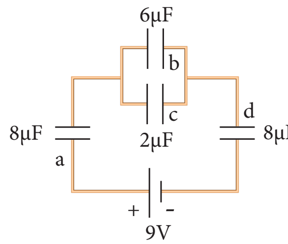
$$= 37.5 \times 10^9 \text{ J.}$$

14. For the given capacitor configuration

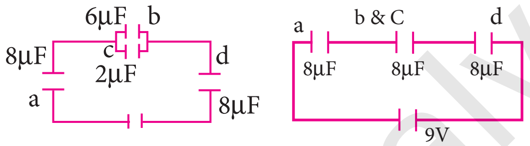
(a) Find the charges on each capacitor

(b) potential difference across them

(c) energy stored in each capacitor



Ans.



B & C are parallel so C = (6 + 2) μF = 8μF

Now all a, b & c, d are in series.

Effective capacitance $\frac{1}{C_s} = \frac{1}{8} + \frac{1}{8} + \frac{1}{8} = \frac{3}{8} \quad \therefore C_s = \frac{8}{3}$

a. Charges on each capacitor :

Total charges on capacitor = $q = C_s$.

$$V = \frac{8}{3} \times 9 \times 10^{-6} = 24 \ \mu C$$

Charge on capacitor $a = q_a$ = C.V.

$$q_a = 24 \ \mu C$$

In case of capacitor in series the charge flowing through capacitor is same.

$$q_a = q_d = 24 \ \mu C$$

But across b & c, the charge is not same total are in parallel.

Charge on b $= q_b = \frac{6}{3} \times 9 \times 10^{-6}$

$= 18 \ \mu C$

Charge on c $= q_c = \frac{2}{3} \times 9 \times 10^{-6}$

$= 6 \ \mu C$

b. Potential difference across capacitor *a*

$$V_a = \frac{q_a}{C_a} = \frac{24 \times 10^{-6}}{8 \times 10^{-6}} = 3V$$

Potential difference across capacitor *b*

$$V_b = \frac{q_b}{C_b} = \frac{18 \times 10^{-6}}{6 \times 10^{-6}} = 3V$$

Potential difference across capacitor *c*

$$V_c = \frac{q_c}{C_c} = \frac{6 \times 10^{-6}}{2 \times 10^{-6}} = 3V$$

Potential difference across capacitor *d*

$$V_d = \frac{q_d}{C_d} = \frac{24 \times 10^{-6}}{8 \times 10^{-6}} = 3V$$

c. Energy stored in *a* $U_a = \frac{1}{2} CV^2$

$$U_a = \frac{1}{2} \times 8 \times 10^{-6} \times 3 \times 3 = 36 \ \mu J$$

Energy stored in b

$$U_b = \frac{1}{2} \times 6 \times 3 \times 3 \times 10^{-6} = 27 \ \mu J$$

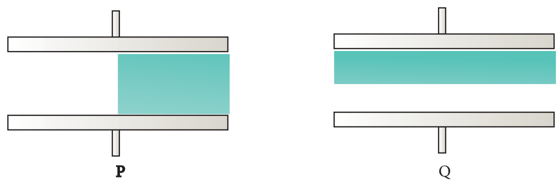
$[C_b = 6 \ \mu F]$

Energy stored in c

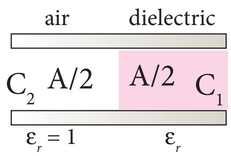
$$U_c = \frac{1}{2} \times 2 \times 3 \times 3 \times 10^{-6} = 9 \ \mu J$$

$[C_c = 2 \ \mu F]$

15. Capacitors P and Q have identical cross sectional areas A and separation d. The space between the capacitors is filled with a dielectric of dielectric constant ε_r as shown in the figure. Calculate the capacitance of capacitors P and Q.



***Ans.* (i)**



The given arrangement is equivalent to parallel combination of the capacitor each plate of

ares $= \frac{A}{2}$

Plate of separation = d

The medium of one dielectric constant = K_1, $\varepsilon_r = 1$ (air) $K_1 = 1$

The medium of other dielectric constant = K_2, i.e, $K_2 = \varepsilon_r$

The capacitance for $K_1 = C_1$

The capacitance for $K_2 = C_2$ $\quad [C = \frac{\varepsilon A}{d}]$

$$C_1 = \frac{\varepsilon_0 \frac{A}{2}.K_1}{d} = \frac{\varepsilon_0 K_1 A}{2d}$$

$$C_2 = \frac{\varepsilon_0 \frac{A}{2}.K_1}{d} = \frac{\varepsilon_0 K_1 A}{2d}$$

If C is the capacitance of the capacitor. then

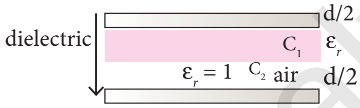
$$C = C_1 + C_2$$

$$= \frac{\varepsilon_0 K_1}{2d} + \frac{\varepsilon_0 K_2 A}{2d} = \frac{\varepsilon_0 (K_1 + K_2)A}{2d}$$

$$C = \frac{\varepsilon_0 (1+\varepsilon_r)A}{2d}$$

For capacitor Q.

(ii)



This is equivalent to a series combination of two capacitors

Plate of separation $\frac{d}{2}$

Dielectric constant for first medium = K_1 [dielectric $K_1 = \varepsilon_r$]

Dielectric constant for second medium = K_2 [air $K_1 = \varepsilon_r$]

$$\text{Capacitance of first} = C_1 = \frac{\varepsilon_0 K_1 A}{\frac{d}{2}} = \frac{2\varepsilon_0 K_1 A}{d}$$

$$\text{For second Capacitance} = C_2 = \frac{\varepsilon_0 K_2 A}{\frac{d}{2}} = \frac{2\varepsilon_0 K_2 A}{d}$$

If C is the capacitance of the capacitor

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$= \frac{d}{2\varepsilon_0 A}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] = \frac{d}{2\varepsilon_0 A}.\left[\frac{K_1 + K_2}{K_1 K_2}\right]$$

$$\frac{1}{C} = \frac{d}{2\varepsilon_0 A}\left[\frac{1+\varepsilon_r}{\varepsilon_r}\right]$$

$$C_R = \frac{2\varepsilon_0 A}{d}\left[\frac{\varepsilon_r}{1+\varepsilon_r}\right].$$

ADDITIONAL QUESTIONS AND ANSWERS

Choose the Correct Answer — 1 Mark

1. Based on Franklin's convention amber rods are ________
(a) positively charged
(b) negatively charged
(c) neutral
(d) none of the above
[Ans. (b) negatively charged]

2. The electrostatic force obeys ________
(a) Newton's I law
(b) Newton's II law
(c) Newton's III law
(d) none of the above
[Ans. (c) Newton's III law]

3. In electrostatics if the charges are in motion, another force named ________ comes into play in addition to coulomb force.
(a) Lorentz force
(b) Repulsive force
(c) Attractive force
(d) electromagnetic force
[Ans. (a) Lorentz force]

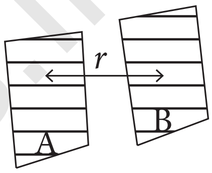
4. The value of constant 'K' in coulomb law is
(a) 0.9×10^9 Nm^2 C^2 (b) 9×10^{-9} Nm^{2}C^2
(c) 9×10^9 Nm^{-2} C^{-2} (d) 9×10^9 Nm^2 C^{-2}
[Ans. (d) 9×10^9 Nm^2 C^{-2}]

5. The electrostatic force is always greater in magnitude than gravitational force for _______ object
(a) bigger size (b) smaller size
(c) medium size (d) all the above
[Ans. (b) smaller size]

6. The relative permittivity of water is _____
(a) $\varepsilon_r = 70$ (b) $\varepsilon_r = 75$
(c) $\varepsilon_r = 80$ (d) $\varepsilon_r = 85$
[Ans. (c) $\varepsilon_r = 80$]

7. ______and Coulomb's law form fundamental principles of electrostatics
(a) Newton's law of gravitation
(b) Superposition principle
(c) Ohm's law (d) Kepler's law
[Ans. (b) Superposition principle]

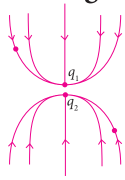
8. The figure shows two parallel equipotential surface A and B kept at a small distance 'r' apart from each other. A point change of Q coulomb is taken from the surface A to B. The amount of net work done will be



(a) $W = \dfrac{-1}{4\pi\varepsilon_0}\dfrac{q}{r}$ (b) $W = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$
(c) $W = \dfrac{-1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$ (d) zero
[Ans. (d) zero]

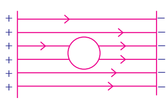
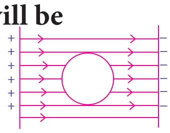
Hint:
$W = (V_A - V_B)\,q$
$\therefore V_A = V_B$ for equipotential surface
$W = O \times q = 0$

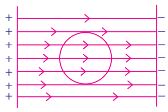
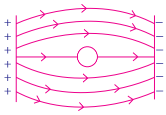
9. The given figure is a plot of lines of force due to two charges q_1 & q_2. Find out the sign of charges

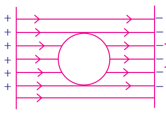


(a) both negative
(b) both positive
(c) upper positive and lower negative
(d) upper negative and lower positive
[Ans. (a) both negative]

10. An uncharged metal sphere is placed between two equal and oppositely charged metal plates. The nature of lines of force will be

(a)  (b) 

(c)  (d) 

[Ans. (b)  **]**

Electrostatics

11. An isolated metal sphere of radius 'r' is given a charge 'q'. The potential energy of the sphere is

(a) $\frac{q^2}{4\pi\varepsilon_0 r}$ (b) $\frac{q}{4\pi\varepsilon_0 r}$

(c) $\frac{q}{8\pi\varepsilon_0 r}$ (d) $\frac{q^2}{8\pi\varepsilon_0 r}$

[Ans. (d) $\frac{q^2}{8\pi\varepsilon_0 r}$]

Hint:

$$P.E = \frac{1}{2}CV^2 \qquad [\because C = 4\pi\varepsilon_0 r]$$

$$V = \frac{q}{4\pi\varepsilon_0 r}$$

$$P.E = \frac{1}{2} \times (4\pi\varepsilon_0 r) \times \left(\frac{q}{4\pi\varepsilon_0 r}\right)^2$$

$$P.E = \frac{q^2}{8\pi\varepsilon_0 r}$$

12. In a hydrogen atom the electron revolves around the proton in an orbit of 0.53 Å . The potential produced by the electron on the nuleus is

(a) 6.8 V (b) 13.6 V

(c) 54.4 V (d) 27.2 V

[Ans. (d) 27.2 V]

Hint:

$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{r}$$

$$= (9 \times 10^9) \times \frac{1.6\times10^{-19}}{0.53\times10^{-10}} = 27.2\text{ V}$$

13. Eight mercury droplets having a radius of 1 mm and charge of 0.066 pC each merge to form one droplet. Its potential is

(a) 2.4 V (b) 1.2 V

(c) 3.6 V (d) 4.8 V

[Ans. (a) 2.4 V]

Hint:

$$8 \times \text{volume of one droplet of Hg} = \frac{4}{3}\pi R^3$$

$$8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$2^3 \times r^3 = R^3$$

$$(2r)^3 = (R)^3$$

$$R = 2r \qquad [\because r = 1\text{ mm}]$$

$$R = 2 \times \frac{1}{q/R} \times 10^{-3}\text{ m (or) 2 mm} \qquad [\because q = ne]$$

$$\therefore V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{R}$$

$$V = \frac{9\times10^9\times0.066\times10^{-12}\times8}{2\times10^{-3}}$$

$$V = 2.4\text{ V}$$

14. A force of 40 N is acting between two charges in air if the space between them is filled with glass ε_r = 8. Then the force between them is

(a) 20 N (b) 10 N

(c) 5 N

(d) the same and does not change

[Ans. (c) 5 N]

Hint:

$$F_a = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r^2}$$

$$F_g = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\cdot\frac{q_1q_2}{r^2}$$

$$\frac{F_g}{F_a} = \frac{1}{\varepsilon_r} = \frac{1}{8}$$

$$F_g = \frac{F_a}{8} = \frac{40}{8} = 5\text{ N}$$

15. The concept of 'Field' was introduced by

(a) Faraday (b) Gauss

(c) Maxwell (d) None

[Ans. (c) Faraday]

16. The force experienced by a unit charge is called

(a) Electric potential (b) Electric flux

(c) Electric field (d) Static electricity

[Ans. (c) Electric field]

17. The expression for electric field in vector form is

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\hat{r}$ (b) $\frac{-1}{4\pi\varepsilon_0}\frac{q}{r}\hat{r}$

(c) $\frac{-1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

[Ans. (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$]

18. Which one of these is a vector quantity?

(a) Electric charge (b) Electric field
(c) Electric flux (d) Electric potential

[*Ans.* (b) Electric field]

19. The electric field created by a _____ is basically a non-uniform electric field.

(a) Test charge (b) Positive charge
(c) Negative charge (d) Point charge

[*Ans.* (d) Point charge]

20. The electric potential V as a function of distance *x* (metres) is given by V = ($5x^2 + 10x - 9$) volt. The value of electric field at a point x = 1m is

(a) 20 Vm^{-1} (b) 6 Vm^{-1}
(c) 11 Vm^{-1} (d) – 23 Vm^{-1}

[*Ans.* (a) 20 Vm^{-1}]

Hint: We know that, $E = \frac{dV}{dx}$

$V = 5x^2 + 10x - 9$

Differentiating w.r. to '*x*' on both sides

$\frac{dV}{dx} = 10x + 10 = E$

At a point, $x = 1$ m, $\frac{dV}{dx} = 10(1) + 10$

$\therefore E = \frac{dV}{dx} = 20\ Vm^{-1}$

21. Two condensers (capacitors) of capacity C_1 and C_2 are connected in parallel. A charge Q given to then is shared. The ratio of the charges Q is

(a) $\frac{C_2}{C_1}$ (b) $\frac{C_1}{C_2}$
(c) $C_1 . C_2$ (d) $\frac{1}{C_1 \times C_2}$

[*Ans.* (b) $\frac{C_1}{C_2}$]

Hint: As they are in parallel, the potential is same across the two,

$\therefore Q_1 = C_1V$ and $4Q_2 = C_2V$

$\therefore \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$

22. What will happen if two conducting spheres are separately charged and then brought in contact?

(a) Total charge on the two sphercs is conserved
(b) The total energy is conserved
(c) Both charge and energy are conserved
(d) The final potential is the mean of the original potentials.

[*Ans.* (a) Total charge on the two sphercs is conserved]

Hint: This is in accordance with the law of conservation of charge.

23. A condenser is charged to a potential of 200V and has a charge of 0.1C. The energy stored in it is

(a) 1 J (b) 2 J
(c) 10 J (d) 20 J

[*Ans.* (c) 10 J]

Hint: Energy stored, $U = \frac{1}{2}CV^2$

$U = \frac{1}{2}(CV)V \quad [\because q = CV]$

$U = \frac{1}{2}qV = \frac{1}{2} \times 0.1 \times 200$

$U = 10\ J$

24. Increasing the charge on the plates of a capacitor means

(a) increasing the capacitance
(b) increasing the potential difference between the plates
(c) both (a) and (b) above
(d) none of the above

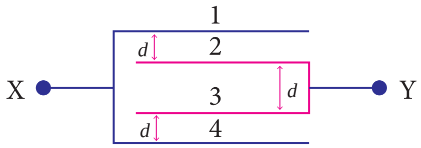
[*Ans.* (b) increasing the potential difference between the plates]

25. **A positively charged body 'A' has been brought near a brass cylinder 'B' mounted on a glass stand as shown in the figure. The potential of 'B' will be**

(a) Zero (b) Negative
(c) Positive (d) Infinite

[*Ans.* (c) Positive]

26. **Four plates each of area 'A' are separated by a distance 'd'. The connection is as shown in figure. What is equivalent capacitance between X and Y?**



(a) $\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$
(c) $\frac{3\varepsilon_0 A}{d}$ (d) $\frac{4\varepsilon_0 A}{d}$

[*Ans.* (b) $\frac{2\varepsilon_0 A}{d}$]

Hint: They constitute two parallel plate capacitors in parallel with each other.

27. **Charge per unit volume is called**

(a) Linear charge density (λ)
(b) Surface charge density (σ)
(c) Volume charge density (ρ)
(d) Electric flux

[*Ans.* (c) Volume charge density (ρ)]

28. **The expression for the electric field due to a surface of total charge 'Q' is given by**

(a) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma dA}{r^2}\hat{r}$

(b) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho dA}{r^2}\hat{r}$

(c) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\lambda dl}{r^2}\hat{r}$

(d) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r^2}\hat{r}$

[*Ans.* (a) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma dA}{r^2}\hat{r}$]

29. **The dipole is called point dipole when the distance**

(a) $2a$ approaches infinity and q approaches zero
(b) $2a$ approaches zero and q approaches infinity
(c) $2a$ approaches zero and q approaches zero
(d) $2a$ approaches infinity and q approaches infinity.

[*Ans.* (b) $2a$ approaches zero and q approaches infinity]

30. **The magnitude of torque on dipole is maximum if**

(a) θ = 0° (b) θ = 90°
(c) θ = 180° (d) θ = 180°

[*Ans.* (b) θ = 90°]

31. **The magnitude of electric dipole moment of water molecule is**

(a) 6×10^{-30} Cm (b) 6.2×10^{-30} Cm
(c) 6.1×10^{-30} (d) $5.9\ 5\ 10^{-30}$ Cm

[*Ans.* (c) 6.1×10^{-30}]

Unit 1

32. The expression for electric potential difference is

(a) $\int_R^P +\vec{E}.\vec{dr}$ (b) $-\int_\infty^P \vec{E}.\vec{dr}$

(c) $\int_\infty^P \vec{E}.\vec{dr}$ (d) $\int_R^P -\vec{E}.\vec{dr}$

[*Ans.* (d) $\int_R^P -\vec{E}.\vec{dr}$]

33. At Infinity (i.e $r = \infty$), the electrostatic potential (V) is

(a) ∞ (b) maximum

(c) minimum (d) zero

[*Ans.* (d) zero]

34. The potential due to a single point charge falls as

(a) $\frac{1}{r^2}$ (b) $\frac{1}{r^3}$

(c) $\frac{1}{r}$ (d) $-\frac{1}{r}$

[*Ans.* (c) $\frac{1}{r}$]

35. The unit for electric flux is

(a) $C^2 N^{-1} m^{-2}$ (b) $Nm^2 C^{-2}$

(c) $Nm^2 C^{-1}$ (d) $Nm^{-2}C^{-1}$

[*Ans.* (c) $Nm^2 C^{-1}$]

36. The electric flux is negative, if the angle between $\vec{dA}$ and $\vec{E}$ is

(a) Less than 90° (b) greater than 90°

(c) equal to 90° (d) equal to 0°

[*Ans.* (b) greater than 90°]

37. The time taken by a conductor to reach electrostatic equilibrium is in the order of

(a) 10^{-18} (b) 10^{-14} s

(c) 10^{-16} s (d) 10^{-20} s

[*Ans.* (c) 10^{-16} s]

38. A non-conducting material which has no free electrons is called

(a) capacitor (b) Dielectric

(c) conductor (d) Inductor

[*Ans.* (b) Dielectric]

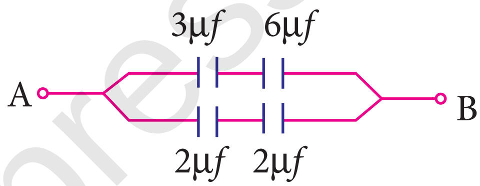
39. The unit for electric susceptibility is

(a) $Nm^2 C^{-2}$ (b) $C^2 N^{-1} m^{-2}$

(c) $C^{-2}Nm^2$ (d) $N^{-1} m^{-2}C^2$

[*Ans.* (b) $C^2 N^{-1} m^{-2}$]

40. In the given cricuit the effective capacitance between A and B will be



(a) 3μf (b) $\frac{36}{13}$ μf

(c) 13 μf (d) 7 μf

[*Ans.* (a) 3μf]

Hint:

$$C = \left(\frac{3\times6}{3+6}\right) + \left(\frac{2\times2}{2+2}\right)$$
$$= 2 + 1$$
$$C = 3\mu f$$

41. The direction of electric field at a point the equatorial line due to an electric dipole is

(a) along the equatorial line towards the dipole.

(b) along the equatorial line away from the dipole.

(c) parallel to the axis of the dipole and opposite to the direction of dipole moment.

(d) parallel to the axis of the dipole and in the direction of dipole moment.

[*Ans.* (c) parallel to the axis of the dipole and opposite to the direction of dipole moment.]

42. The lower comb of van de graaff generator is maintained at a positive potential of

(a) 10 kV (b) 10^7 V
(c) 100 V (d) 10^3 V

[Ans. (a) 10 kV]

43. The negative gradient of potential is

(a) torque (b) electric current
(c) electric field intensity (d) electric force

[Ans. (c) electric field intensity]

44. Two charges are kept at a distance in air what should be the relative permittivity of the medium in which the two charges should be kept at the same distance so that they experience half of the force which they experienced in air?

(a) $\frac{1}{2}$ (b) $\frac{1}{0.2}$
(c) 2 (d) 0.2 **[Ans. (c) 2]**

Hint:

$$\frac{F}{F_m} = \varepsilon_r \Rightarrow F_m = \frac{F}{2} \text{ (given)}$$

$$\frac{F}{\left(F/2\right)} = \varepsilon_r \Rightarrow \varepsilon_r = 2$$

45. An uniformly charged conducting shell of 2cm diameter has a surface charge density of 80μC / m². The charge on the shell is

(a) 100.48 nC (b) 100.48 μC
(c) 100.48 C (d) 100.48×10^{-12} C

[Ans. (a) 100.48 nC]

Hint:

$$\sigma = \frac{Q}{A} \Rightarrow Q = \sigma A$$
$$= (80 \times 10^{-6}) \times 4\pi R^2$$
$$Q = (80 \times 10^{-6}) \times 4 \times 3.14 \times (1\times10^{-2})$$
$$= 100.48 \times 10^{-9} \text{ C} = 100.48 \text{ nC}$$

46. In tuning radio we use,

(a) capacitors (b) transistors
(c) diodes (d) LEDs

[Ans. (a) capacitors]

47. Dielectric constant for the metals is

(a) Zero (b) >1
(c) <1 (d) Infinite

[Ans. (d) Infinite]

48. If C is the capacitance of an air filled capacitor and C' is the capacitance of dielectric filled capacitor, then

(a) $C' = \varepsilon_r C$ (b) $C' = \frac{C}{\varepsilon_r}$
(c) $C' = \frac{\varepsilon_r}{C}$ (d) $C' = \varepsilon_0 \varepsilon_r C$

[Ans. (a) $C' = \varepsilon_r C$]

49. The capacitance of a parallel plate capacitor increases from 5μf of 50μf when a dielectric is filled between the plates. The permitivity of the dielectric is

(a) 8.854×10^{-12} C² N⁻¹ m⁻²
(b) 8.854×10^{-11} C² N⁻¹ m⁻²
(c) 10×10^{-12} C² N⁻¹ m⁻²
(d) 12×10^{-12} C² N⁻¹ m⁻²

[Ans. (b) 8.854×10^{-11} C² N⁻¹ m⁻²]

Hint:

$$\varepsilon = \varepsilon_0 \varepsilon_r \quad \left[\varepsilon_r = \frac{C_2}{C_1}\right]$$
$$= 8.854 \times 10^{-12} \times \left(\frac{C_2}{C_1}\right)$$
$$= 8.854 \times 10^{-12} \times \frac{50 \times 10^{-6}}{5 \times 10^{-6}}$$
$$= 8.854 \times 10^{-11} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

50. An electric dipole placed at an angle in a non-uniform electric field experiences

(a) neither a force nor a torque
(b) torque
(c) both force and torque
(d) force only

[Ans. (c) both force and torque]

Unit 1

51. **Two copper spheres A and B of same size are charged to same potential. A is hollow and B is solid. Which of the two holds more charge?**
(a) Solid sphere cannot hold any charge
(b) hollow sphere cannot hold any charge
(c) both have zero charge
(d) both have the same charge
[*Ans.* (d) both have the same charge]

52. **A bird sitting on a high power line**
(a) gets killed instantly
(b) gets a mild shock
(c) is not affected practically
(d) gets a fatal shock
[*Ans.* (c) is not affected practically]

53. **Two conducting charged spheres *x* and *y* having unequal charges are connected by a wire. Which of the following is true?**
(a) charge is conserved
(b) electrostatic energy is conserved
(c) both the charge and electrostatic energy are conserved
(d) neither of these is conserved
[*Ans.* (a) charge is conserved]

54. **Which of the following statement on equipotential surface is wrong?**
(a) The potential difference between any two points on the surface, is zero.
(b) The electric field is always perpendicular to the surface.
(c) Equipotential surface is always spherical.
(d) No work is done in moving a charge along the surface.
[*Ans.* (c) Equipotential surface is always spherical.]

55. **Two identical metal balls with charges +2Q and –Q are separated by some distance and exerts a force F on each other. They are joined by a conducting wire, which is then removed. The force between them will now.**
(a) $F/12$ (b) $F/8$ (c) F (d) $F/4$
[*Ans.* (b) $F/8$]

56. **A spherical equipotential surface is not possible**
(a) for a point charge
(b) for a dipole
(c) inside a spherical capacitor
(d) inside a uniformly charged sphere
[*Ans.* (b) for a dipole]

57. **Charge Q is divided into two parts which are then kept some distance apart. The force between them will be maximum if the two parts are**
(a) each $\frac{Q}{2}$ (b) each $\frac{Q}{5}$
(c) $\frac{Q}{3}$ and $\frac{2Q}{3}$ (d) $\frac{Q}{4}$ and $\frac{3Q}{4}$
[*Ans.* (a) each $\frac{Q}{2}$]

58. **In a parallel plate capacitor of capacitance C, a metal sheet is inserted between the plates, parallel to them. The thickness of the sheet is half of the separation between the plates. The capacitance now becomes**
(a) 2C (b) $\frac{C}{4}$
(c) 4C (d) $\frac{C}{2}$ [*Ans.* (a) 2C]

59. **When 4V emf is applied across a 1F capacitor, it will store energy of**
(a) 2J (b) 4J
(c) 6J (d) 8J [*Ans.* (d) 8J]

60. **Value of *k* in Coulomb's law depends upon**
(a) magnitude of charges
(b) distance between charges
(c) both (a) and (b)
(d) medium between two charges
[*Ans.* (d) medium between two charges]

61. **Region around a charge *q* in which it exerts force on a test charge is called**
(a) electric flux intensity
(b) electric force
(c) electric field
(d) Coulomb's force [*Ans.* (c) electric field]

62. **Which of the following cannot be the units of electric field intensity?**

(a) NC^{-1} (b) Vm^{-1}
(c) JC^{-1} /m (d) JC^{-1}

[*Ans.* (d) JC^{-1}]

63. **The electric flux through a surface will be minimum when the angle between E and A is**

(a) 90° (b) 60° (c) 0° (d) 45°

[*Ans.* (a) 90°]

64. **One Joule per Coulomb is called**

(a) Gauss (b) ampere
(c) farad (d) volt

[*Ans.* (d) volt]

65. **When three capacitors are joined in series, the total capacitance is**

(a) Equal to the sum of the capacitance
(b) Greater than the value of the maximum capacitance
(c) Less than the value of the minimum capacitance
(d) none of the above **[*Ans.* (b) greater than the value of the maximum capacitance]**

66. **The concentric spheres of radii R and r have similar charges with equal surface densities (σ). What is the electric potential at their common centre?**

(a) $\frac{\sigma}{\varepsilon_o}(R - r)$ (b) $\frac{\sigma}{\varepsilon_o}(R + r)$
(c) $R\frac{\sigma}{\varepsilon_o}$ (d) $\frac{\sigma}{\varepsilon_o}$

[*Ans.* (b) $\frac{\sigma}{\varepsilon_o}(R + r)$]

67. **A charge Q μC is placed at the center of a cube. The flux coming out from any surface will be**

(a) $\frac{Q}{24\varepsilon_o}$ (b) $\frac{Q}{8\varepsilon_o}$
(c) $\frac{Q}{6\varepsilon_o} \times 10^{-6}$ (d) $\frac{Q}{6\varepsilon_o} \times 10^{-3}$

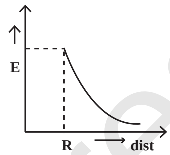
[*Ans.* (c) $\frac{Q}{6\varepsilon_o} \times 10^{-6}$]

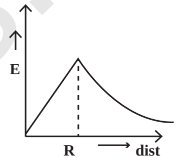
68. **A charge Q is placed at the corner of a cube. The electric flux through all the six faces of the cube is**

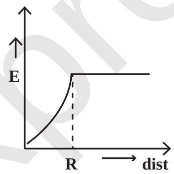
(a) $\frac{Q}{3\varepsilon_o}$ (b) $\frac{Q}{6\varepsilon_o}$ (c) $\frac{Q}{8\varepsilon_o}$ (d) $\frac{Q}{\varepsilon_o}$

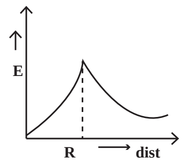
[*Ans.* (d) $\frac{Q}{\varepsilon_o}$]

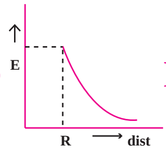
69. **Which graph shows the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere?**

(a) 

(b) 

(c) 

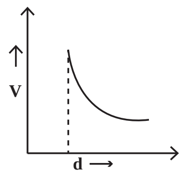
(d) 

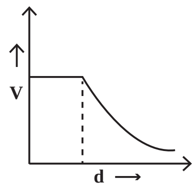
[*Ans.* (a) 

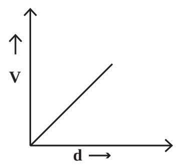
]

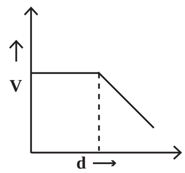
70. **Which graph shows that in a hollow spherical shell potential (V) changes with respect to distance (r) from centre?**

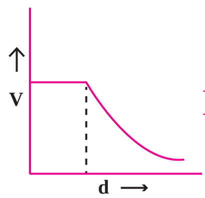
$$\left[V_{inside} = \frac{Q}{4\pi\varepsilon_o R} r \le R, \quad V_{outside} = \frac{Q}{4\pi\varepsilon_o r} r \ge R, \quad V \alpha \frac{1}{r}\right]$$

(a) 

(b) 

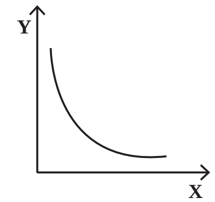
(c) 

(d) 

[*Ans.* (b) 

]

71. What physical quantities may X and Y represent? [Y represents the first mentioned quantity].



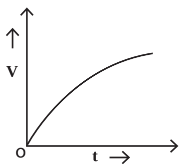
(a) K.E - velocity of a particle

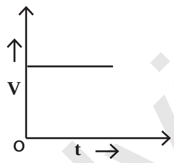
(b) pressure - temperature of a given gas (constant volume)

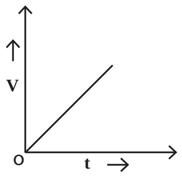
(c) capacitance - charge to give a constant potential

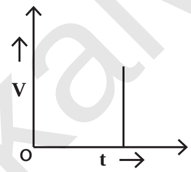
(d) potential - capacitance to give a constant charge **[*Ans.* (d) potential - capacitance to give a constant charge]**

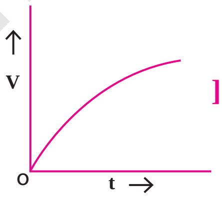
72. During charging a capacitor variation of potential V of the capacitor with time *t* is shown as

(a) 

(b) 

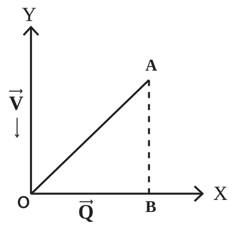
(c) 

(d) 

[*Ans.* (a) 

]

73. Charge Q on a capacitor varies with voltage V as shown in graph, where Q is along X-axis and V along Y-axis. The area of triangle OAB represents



(a) capacitance

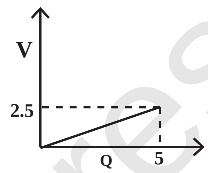
(b) capacitive reactance

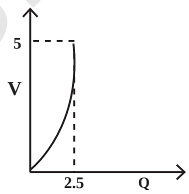
(c) magnetic field between the plates

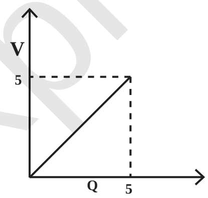
(d) energy stored in the capacitor

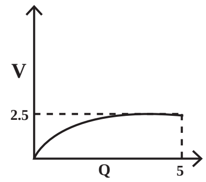
[*Ans.* (d) energy stored in the capacitor]

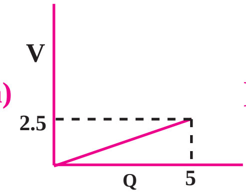
74. A condenser of 2μF capacitance is charged steadily from 0 to 5 coulomb. Which of the following graphs correctly represents the variation of potential difference across its plates with respect to the charge on the condensor [Q = C $\bar{V}$]

(a) 

(b) 

(c) 

(d) 

[*Ans.* (a) 

]

75. In two concentric hollow spheres of radii r and R (>r), the charge Q is distributed such that their surface densities are some. Then the potential at their common centre is

(a) $\frac{Q(R^2+r^2)}{4\pi\varepsilon_o(R+r)}$ (b) $\frac{QR}{R+r}$

(c) Zero (d) $\frac{Q(R+r)}{4\pi\varepsilon_o(R^2+r^2)}$

[*Ans.* (d) $\frac{Q(R+r)}{4\pi\varepsilon_o(R^2+r^2)}$]

Electrostatics

76. **A point charge q is placed at a distance $a/2$ directly above the centre of a square of side 'a'. The electric flux through the square is**

(a) $\frac{q}{\varepsilon_o}$ (b) $\frac{q}{\pi\varepsilon_o}$

(c) $\frac{q}{4\varepsilon_o}$ (d) $\frac{q}{6\varepsilon_o}$

[*Ans.* (d) $\frac{q}{6\varepsilon_o}$]

77. **A polythene piece rubbed with wool is found to have negative charge of 3.2×10^{-7}C. Estimate the number of electrons transferred from wool to polythene**

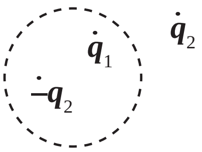
(a) 2×10^{12} (b) 3×10^{12}

(c) 4×10^{12} (d) 5×10^{12}

[*Ans.* (a) 2×10^{12}]

Unit 1

78. **A Gaussian surface in the figure is shown by dotted line. The electric field on the surface will be**



(a) due to q_1 and q_2 only

(b) due to q_2 only

(c) zero

(d) due to all [*Ans.* (d) due to all]

79. **A charge q is placed at the centre of a cubical box of side with top open. The flux of electric field through the surface of the cubical box is**

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

(c) $\frac{q}{6\varepsilon_o}$ (d) $\frac{5q}{6\varepsilon_o}$

[*Ans.* (d) $\frac{5q}{6\varepsilon_o}$]

80. **Electric field intensity at a point due to an infinite sheet of charge having surface charge density σ is E. If the sheet were conducting, electric intensity would be**

(a) $\frac{E}{2}$ (b) E (c) 2E (d) 4E

[*Ans.* (c) 2E]

81. **Surface density of charge on a sphere of radius R in terms of electric intensity E at a distance r in free space is**

(a) $\varepsilon_o E\left(\frac{R}{r}\right)^2$ (b) $\frac{\varepsilon_o ER}{r^2}$

(c) $\varepsilon_o E\left(\frac{r}{R}\right)^2$ (d) $e_o E\frac{r}{R^2}$

[*Ans.* (c) $\varepsilon_o E\left(\frac{r}{R}\right)^2$]

82. **The electric flux over a sphere of radius 1m is ϕ. If radius of the sphere were doubled without changing the charge enclosed, electric flux would become**

(a) 2ϕ (b) $\frac{\phi}{2}$ (c) $\frac{\phi}{4}$ (d) ϕ

[*Ans.* (d) ϕ]

83. **Electric field at a distance r from infinitely long conducting sheet is proportional to**

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

(c) $r^{3/2}$ (d) independent of r

[*Ans.* (d) independent of r]

84. **A charge q is enclosed as shown in fig. The electric flux is**

(a) maximum in (i) (b) maximum in (ii)

(c) maximum in (iii) (d) equal in all

[*Ans.* (d) equal in all]

85. **A charge q_1 exerts force on charge q_2. If another charge q_3 is brought near, the force of q_1, exerted on q_2, will be**

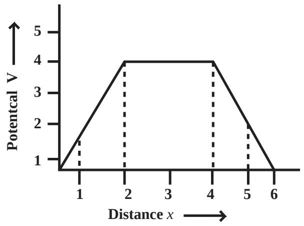
(a) decreased (b) increased

(c) remains unchanged

(d) increased if q_3 is of same sign as q_1 and decreased if q_2 is of opposite sign.

[*Ans.* (c) remains unchanged]

86. Find the electric field at $x = 5$m from the graph.



(a) 2 V/m (b) –2.5 V/m
(c) 2/5 V/m (d) –2/5 V/m

[Ans. (a) 2 v/m]

Match the Following

1.

1.	Benjamin Franklin	(a)	Electrical battery
2.	Michael Faraday	(b)	Frictional electricity
3.	Alessandro Volta	(c)	Concept of field
4.	Thales	(d)	Lightning Arrestor

	(1)	(2)	(3)	(4)
(a)	b	c	d	a
(b)	c	d	b	a
(c)	d	c	a	b
(d)	b	d	a	c

[Ans. (c) d c a b]

2.

1.	Amber	(a)	negatively charged
2.	Rubber	(b)	$\varepsilon_r = 1$
3.	glass rod	(c)	a kind of resin
4.	Air	(d)	Positively charged

	(1)	(2)	(3)	(4)
(a)	c	b	d	a
(b)	c	a	d	b
(c)	b	c	d	a
(d)	d	c	a	b

[Ans. (b) c a d b]

3.

1.	Dielectric	(a)	Faraday cage
2.	Capacitor	(b)	Insulator
3.	Electrostatic shielding	(c)	Van de graaff generator
4.	Electrostatic Induction	(d)	Condenser

	(1)	(2)	(3)	(4)
(a)	b	d	a	c
(b)	c	d	a	b
(c)	d	a	b	c
(d)	d	c	a	b

[Ans. (a) b d a c]

4.

1.	Permittivity of free space	(a)	Newton's III law
2.	Electrostatic force	(b)	Inverse law
3.	Coulomb law	(c)	Conservative force
4.	Coulomb force	(d)	8.854×10^{-12} $C^2N^{-1}m^{-2}$

	(1)	(2)	(3)	(4)
(a)	b	d	a	c
(b)	d	b	c	a
(c)	b	a	c	d
(d)	d	a	b	c

[Ans. (d) d a b c]

5.

1.	Electric flux	(a)	Maximum electric field
2.	Electric field	(b)	Scalar quantity
3.	Electric dipole moment	(c)	Vector quantity
4.	Dielectric strength	(d)	acts from $-q$ to $+q$

	(1)	(2)	(3)	(4)
(a)	a	d	b	c
(b)	b	c	d	a
(c)	c	d	b	a
(d)	b	a	d	c

[Ans. (b) b c d a]

Fill in the Blanks

1. Van de Graaff generator produces an electrostatic potential difference of _______ volts.

(a) 10^8 (b) 10^9
(c) 10^7 (d) 10^{10}

[Ans. (c) 10^7]

Electrostatics

2. For sharper edge, the _____ is greater. This principle is used in Lightning arrester.
(a) linear charge density
(b) surface charge density
(c) volume charge density
(d) capacitance
[*Ans.* (b) surface charge density]

3. For continuous charge distributions, ______ methods can be used.
(a) integration (b) differentiation
(c) multiplication (d) addition
[*Ans.* (a) integration]

4. For a large charge accumulation, the end of the conductor should have larger curvature that is ________.
(a) bigger radius (b) Smaller radius
(c) maximum radius (d) less bent
[*Ans.* (b) Smaller radius]

5. Relative permittivity (ε_r) is also known as _______.
(a) dielectric strength
(b) dielectric constant
(c) polarisability
(d) susceptibility
[*Ans.* (b) dielectric constant]

6. The energy stored per unit volume of space is defined as __________.
(a) linear density
(b) surface density
(c) volume density
(d) energy density [*Ans.* (d) energy density]

7. ________ is a very large unit of capacitance.
(a) Farad (b) Microfarad
(c) Picofarad (d) Nanofarad
[*Ans.* (a) Farad]

8. The total dipole moment per unit volume of the diclectric is _______.
(a) induction
b) charge distribution
(c) polarisation
(d) quantisation [*Ans.* (c) polarisation]

9. An example for a Non-polar molecule is
(a) H_2O (b) N_2O
(c) CO_2 (d) NH_3
[*Ans.* (c) CO_2]

10. Which instrument was used to demonstrate the electrostatic shielding?
(a) Lightning arrester
(b) Van de graaff generator
(c) Faraday cage
(d) Gold leaf electroscope
[*Ans.* (c) Faraday cage]

11. Gauss law is another form of _______.
(a) Newton's law (b) Kepler's law
(c) Ohm's law (d) Coulomb's law
[*Ans.* (d) Coulomb's law]

12. If a cube of side 5cm has a charge of 6 micro coulomb, then the surface charge density is _________.
(a) $4 \times 10^2\ \mu C / m^2$ (b) $4 \times 10^2\ C / m^2$
(c) $4 \times 10^3\ \mu C / m^2$ (d) $4 \times 10^3\ C / m^2$
[*Ans.* (a) $4 \times 10^2\ \mu C / m^2$]

Hint:
$$\sigma = \frac{Q}{6 \times A} = \frac{6\times10^{-6}}{6\times5\times10^{-2}\times5\times10^{-2}}$$
Where, [A = (side)²]
$$\sigma = \frac{10^{-6}\times10^{4}}{25} = 0.04 \times 10^{-2}\ C/m^2$$
$$= 4 \times 10^{-4}\ C/m^2 \text{ (or) } 400\ \mu C/m^2.$$

13. The electric flux is ____________ if the electric field lines enter the closed surface.
(a) positive (b) negative
(c) zero (d) maximum
[*Ans.* (b) negative]

Unit 1

14. Electrostatic force is stronger than gravitational force by ______.

(a) 2.23×10^{39} times
(b) 2.25×10^{39} times
(c) 2.27×10^{39} times
(d) 2.29×10^{39} times

[*Ans.* (c) 2.27×10^{39} times]

15. Which of the following is a scalar quantity?

(a) electric dipole moment
(b) electric field intensity
(c) electric potential
(d) current density

[*Ans.* (c) electric potential]

16. Capacitors use the principle of ________.

(a) self induction
(b) mutual induction
(c) electrostatic induction
(d) dielectric polarisation

[*Ans.* (c) electrostatic induction]

17. When a point charge of 6mC is moved between two points in an electric field, the work done is 1.8×10^{-5} J. The potential difference between the two points is

(a) 1.08 V (b) 1.08 μV
(c) 3 V (d) 30 V

[*Ans.* (c) 3 V]

Hint: $V = \frac{W}{q} = \frac{1.8\times10^{-5}}{6\times10^{-6}}$
$= 3$ V

18. Electrostatics deals with the _______.

(a) charges in motion
(b) static electric charges
(c) charges through conductors
(d) accelerated charges

[*Ans.* (b) static electric charges]

19. When the amber is rubbed with fur, it absorbs bits of papers. This was invented by _______.

(a) Amber (b) Thales
(c) Gilbert
(d) Benjamin Franklin

[*Ans.* (b) Thales]

20. The force between like charges is _______.

(a) attraction (b) repulsion
(c) no force (d) none

[*Ans.* (b) repulsion]

21. The charge of an electron is _______.

(a) 1.6×10^{-19} C (b) 1.6×10^{-91} C
(c) 16×10^{-20} C (d) 6.1×10^{-19} C

[*Ans.* (a) 1.6×10^{-19} C]

22. The force between two charges at a particular distance in air is 36 N. If the distance between the charges is filled by a medium of dielectric constant 6, then the force is _______.

(a) 216 N (b) 6 N
(c) 30 N (d) 24 N

[*Ans.* (b) 6 N]

23. Device used for storing charges is _______.

(a) resistor (b) capacitor
(c) inductor (d) insulator

[*Ans.* (b) capacitor]

24. A closed system contains four charges –8.1C, 14.6C, 20.2C and –200 mC. The total charge in the system _______.

(a) 26.5 C (b) –173.3 C
(c) 43.1 C (d) 243.9 C

[*Ans.* (a) 26.5 C]

25. The repulsive force between two like charges of 1 coulomb each separated by a distance of 1 m in vacuum is equal to :

(a) 9×10^{9} N (b) 10^{9} N
(c) 9×10^{-9} N (d) 9 N

[*Ans.* (a) 9×10^{9} N]

26. Two charged bodies of charges +q, –3q are brought in contact and separated. The charges possessed by each body after separation.

(a) $-q, -q$ (b) $+q, -2q$
(c) $-q, +3q$ (d) $+q, +q$

[*Ans.* (a) $-q, -q$]

Electrostatics

27. The unit of relative permittivity is

(a) $C^2N^{-1}m^{-2}$ (b) Nm^2C^{-2}
(c) No unit (d) $NC^{-2}\ m^{-2}$

[*Ans.* (c) No unit]

28. The value of relative permittivity of air is

(a) $8.854 \times 10^{-12}\ C^2 N^{-1} m^{-2}$
(b) $9 \times 10^9\ C^2 N^{-1} m^{-2}$
(c) 1
(d) 8.854×10^{12}

[*Ans.* (c) 1]

29. By using law of conservation of electric charge balance the following equations : ${}_{92}U^{238} \rightarrow {}_{90}Th^{234} +$ _______.

(a) ${}_2He^4$ (b) ${}_1H^3$ (c) ${}_1H^2$ (d) ${}_1H^1$

[*Ans.* (a) ${}_2He^4$]

30. The value of $\frac{1}{4\pi\varepsilon_o}$ is _______.

(a) $9 \times 10^{9}\ N\ m^2 C^{-2}$
(b) $8.85 \times 10^{-12}\ N\ m^2\ C^{-2}$
(c) $9 \times 10^{-9}\ N\ m^2\ C^{-2}$
(d) $8.85 \times 10^{9}\ N\ m^2\ C^{-2}$

[*Ans.* (a) $9 \times 10^{9}\ N\ m^2 C^{-2}$]

31. Torque on a dipole in a uniform electric field is maximum when the angle between $\vec{P}$ and $\vec{E}$ is _______.

(a) 0° (b) 90°
(c) 45° (d) 180°

[*Ans.* (b) 90°]

32. Electric field intensity and electric potential are related by _______.

(a) $E = -\frac{dV}{dt}$ (b) $E = -\frac{dV}{dx}$
(c) $E = \frac{dV}{dt}$ (d) $E = \frac{-dx}{dV}$

[*Ans.* (b) $E = -\frac{dV}{dx}$]

33. Torque experienced by a dipole in an electric field when it is placed parallel to the field is_______.

(a) $pE \sin\theta$ (b) $-pE \cos\theta$
(c) infinity (d) zero

[*Ans.* (d) zero]

34. Which one of the following relation is correct?

(a) $V = \frac{q}{C}$ (b) $C = q \tan q$
(c) $V = qC$ (d) $q = \frac{1}{2}C^2V$

[*Ans.* (a) $V = \frac{q}{C}$]

35. The unit of electric field intensity is _______.

(a) NC^{-1} (b) $NC^{-1}C^2m^{-1}$
(c) Cm (d) JC^{-1}

[*Ans.* (a) NC^{-1}]

36. The electric field intensity at a short distance r from uniformly charged infinite plane sheet of charge is

(a) proportional to r
(b) proportional to $\frac{1}{r}$
(c) proportional to $\frac{1}{r^2}$
(d) independent of *r*

[*Ans.* (d) independent of *r*]

37. The intensity of electric field at a point is

(a) the force experienced by a charge *q*
(b) the work done in bringing unit positive charge from infinity to that point
(c) the positive gradient of the potential
(d) the negative gradient of the potential

[*Ans.* (a) the force experienced by a charge *q*]

38. The intensity of the electric field that produces a force of 10^{-5} N on a charge of 5 µC is

(a) $5 \times 10^{-11}\ NC^{-1}$ (b) $50\ NC^{-1}$
(c) $2\ NC^{-1}$ (d) $0.5\ NC^{-1}$

[*Ans.* (c) $2\ NC^{-1}$]

39. Two point charges +*q* and −*q* are placed at points A and B respectively separated by a small distance. The electric field intensity at the midpoint O of AB :

(a) is zero
(b) acts along AB
(c) acts along BA
(d) acts perpendicular to AB

[*Ans.* (b) acts along AB]

40. **The number of electric lines of forces moving outwards from 1C charge is ________.**

(a) 1.13×10^{11} (b) 8.85×10^{-11}
(c) 9×10^{9} (d) infinite

[*Ans.* (c) 9×10^{9}]

41. **Electric lines of force ________.**

(a) intersect each other
(b) never intersect
(c) intersect at infinity
(d) are always parallel

[*Ans.* (b) never intersect]

42. **The force between two charges in vacuum is 0.1N. What is the force if the vacuum is replaced by medium whose permittivity is 10 times greater than that of vacuum?**

(a) 0.1 N (b) 0.01 N
(c) 0.001 N (d) 0.0001 N

[*Ans.* (b) 0.01 N]

43. **The unit of electric dipole moment is ________.**

(a) volt/metre $\left[\frac{V}{m}\right]$
(b) coulomb/metre $\left[\frac{C}{m}\right]$
(c) volt. metre [Vm]
(d) Coulomb.metre (Cm)

[*Ans.* (d) Coulomb.metre (Cm)]

44. **The torque (τ) experienced by an electric dipole placed in a uniform electric field (E) at an angle θ with the field is**

(a) pE cosθ (b) pE cosθ
(c) pE sinθ (d) 2pE sinθ

[*Ans.* (c) pE sinθ]

45. **An electric dipole of moment $\vec{p}$ is placed in a uniform electric field of intensity $\vec{E}$ at an angle θ with respect to the field. The direction of the torque is**

(a) along the direction of $\vec{p}$
(b) along direction of $\vec{E}$
(c) opposite to the direction of $\vec{p}$
(d) perpendicular to plane containing $\vec{p}$ and $\vec{E}$

[*Ans.* (b) along direction of $\vec{E}$]

46. **The tangent to line of force at any point gives the direction of the ________ at that point.**

(a) electric potential (b) electric field
(c) electric flux
(d) electric field energy **[*Ans.* (b) electric field]**

47. **When an electric dipole of dipole moment p is aligned parallel to the electric field E then the potential energy of the dipole is given as ________.**

(a) pE (b) zero (c) –pE (d) $\frac{pE}{\sqrt{2}}$

[*Ans.* (c) –pE]

48. **Near a charged object A another earthed object B is placed. Charges are induced on B. If B is removed after some time, than the charge on A will ________.**

(a) remain the same (b) decrease
(c) increase (d) become zero

[*Ans.* (a) remain the same]

49. **When an electric dipole is placed in a uniform external electric field parallel to the field, it will experience ________.**

(a) a torque but no force
(b) a force but no torque
(c) a torque as well as a force
(d) neither a force nor a torque

[*Ans.* (b) a force but no torque]

Find the Odd One Out

1.

(a) Electric dipole moment
(b) Electric field intensity
(c) Electric potential difference
(d) Electrostatic shielding

[*Ans.* (d) Electrostatic shielding]

Hint: (a), (b), (c) are quantities, (d) is a process.

2.

(a) Mica (b) Ebonite
(c) Aluminium (d) Oil

[*Ans.* (c) Aluminium]

Hint: (a), (b), (d) are dielectrics, (c) is a conductor.

Electrostatics

3.

(a) O_2 (b) HCl
(c) CO_2 (d) H_2

[Ans. (b) Hcl]

Hint: (a), (c), (d) are Non-polar molecules, but (b) is a polar molecule.

4.

(a) α - particle (b) electron
(c) proton (d) deutron

[Ans. (b) electron]

Hint: electron cannot be accelerated using van de graaff generator, but (a), (c) & (d) can be accelerated by it.

5.

(a) To eliminate sparkling in engines
(b) To reduce voltage fluctuations
(c) To protect tall buildings
(d) To generate electromagnetic oscillations

[Ans. (c) To protect tall buildings]

Hint: (a), (c) and (d) are the applications of capacitors but (c) is the usage of lightning arrester.

Choose the incorrect pair

1.

(a)	Franklin	-	+ve, –ve charges
(b)	Gauss	-	electrical battery
(c)	Van de graaff	-	high potential
(d)	Faraday	-	Unit of capacitance

[Ans. (b) Gauss - electrical battery]

2.

(a)	Corona discharge	-	Lightning arrester
(b)	Electrostatic induction	-	Van de graaff generator
(c)	ε_r of any medium	-	Less than one
(d)	Charge per unit area	-	Surface charge density

[Ans. (c) ε_r of any medium - Less than one]

Choose the correct pair

1.

(a)	NH_3	-	Non - polar molecule
(b)	O_2	-	Polar molecule
(c)	Mica	-	Conductor
(d)	Ceramic	-	Capacitor

[Ans. (d) Ceramic - Capacitor]

2.

(a)	Volt	-	electric current
(b)	C/m	-	electric dipole moment
(c)	NC^{-1}	-	electric field intensity
(d)	C^2Nm^2	-	electric flux

[Ans. (c) NC^{-1} - electric field intensity]

Assertion - Reason

Direction:

(a) Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Assertion and Reason are true but Reason is the false explanation of the Assertion.
(c) Assertion is true but Reason is false.
(d) Assertion is false but Reason is true.

1. Assertion : Two surfaces of spheres A and B of radii r_1 and r_2 when connected by a wire, form an equipotential surface. i.e $V_A = V_B$

Reason : Surface charge density (σ) is inversely proportional to the radius of the sphere i.e $\sigma \propto \frac{1}{r}$. [If radius is smaller, σ will be larger]

[Ans. (a) Assertion and Reason are correct and Reason is the correct explanation of Assertion]

2. Assertion : When dielectrics like mica or paper or oil are introduced between the plates of a capacitor then the capacitance will increase.

Reason : Capacitance is directly proportional to the potential difference.

[Ans. (c) Assertion is true but Reason is false]

Unit 1

Choose the correct or Incorrect statements

1. (I) For most dielectrics the polarisation is directly proportional to the strength of external electronic field $(\vec{E}_{ext})$.

(II) A dielectric is made up of only non-polar molecules.

Which is correct statement?

(a) I only (b) II only
(c) both are correct
(d) none of these **[*Ans.* (a) I only]**

2. (I) There is no net charge inside the conductors. The charges must reside only one the surface of the conductors.

(II) The electric field is not zero everywhere inside the conductor .

Which one is Incorrect statment?

(a) I only
(b) II only
(c) both are correct
(d) none of these **[*Ans.* (b) II only]**

Very Short Answer — 2 marks

1. Give a comparison of electrical and gravitional forces?

Ans. **(i)** Both forces obey inverse square law, $F \propto \frac{1}{r^2}$

(ii) Both forces are proportional to product of masses or charges.

(iii) Both forces are conservative forces.

(iv) Both forces can operate in vacuum.

2. What are Non-polar molecules.

Ans. A non-polar molecule is one in which centers of positive and negative charges coincide. As a result, it has no permanent dipole moment. Examples of non-polar molecules are hydrogen (H_2), oxygen (O_2), and carbon dioxide (CO_2) etc.

3. When does a dielectric said to be polarized?

Ans. When an external electric field is applied, the centers of positive and negative charges are separated by a small distance which induces dipole moment in the direction of the external electric field. Then the dielectric is said to be polarized by an external electric field.

4. What are Polar molecules?

Ans. **(i)** In polar molecules, the centers of the positive and negative charges are separated even in the absence of an external electric field.

(ii) They have a permanent dipole moment. Due to thermal motion, the direction of each dipole moment is oriented randomly. Hence the net dipole moment is zero in the absence of an external electric field. Examples of polar molecules are H_2O, N_2O, HCl, NH_3.

5. What are induced dipoles?

Ans. When an external electric field is applied, the dipoles inside the polar molecule tend to align in the direction of the electric field. Hence a net dipole moment is induced in it. Then the dielectric is said to be polarized by an external electric field.

6. What is dielectric breakdown?

Ans. When the external electric field applied to a dielectric is very large, it tears the atoms apart so that the bound charges become free charges. Then the dielectric starts to conduct electricity. This is called dielectric breakdown.

7. What is a Capacitor?

Ans. Capacitor is a device used to store electric charge and electrical energy. It consists of two conducting objects (usually plates or sheets) separated by some distance.

8. When we rotate the blades, it starts to rotate as usual. Why it is so?

Ans. To rotate any object, there must be a torque applied on the object. For the ceiling fan, the initial torque is given by the capacitor widely known as a condenser. If the condenser is faulty, it will not give sufficient initial torque to rotate the blades when the fan is switched on.

9. (i) **Two insulated charged copper spheres A & B of identical size have charges q_A and $-3q_A$ respectively. When they are brought in contact with each other and then separated, what are the new charges on them?**

(ii) **When third sphere of same size but uncharged is brought in contact with first and then with second and finally removed from both, what are the new charges?**

Ans. (i) Charge on each sphere = $\dfrac{q_A - 3q_A}{2} = -q_A$

(ii) New charge on A is $\dfrac{q_A}{2}$

New charge on B is $\dfrac{q_A + (2q_B)}{4}$

$$\because \frac{\frac{q_A}{2} + q_B}{2} = \frac{q_A}{4} + \frac{q_B}{2} = \frac{q_A + 2q_B}{4}$$

$$q_B = -3q_A$$

$$\because \quad q_B = -3q_A$$

$\therefore$ New charge on B_1 is $\dfrac{q_A - 6q_A}{4}$

New charge on B = $-\dfrac{5}{4}\, q_A$

10. **What is the electric flux through a cube of side 1 cm which encloses on electric dipole?**

Ans. Net electric flux is zero because

(i) It is independent to the shape and size

(ii) Net charge of the electric dipole is zero.

11. **A charge Q μc is placed at the centre of a cube what would be the (i) flux through one face? (ii) flux passing through two opposite faces of the cube?**

Electric flux through whole cube = $\dfrac{Q}{\varepsilon_0}$

Ans. (i) Electric flux through one face = $\dfrac{1}{6}.\dfrac{Q}{\varepsilon_0}$ μV_m

(ii) By symmetry the flux through each of the six faces of cube will be same when charge is placed at the centre.

$$\therefore \varphi_E = \frac{1}{6}.\frac{Q}{\varepsilon_0}$$

Thus electric flux passing through two opposite faces of the cube

$$= 2.\frac{1}{6}.\frac{Q}{\varepsilon_0}$$

$$\varphi = \frac{1}{3}.\frac{Q}{\varepsilon_0}$$

12. **What orientation of an electric dipole in a uniform electric field corresponds to its**

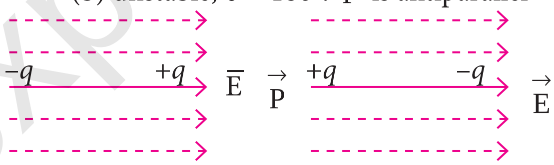
(i) **stable and (ii) unstable equilibrium? Depict the orientations.**

Ans. (i) In stable equilibrium the dipole moment is parallel to he direction of electric field. i.e. $\theta = 0$.

(ii) In unstable equilibrium, P.E. is max., so $\theta = \pi$. i.e. dipole moment is antiparallel to electric field.

(iii) $\theta = 0°$ $\vec{P}$ is parallel to $\vec{E}$ stable equilibrium

(b) unstable, $\theta = 180°$. $\vec{P}$ is antiparallel



13. (i) **Electric field lines do not have sudden breaks why is it so?**

(ii) **Explain why two field lines never cross each other at any point.**

Ans. (i) In electric field line is the path of movement of a positive test charge ($q_0 \to 0$) A moving charge experiences a continuous force is an electric field, so field line is always continuous

(ii) The field lines never intersect since if they cross, there will be two directions of electric field at the point of intersection, which is impossible.

14. **An electric dipole is held in a uniform electric field.**

(i) **Show that the net force acting on it is zero.**

(ii) **The dipole is aligned parallel to the field. Find the work done in rotating it through the angle of 180°**

Ans. (i) The dipole moment of dipole $|\vec{P}| = q \times 2a$

Force on $-q$ at A = $-q\,\vec{E}$

Force on + q at B = $+q\vec{E}$

Net force on the dipole = $q\vec{E} - q\vec{E} = 0$

(ii) Work done on dipole when it is rotated through 180°

$W = \Delta U = pE(\cos\theta_1 - \cos\theta_2)$

$= pE(\cos 0° - \cos 180°)$

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

$W = 2pE$

15. A sphere of charge +Q is fixed. A smaller sphere of charge +q is placed near the larger sphere and released from rest. The small sphere will move away from large sphere with

a. decreasing velocity & decreasing acceleration.

b. decreasing velocity & increasing acceleration.

c. decreasing velocity & constant acceleration

d. increasing velocity & decreasing acceleration

e. increasing velocity & increasing acceleration

Which of the above statement is correct? Explain.

Ans. (i) At a distance r, the force on the small sphere due to large sphere

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{mr^2}$$

(ii) If m is the mass of small sphere then its acceleration

$$a = \frac{F}{m} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{mr^2}$$

(iii) As the small sphere is pushed away (i.e. r increased) 'a' decreases.

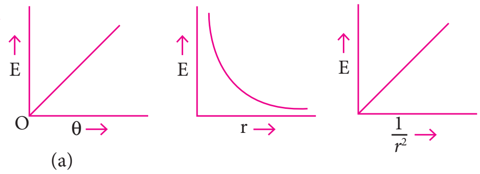
(iv) As 'a' is always +ve the speed of the small sphere goes on increasing.

(v) ∴ increasing velocity and decreasing acceleration.

(d) is correct.

16. Graphically represent the variation of electric field due to point charge Q with (a) magnitude of charge Q (b) r and (c) $\frac{1}{r^2}$ where r is the distance of the observation point from the charge.

Ans.



17. A positive charge +q is located at a point, what is the work done, if a unit positive charge is carried once around this charge along a circle of radius r about this point?

Ans. The potential at each point on the circular path around the charge is same i.e. potential difference between the initial and final position is zero.

∴ Work done $W = V \times q = 0 \times 1 = 0$.

18. What do you mean by Potential Energy of an electric dipole, when placed in electric field?

Ans. An electric dipole always tends to current it self along the direction of electric field, work has to be done in rotating the dipole to some other orientation θ. This work done in rotating dipole gets stored in the dipole in the form of potential energy.

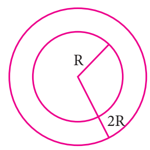
19. Two concentric metallic spherical shells of radii R and 2 R are given charges Q_1 & Q_2 respectively. The surface charge density on the outer surfaces of the shells are equal. Determine the ratio $Q_1 = Q_2$.

Ans. Surface charge density σ is same

∴ charge $Q_1 = 4\pi R^2\sigma$

charge $Q_2 = 4\pi(2R^2)\sigma$

$$\frac{Q_1}{Q_2} = \frac{4\pi R^2\sigma}{4\pi(4R^2)\sigma} = \frac{1}{4}$$



20. Two isolated metal spheres A & B have radii R & 2R respectively and same charge q. Find which of the two spheres have greater energy density just outside the surface of the sphere.

Ans. Energy density $U = \frac{1}{2}\varepsilon_0 E_2$

But $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

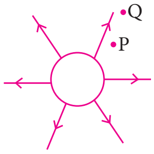
$$\therefore U = \frac{1}{2}\cdot\frac{\varepsilon_0 Q_2}{A^2\varepsilon_0} \Rightarrow U = \frac{Q_2}{2A^2}$$

$$U \propto \frac{1}{A^2} \Rightarrow U_A > U_B$$

Electrostatics

21. What is the work done by the field in moving a small positive charge from Q to P? Give reason.

Ans. The work done by the field is negative. This is since the charge is moved against the force exerted by the field.



22. A point charge Q is placed at point O. Potential difference $V_A - V_B$ is positive. Is the charge Q negative or positive?

Ans. The electric potential $V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$

$$V = \frac{1}{r}$$

The potential due to a point charge decreases with increase of distance.

$V_A - V_B > 0 \Rightarrow V_A > V_B$.

Hence the charge Q is positive.

23. The electric field due to a point charge depends on the distance *r* as parallelly indicate how each of the following quantities depends on *r*?

a. Intensity of light from a point source.

b. Electrical potential due to a point charge.

c. Electrical potential at a distance *r* from to centre of a charged metallic sphere

Given *r* < radius of the sphere.

Ans. (a) $I \propto \frac{1}{r^2}$

(b) $V \propto \frac{1}{r}$

(c) V does not depend on *r*.

24. What are the factors on which the capacity of a parallel plate capacitor with dielectric depend?

Ans. (i) Area of the plates

(ii) Separation between the plates.

(iii) Dielectric constant of the dielectric between the plates. The capacitance of a capacitor depend upon geometrical dimension and the nature of the dielectric between the plates.

25. A parallel plate capacitor is charged by a battery. After some time, the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. How will (i) the capacitance of the capacitor (ii) potential difference between the plates & (iii) the energy stored in the capacitor be affected?

Ans. Q_0 - charge, V_0 - potential difference, C_0 - capacitance,

U_0 - energy stored, before the dielectric slab is inserted.

(i) The Capacitance of the capacitor without the dielectric is $C_0 = \frac{Q_0}{V_0}$

When the battery is disconnected and the dielectric is inserted, the capacitance increases from C_0 to C.

$\therefore C = \varepsilon_r C_0$, where ε_r is the dielectric constant.

(ii) The electrostatic potential difference is reduced and the charge Q_0 will remain constant, after the battery is disconnected.

$\therefore$ The new potential difference is, $V = \frac{V_0}{\varepsilon_r}$.

(iii) The energy stored in the capacitor before the insertion of the dielectric is,

$$U_0 = \frac{1}{2}\frac{Q_0^2}{C_0}$$

After the dielectric is inserted, the charge Q_0 remains constant but the capacitance is increased. As a result, the stored energy is decreased.

$$U = \frac{1}{2}\frac{Q_0^2}{C} = \frac{1}{2}\frac{Q_0^2}{\varepsilon_r C_0} = \frac{U_0}{\varepsilon_r}$$

SHORT ANSWER — 3 MARKS

1. Deduce an expression for the electric field due to the system of point charges.

Ans. (i) Suppose a number of point charges are distributed in space. To find the electric field at some point P due to this collection of point charges, superposition principle is used.

(ii) The electric field due to a collection of point charges at an arbitrary point is simply equal to the vector sum of the electric fields created by the individual point charges. This is called superposition of electric fields.

(iii) Consider a collection of point charges $q_1, q_2, q_3, \ldots\ldots q_n$ located at various points in space. The total electric field at some point P due to all these n charges is given by

$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots\ldots\ldots + \vec{E}_n \quad \ldots(1)$$

Unit 1

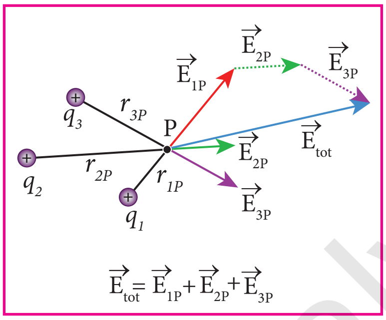
$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\left\{\frac{q_1}{r_{1P}^2}\hat{r}_{1P} + \frac{q_2}{r_{2P}^2}\hat{r}_{2P} + \frac{q_3}{r_{3P}^2}\hat{r}_{3P} + \ldots + \frac{q_n}{r_{nP}^2}\hat{r}_{nP}\right\} \quad (2)$$

(iii) Here r_{1P}, r_{2P}, r_{3P}.........r_{nP} are the distances between the point P and the charges q_1, q_2, q_3 .... q_n respectively. Also $\hat{r}_{1P}, \hat{r}_{2P}, \hat{r}_{3P}$ ....$\hat{r}_{nP}$ are the unit vectors directed from q_1, q_2, q_3 .... q_n respectively to P. Equation (2) can be re-written as,

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\left(\frac{q_i}{r_{iP}^2}\hat{r}_{iP}\right) \quad ...(3)$$

(iv) For example in Figure, the resultant electric field due to three point charges q_1, q_2, q_3, at point P is shown.

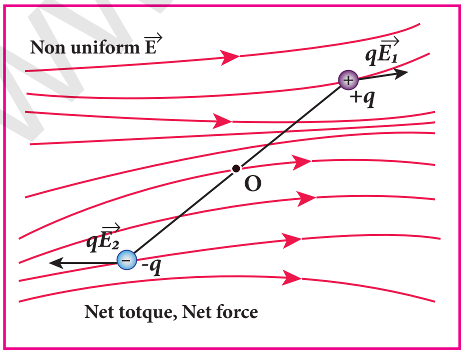
Note that the relative lengths of the electric field vectors for the charges depend on relative distances of the charges to the point P.



Superposition of Electric field

2. What happens when an electric dipole is held in a non-uniform electric field?

Ans. If the electric field is not uniform, then the force experienced by $+q$ is different from that experienced by $-q$. In addition to the torque, there will be net force acting on the dipole.



The dipole in a non-uniform electric field

3. What is principle used in Microwave oven? Explain.

Ans. (i) Microwave oven works on the principle of torque acting on an electric dipole. The food we consume has water molecules which are permanent electric dipoles.

(ii) Oven produces microwaves that are oscillating electromagnetic fields and produce torque on the water molecules.

(iii) Due to this torque on each water molecule, the molecules rotate very fast and produce thermal energy. Thus, heat generated is used to cook the food.

4. Define potential difference and derive.

Ans. (i) The potential energy difference per unit charge is given by

$$\frac{\Delta U}{q'} = \frac{q'\int_R^P (-\vec{E}).d\vec{r}}{q'} = -\int_R^P \vec{E}.d\vec{r} \quad ...(1)$$

(ii) The above equation (1) is independent of q′. The quantity $\frac{\Delta U}{q'} = -\int_R^P \vec{E}.d\vec{r}$ is called electric potential difference between P and R and is denoted as $V_P - V_R = \Delta V$.

(iii) In otherwords the electric potential difference is also defined as the work done by an external force to bring unit positive charge from point R to point P.

$$V_P - V_R = \Delta V = \int_R^P -\vec{E}.d\vec{r}$$

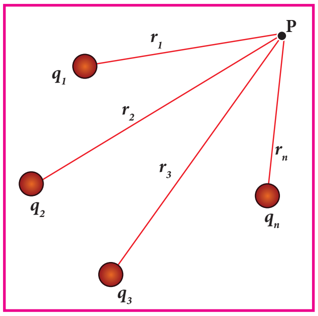
(iv) The electric potential energy difference can be written as $\Delta U = q'\Delta V$.

5. Derive the expressions for the potential energy of a system of point charges.

Ans. (i) The electric potential at a point P due to a collection of charges q_1, q_2, q_3.....q_n is equal to sum of the electric potentials due to individual charges.

$$V_{tot} = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3} + \ldots + \frac{kq_n}{r_n}$$
$$= \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$$

(ii) where $r_1, r_2, r_3 \ldots\ldots r_n$ are the distances of $q_1, q_2, q_3 \ldots\ldots q_n$ respectively from P (Figure).



Electrostatic potential due to collection of charges

6. How is electric flux is related to electric field?

***Ans.* (i)** Consider a uniform electric field in a region of space. Let us choose an area A normal to the electric field lines as shown in Figure (a). The electric flux for this case is

$$\Phi_E = EA \quad \ldots(1)$$

(ii) Suppose the same area A is kept parallel to the uniform electric field, then no electric field lines pierce through the area A , as shown in Figure (b). The electric flux for this case is zero.

$$\Phi_E = 0 \quad \ldots(2)$$

(iii) If the area is inclined at an angle θ with the field, then the component of the electric field perpendicular to the area alone contributes to the electric flux. The electric field component parallel to the surface area will not contribute to the electric flux. This is shown in Figure (c). For this case, the electric flux

$$\Phi_E = (E\cos\theta)A \quad \ldots(3)$$

(iv) Further, θ is also the angle between the electric field and the direction normal to the area. Hence in general, for uniform electric field, the electric flux is defined as

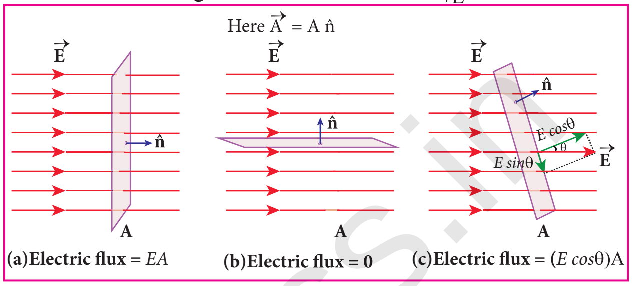
$$\Phi_E = \vec{E}.\vec{A} = EA\cos\theta$$

Here, note that $\vec{A}$ is the area vector $\vec{A} = A\hat{n}$

(v) Its magnitude is simply the area A and the direction is along the unit vector $\hat{n}$ perpendicular to the area as shown in Figure. Using this definition for flux $\phi_E = \vec{E}.\vec{A}$, equations (1) and (2) can be obtained as special cases.

In Figure (a), θ = 0º so $\phi_E = \vec{E}.\vec{A} = EA$

In Figure (b), θ = 90º so $\phi_E = \vec{E}.\vec{A} = 0$



The electric flux for Uniform electric field

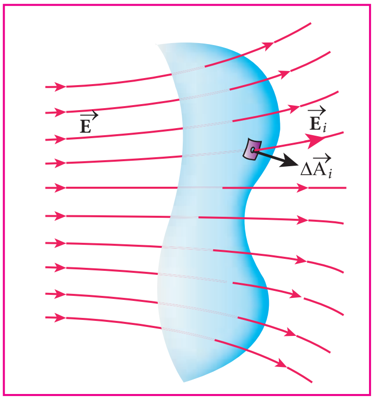
7. Derive an expression for electric flux in a non uniform electric field and an arbitrarily shaped area.

***Ans.* (i)** Suppose the electric field is not uniform and the area A is not flat (Figure), then the entire area is divided into n small area segments $\Delta\vec{A}_1, \Delta\vec{A}_2, \Delta\vec{A}_3 \ldots\ldots \Delta\vec{A}_n$, such that each area element is almost flat and the electric field through each area element is considered to be uniform.

(ii) The electric flux for the entire area A is approximately written as

$$\phi_E = \vec{E}_1\cdot\Delta\vec{A}_1 + \vec{E}_2\cdot\Delta\vec{A}_2 + \vec{E}_3\cdot\Delta\vec{A}_3 \ldots\ldots \vec{E}_n\cdot\Delta\vec{A}_n$$

$$= \sum_{i=1}^{n} \vec{E}_1\cdot\Delta\vec{A}_1 \quad \ldots(1)$$



Electric flux for non-uniform electric Field

(iii) By taking the limit $\Delta\vec{A}_i \to 0$ (for all i) the summation in equation (1) becomes integration. The total electric flux for the entire area is given by

$$\phi_E = \int \vec{E}.d\vec{A} \quad ...(2)$$

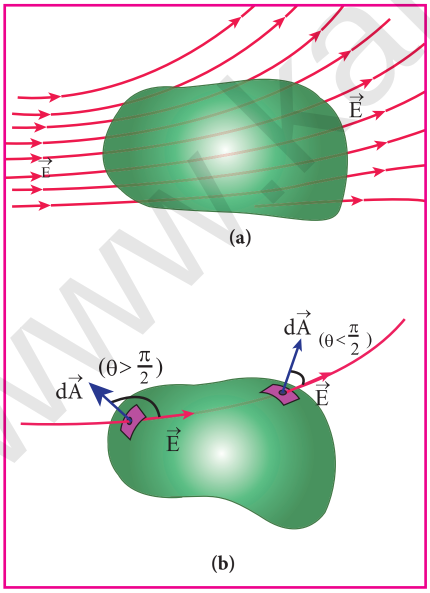
(iv) From Equation (2), it is clear that the electric flux for a given surface depends on both the electric field pattern on the surface area and orientation of the surface with respect to the electric field.

8. Deduce electric flux for closed surfaces.

Ans. **(i)** A closed surface is present in the region of the non-uniform electric field as shown in Figure (a). The total electric flux over this closed surface is written as

$$\phi_E = \oint \vec{E}\cdot d\vec{A} \quad ...(1)$$

(ii) **Note** the difference between equations $\phi_E = \int \vec{E}.d\vec{A}$ and (1). The integration in equation (1) is a closed surface integration and for each areal element, the outward normal is the direction of $d\vec{A}$ as shown in the Figure (b).



Electric flux over a closed surface

(iii) The total electric flux over a closed surface can be negative, positive or zero. In the Figure (b), it is shown that in one area element, the angle between $d\vec{A}$ and $\vec{E}$ is less than 90°, then the electric flux is positive and in another areal element, the angle between $d\vec{A}$ and $\vec{E}$ is greater than 90°, then the electric flux is negative.

(iv) In general, the electric flux is negative if the electric field lines enter the closed surface and positive if the electric field lines leave the closed surface.

9. Write the special features of Gauss law.

Ans. **(i)** The total electric flux through the closed surface depends only on the charges enclosed by the surface and the charges present outside the surface will not contribute to the flux and the shape of the closed surface which can be chosen arbitrarily.

(ii) The total electric flux is independent of the location of the charges inside the closed surface.

(iii) To arrive at equation $\phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$ a spherical surface is chosen. This imaginary surface is called a Gaussian surface. The shape of the Gaussian surface to be chosen depends on the type of charge configuration and the kind of symmetry existing in that charge configuration. The electric field is spherically symmetric for a point charge, therefore spherical Gaussian surface is chosen. cylindrical and planar Gaussian surfaces can be chosen for other kinds of charge configurations.

(iv) In the L.H.S of equation $\phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$ the electric field $\vec{E}$ is due to charges present inside and outside the Gaussian surface but the charge Q_{encl} denotes the charges which lie only inside the Gaussian surface.

Electrostatics

(v) The Gaussian surface cannot pass through any discrete charge but it can pass through continuous charge distributions. It is because, very close to the discrete charges, the electric field is not well defined.

(vi) Gauss law is another form of Coulomb's law and it is also applicable to the charges in motion. Because of this reason, Gauss law is treated as much more general law than Coulomb's law.

10. What is dielectrics or insulators?

Ans. **(i)** A dielectric is a non-conducting material and has no free electrons. The electrons in a dielectric are bound within the atoms. Ebonite, glass and mica are some examples of dielectrics.

(ii) When an external electric field is applied, the electrons are not free to move anywhere but they are realigned in a specific way. A dielectric is made up of either polar molecules or non-polar molecules.

11. Explain the Lightning arrester or lightning conductor.

Ans. **(i)** This device consists of a long thick copper rod passing from top of the building to the ground. The upper end of the rod has a sharp spike or a sharp needle as shown in Figure (a) and (b).

(ii) The lower end of the rod is connected to the copper plate which is buried deep into the ground. When a negatively charged cloud is passing above the building, it induces a positive charge on the spike.

(iii) Since the induced charge density on thin sharp spike is large, it results in a corona discharge.

(iv) This positive charge ionizes the surrounding air which in turn neutralizes the negative charge in the cloud.

(a) Schematic diagram of a lightning arrestor.
(b) A house with a lightning arrestor

(v) The negative charge pushed to the spikes passes through the copper rod and is safely diverted to the earth.

(vi) The lightning arrester does not stop the lightning; rather it diverts the lightning to the ground safely.

12. Define and derive an expression for the energy density in parallel plate capacitor.

Ans. Energy stored in the capacitor

$$U_E = \frac{1}{2}CV^2 \qquad ...(1)$$

This is rewritten as using $C = \frac{\varepsilon_0 A}{d}$ & $Ed = V$

$$U_E = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2 = \frac{1}{2}\varepsilon_0 (Ad)E^2 \qquad ...(2)$$

where Ad = volume of the space between the capacitor plates. The energy stored per unit volume of space is defined as energy density $u_E = \frac{U}{\text{Volume}}$ From equation (4), We get

$$u_E = \frac{1}{2}\varepsilon_0 E^2 \qquad ...(3)$$

(iv) The energy density depends only on the electric field and not on the size of the plates of the capacitor.

Long Answer — 5 Marks

1. Explain in detail the Electrostatic Potential difference between the charges.

Ans. **(i)** Consider a positive charge q kept fixed at the origin which produces an electric field $\vec{E}$ around it.

(ii) A positive test charge q' is brought from point R to point P against the repulsive force between q and q' as shown in Figure. Work must be done to overcome this repulsion. This work done is stored as potential energy.

(iii) The test charge q' is brought from R to P with constant velocity which means that external force used to bring the test charge q' from R to P must be equal and opposite to the coulomb force $\left(\vec{F}_{ext} = -\vec{F}_{coloumb}\right)$

The work done is

$$W = \int_R^P \vec{F}_{ext} \cdot d\vec{r} \qquad ...(1)$$

(iii) Since coulomb force is conservative, work done is independent of the path and it depends only on the initial and final positions of the test charge. If potential energy associated with q' at P is U_P and that at R is U_R, then difference in potential energy is defined as the work done to bring a test charge q' from point P to R and is given as $U_P - U_R = W$.

$$\Delta U = \int_R^P \vec{F}_{ext} \cdot d\vec{r}$$

$$\text{Since } \vec{F}_{ext} = -\vec{F}_{coloumb} = -q'\vec{E}$$

$$\Delta U = \int_R^P \left(-q'\vec{E}\right) \cdot d\vec{r} = q'\int_R^P \left(-\vec{E}\right) \cdot d\vec{r}$$

Numerical Problems

1. It requires 50 µJ of work to carry a 2 C charge from point R to S. What is the potential difference between these points?

Ans. $V_S - V_R = \dfrac{W}{q}$

Work W = 50 µJ = 50×10^{-6} J

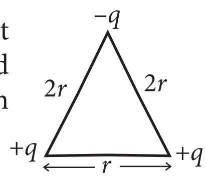
charge q = 2 µC = 2×10^{-6} C

$$V = V_S - V_R = \frac{W}{q} = \frac{50\times10^{-6}}{2\times10^{-6}} = 25 \text{ V}$$

V = 25 V.

2. Devise an arrangement of three point charges separated by finite distances that has zero electric potential energy.

Ans. An arrangement of three point $-q$, $+q$ and $+q$ charges separated by finite distances, is as shown below.



Electric potential energy

$$u = \frac{kq(q)}{r} + \frac{kq(-q)}{2r} + \frac{k(-q)(+q)}{2r}$$

$$= \left(\frac{kq^2}{r}\right) - \left(\frac{kq^2}{2r}\right) - \left(\frac{kq^2}{2r}\right) = 0$$

3. An electron is released from the bottom plate ($E = 10^4$ NC^{-1}) Find the velocity of the electron when it reaches plate B. ($e/m = 1.76 \times 10^{11}$ Ckg^{-1}).

Ans. **Given:** Electric field strength E = 10^4 NC^{-1} between the plates

Distance of separation between the plates = 2 cm

s = 2×10^{-2} m.

To find:

Velocity of the electron when it reaches B = v = ?

Formula:

According to equation of motion $v^2 = u^2 + 2as$

u - initial velocity = 0; $a = \dfrac{F}{m} = \dfrac{Ee}{m} = E\left(\dfrac{e}{m}\right)$

Solution:

$$v^2 = 0 + (2 \times E\frac{e}{m} \times s)$$

$$v = \sqrt{2\times10^4 \times 1.76\times10^{11} \times 2\times10^{-2}}$$

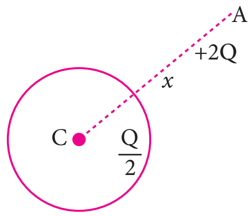
$$v = \sqrt{7.04\times10^{13}} = \sqrt{0.704\times10^{14}}$$

$$v = 0.84 \times 10^7 \text{ m s}^{-1}$$

Electrostatics

4. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at the centre C and another charge +2 Q is placed outside the shell at A at a distance x from the centre as shown in the figure.

(i) Find the electric flux through the shell.



(ii) Find the force on the charges at C and A.

Ans. (i) Electric flux $\phi = \frac{\text{Total enclosed charge}}{\varepsilon_0}$

Net charge enclosed inside the shell $q = 0$

$\therefore$ electric flux through the shell $\frac{q}{\varepsilon_0} = 0$

(ii) The electric field or net charge inside the spherical conducting shell is zero.

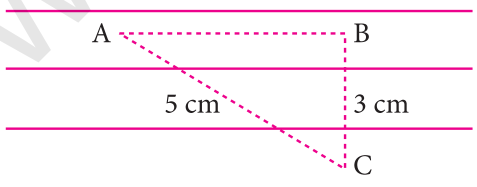
Hence the force on charge $\frac{Q}{2}$ is zero.

Force on charge at A, $F_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2Q\left(Q+\frac{Q}{2}\right)}{x^2}$

$$= \frac{1}{4\pi\varepsilon_0}\frac{1}{x^2}\left[2Q^2 + \frac{2Q^2}{2}\right] = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3Q^2}{x^2}$$

5. Three points A, B & C lie in a uniform electric field (E) of 5×10^3 NC^{-1}. Find the potential difference between A & C.

Ans. The line joining B to C is perpendicular to electric field



So potential of B = potential of C

i.e. $V_B = V_C$

Distance AB = 4 cm

$AC^2 = AB^2 + BC^2$
$AB^2 = AC^2 - BC^2$
$= 25 - 9 = 16$
AB = 4cm

Potential difference between A & C = E × AB

$= 5 \times 10^3 \times (4 \times 10^{-2})$

= 200 volt.

6. A polythene piece rubbed with wool is found to have a negative charge of 3×10^{-7} C. Estimate the number of electrons transferred from which to which?

Ans. Here, $q = -3 \times 10^{-7}$ C

Charge of one electron, $e = -1.6 \times 10^{-19}$ C

Number of electrons transferred from wool to polythene piece, $n = \frac{q}{e} = \frac{-3\times10^{-7}\,C}{-1.6\times10^{-19}\,C}$

$= 1.875 \times 10^{12}$.

7. A copper slab of mass 2g contains 2×10^{22} atoms. The charge on the nucleus of each atom is 29e. What fraction of the electrons must be removed from the slab to give it a charge of +2μC?

Ans. Given:

Total number of electrons in the slab,

$N = 29 \times e = 29 \times 2 \times 10^{22}$

Number g electrons removed, $n = \frac{q}{e}$

$$n = \frac{2\times10^{-6}}{1.6\times10^{-19}}$$

$$n = 1.25 \times 10^{13}$$

$\therefore$ Fraction of electrons removed

$$= \frac{\text{No.of electrons removed (n)}}{\text{Total No.of electrons(N)}}$$

$$= \frac{1.25\times10^{13}}{29\times2\times10^{22}} = 2.16 \times 10^{-11}.$$

Unit 1

8. How many electrons are there in one coulomb of negative charge?

Ans. Charge of an electron, $e = 1.6 \times 10^{-19}$C

$$q = 1\text{C}$$

$$\therefore \quad \text{No of electrons, } n = \frac{q}{e}$$

$$n = \frac{1}{1.6 \times 10^{-19}}$$

$$= 6.25 \times 10^{18}$$

$$n = 6.25 \times 10^{18} \text{ electrons}$$

9. A metal sphere has a charge of –6μC. When 5 × 10[12] electrons are removed from the sphere, what would be net charge on it?

Ans. $q_1 = 6\mu\text{C}$

$$q_2 = ne = 5 \times 10^{12} \times (1.6 \times 10^{-19})$$

$$q_2 = 8.0 \times 10^{-7}\text{ C}$$

$$= 0.8 \times 10^{-6}\text{ C} = 0.8\ \mu\text{C}$$

Since electrons are removed from the sphere, q_2 is positive.

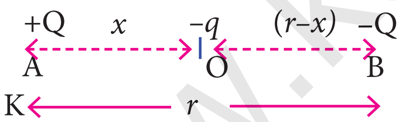
∴ Net charge on the sphere,

$$q = q_1 + q_2$$

$$q = (-6.0 + 0.8) \times 10^{-6}\text{C}$$

$$q = -5.2 \times 10^{-6}\text{C}.$$

10. Two charges each of +*q* coulomb are placed along a line. A third charge –*q* is placed between them. At what position will the system be in equilibrium?



Ans. For charge –*q* to be in equilibrium, the charge due to +Q at point A should be equal and opposite to that due to – Q at point B.

$$\text{i.e} \quad \frac{1}{4\pi\varepsilon_0}\frac{Qq}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{Q.q}{(r-x)^2}$$

$$x^2 = (r-x)^2$$

$$x = r - x$$

$$x = \frac{r}{2}$$

∴ for equilibrium, –*q* must be kept at the middle of the line joining the A and B.

11. What charge would be required to electrify a sphere of radius 25cm, so as to get a surface charge density of $\frac{3}{\pi}$ Cm^{-2}?

Ans. $r = 25\text{cm} = 0.25\text{ m}$

$$\sigma = \frac{3}{\pi}\text{ Cm}^{-2}$$

$$\text{As, } \sigma = \frac{q}{A} = \frac{q}{4\pi r^2} \quad \text{[A - surface area of the sphere]}$$

$$q = (4\pi r^2)\,\sigma$$

$$= 4\pi \times (0.25)^2 \times \frac{3}{\pi}$$

$$= 0.75\text{ C.}$$

12. The radius of gold nucleus (Z = 79) is about 7 × 10[–15]m. Assume that the positive charge is distributed uniformly throughout the nuclear volume. Find the volume charge density.

Ans. The total positive charge in the nucleus is,

$$q = +ze = 79 \times 1.6 \times 10^{-19}\text{ C.}$$

$$\text{Volume charge density, } \sigma = \frac{q}{\frac{4}{3} \times \pi R^3}$$

$$\sigma = \frac{q}{\frac{4}{3} \times 3.14 \times (7 \times 10^{-15})^3}$$

$$= 0.088 \times 10^{26}$$

$$= 8.8 \times 10^{24}\text{ Cm}^{-3}.$$

13. The dielectric constant of water is 80. What is its permittivity?

Ans. $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = 80; \quad \varepsilon_0 = 8.854 \times 10^{-12}$

$$\varepsilon = 80 \times \varepsilon_0$$

$$= 80 \times 8.854 \times 10^{-12}$$

$$= 708 \times 10^{-12}$$

$$\varepsilon = 7.08 \times 10^{-10}\text{ C}^2\text{ N}^{-1}\text{ m}^{-2}.$$

14. Two point charges having equal charges separated by 1m distance experience a force of 8N. What will be the force experienced by them, if they are held in water at the same distance? (Given = K_{water} = 80)

Ans.

$$K_W = \frac{F_{air}}{F_{water}} \quad (F_{air} = 8\text{N})$$

Electrostatics

$$F_{water} = \frac{F_{air}}{K_W} = \frac{8}{80} = \frac{1}{10}N$$

Note:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

$$F_{medium} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^2}$$

$$\frac{F}{F_{medium}} = \varepsilon_r \Rightarrow [\therefore \frac{F_{air}}{F_{water}} = K_{water}]$$

15. An infinite number of charges each equal to q are placed along X-axis at $x = 1$, $x = 2$, $x = 3$, $x = 4$, $x = 8$ and soon. Find the electric field at the point $x = 0$ due to this set up of charges.

Ans. At the point $x = 0$, the electric field due to all the charges are in the same negative X-direction and hence get added up, i.e.,

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(1)^2}+\frac{q}{(2)^2}+\frac{q}{(4)^2}+\frac{q}{(8)^2}+....\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1}+\frac{1}{4}+\frac{1}{16}+\frac{1}{64}+.....\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1-\frac{1}{4}}\right] = \frac{q}{3\pi\varepsilon_0}$$ (along negative X-axis)

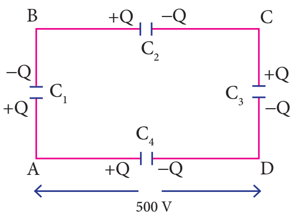
16. Calculate the potential at a point P due to charge of 5×10^{-7}C located 11 cm away.

Ans. $$V = \frac{q}{4\pi\varepsilon_0 r}$$

$$= \frac{9\times10^9\times5\times10^{-7}}{11\times10^{-2}}$$

$$= 40.9 \text{ kV}$$

17. A network of four 10μF capacitors is connected to a 500V supply as shown in the figure. Determine the equivalent capacitance of the network along AD.



Ans. $$\frac{1}{C_S} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3} = 3\times\frac{1}{10} = \frac{3}{10}$$

$$C_s = \frac{10}{3} = 3.33\ \mu F$$

$$C_1 = C_{eq} = C_S + C_4$$

$$= 3.33 + 10 = 13.33\mu F.$$

18. A capacitor of capacity 10μF is subjected to charge by a battery of 10V. Calculate the energy stored in the capacitor.

Ans. Capacitance, $C = 10\mu F = 10 \times 10^{-6}F$

Voltage, V = 10V

Energy, E = ?

Energy stored in the capacitor, $E = \frac{1}{2}CV^2$

$$= \frac{1}{2}\times 10\times10^{-6}\times10\times10$$

$$= 5\times10^{-4}\ J$$

19. A parallel plate capacitor has plate area, 25 cm and a separation of 2 mm between the plates. The capacitor is connected to a battery of 12V. Find the charge on the capacitor.

Ans. Area of the plate, $A = 25cm^2$

$$= 25\times10^{-4}m^2$$

Distance between the plates, d = 2 mm

$$d = 2\times10^{-3}m$$

Potential difference, V = 12V

Permittivity, $\varepsilon_0 = 8.85\times10^{-12}\ C^2N^{-1}m^{-1}$

Charge, $q = CV$ $\left[C = \frac{\varepsilon_0 A}{d}\right]$

$$q = \left(\frac{\varepsilon_0 A}{d}\right)V$$

$$= \frac{8.85\times10^{-12}\times25\times10^{-4}\times12}{2\times10^{-3}}$$

$$q = 1.33\times10^{-10}C$$

20. The electric potential in region is represented as $V = 2x + 3y - z$. Obtain an expression for electric field strength.

Ans. $$E = -\left[\frac{\partial V}{\partial x}\hat{i}+\frac{\partial V}{\partial y}\hat{j}+\frac{\partial V}{\partial z}\hat{k}\right]$$

$$\frac{\partial V}{\partial x} = \frac{\partial}{\partial x}(2x+3y-z) = 2$$

$$\frac{\partial V}{\partial y} = 3;\ \frac{\partial V}{\partial z} = -1$$

$\therefore$ Electric field, $E = -2\hat{i}-3\hat{j}+1\hat{k}$

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

Ans. Length, $l = 2a = 4\text{cm} = 4 \times 10^{-2}\text{m}$

Angle, $\theta = 60°$

torque $\tau = 4\sqrt{3}$ Nm

Charge, $Q = 8 \times 10^{-9}$ C

We know that, $\tau = pE\sin\theta$ [where $p = Q \times 2a$]

$$\tau = (Q \times 2a)E\sin\theta$$

$$\therefore E = \frac{\tau}{Q \times (2a)\sin\theta}$$

$$= \frac{4\sqrt{3}}{8\times10^{-9}\times4\times10^{-2}\times\sin 60°}$$

$\therefore$ Potential energy, $U = -pE\cos\theta$

$$= -Q(2a) \times E \times \cos\theta$$

$$= -8 \times 10^{-9} \times 4 \times 10^{-2} \times \frac{4\sqrt{3}\times\cos 60°}{8\times10^{-9}\times4\times10^{-2}\times\sin 60°}$$

$$U = \frac{-4\sqrt{3}}{\sqrt{3}} = -4\text{J}$$

22. Three capacitors each of capacitance 9pF are connected in series

(i) What is the total capacitance of the combination?

(ii) What is the potential difference across each capacitor, if the combination is connected to a 120 V supply.

Ans. Here, $C_1 = C_2 = C_3 = 9\,pF$

Voltage, $V_2 = 120\text{V}$

(i) Total capacitance in series combination,

$$\frac{1}{C_S} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3} = \frac{1}{9}+\frac{1}{9}+\frac{1}{9}$$

$$\frac{1}{C_S} = \frac{3}{9}$$

$$\Rightarrow C_S = 3\,pF$$

(ii) Total charge, $q = V \times C_S$

where $V = 120$ V

$$q = 120 \times 3 \times 10^{-9}$$

$$= 360\,pC$$

$\therefore$ Potential difference across C_1, $V_1 = \frac{q}{C_1}$

$$V_1 = \frac{360\times10^{-12}}{9\times10^{-12}} = 40\text{V}$$

$$V_2 = \frac{q}{C_2} = \frac{360}{9} = 40\text{V}$$

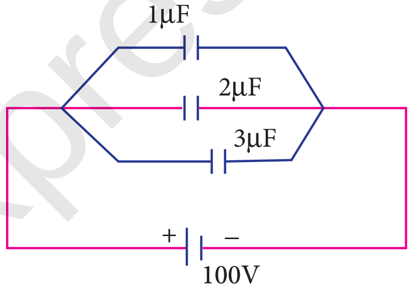
$$V_3 = \frac{q}{C_3} = \frac{360}{9} = 40\text{V}$$

$\therefore$ Potential difference across each capacitor is 40V.

23. In the circuit shown in figure, find

(i) the equivalent capacitance and

(ii) the charge stored in each capacitor.



Ans. (i) The equivalent capacitance is,

$$C_P = C_1 + C_2 + C_3$$

$$= (1 + 2 + 3) = 6\mu F$$

(ii) Total charge, $q = C_P V$

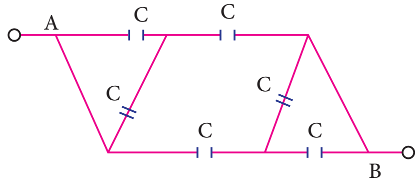
$$= 6 \times 10^{-6} \times 100 = 600\mu C$$

$$q_1 = C_1 V = 1 \times 100 = 100\mu C$$

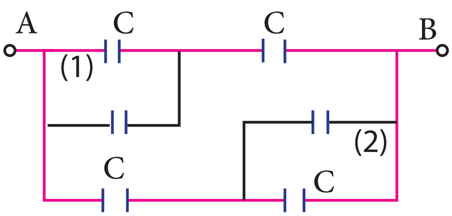
$$q_2 = C_2 V = 2 \times 100 = 200\mu C$$

$$q_3 = C_3 V = 3 \times 100 = 300\mu C$$

24. A network of six identical capacitors, each of value C is made as shown in the figure find the equivalent capacitance between the points A & B.



Ans. The equivalent network of the given network is



Electrostatics

51. (C)	**52.** (A)	**53.** (B)	**54.** (D)	**55.** (C)
56. (C)	**57.** (A)	**58.** (B)	**59.** (D)	**60.** (D)
61. (B)	**62.** (A)	**63.** (A)	**64.** (D)	**65.** (B)
66. (B)	**67.** (B)	**68.** (C)	**69.** (A)	**70.** (C)
71. (B)	**72.** (D)	**73.** (D)	**74.** (B)	**75.** (D)
76. (B)	**77.** (C)	**78.** (C)	**79.** (A)	**80.** (C)
81. (D)	**82.** (D)	**83.** (D)	**84.** (C)	**85.** (B)
86. (D)	**87.** (A)	**88.** (C)	**89.** (D)	**90.** (B)
91. (B)	**92.** (D)	**93.** (C)	**94.** (D)	**95.** (A)
96. (A)	**97.** (D)	**98.** (A)	**99.** (C)	**100.** (A)

Explanatory Notes:

1. Rotational K.E., $E = \frac{1}{2}I\omega^2$ or, $2EI = (I\omega)^2$

Angular momentum $I\omega = \sqrt{2EI}$

In absence of any external torque, the net angular momentum of the system remains conserved. Thus,

$$\sqrt{2E_1I_1} = \sqrt{2E_2I_2}$$

$$\frac{E_2}{E_1} = \frac{I_1}{I_2} = \frac{3}{1}$$

2. The gravitational potential energy is obtained as kinetic energy

$$\therefore \frac{1}{2}mv^2 = 6{\cdot}25 \times 10^8$$

$$v = \sqrt{\frac{2 \times 6{\cdot}25 \times 10^8}{10}}$$

$$\Rightarrow v = 11{\cdot}2 \text{ km/sec}$$

3. The escape velocity does not depend on direction and angle of projection.

5. The radii of curvature of the two faces of the lens remain unchanged. Hence, focal length will also remain unchanged.

6. $_0n^1 \longrightarrow {_1H^1} + {_{-1}\beta^0}$
(neutron) (proton) (electron)

7.
$$I_{max} = (a + a)^2 = 4a^2 = I$$

when one slit is closed, intensity at the same point is

$$I' = a^2 = I_0$$

$$\therefore I = 4I_0$$

8. X-ray spectrum is continuous with a cut-off at a minimum wavelength

$$\lambda_{min} = \frac{hc}{eV}$$

At a given V, X-rays of wavelength lower than λ_{min} are not emited.

9.
$$\beta = \frac{\alpha}{1-\alpha} = \frac{0{\cdot}96}{1-0{\cdot}96} = \frac{0{\cdot}96}{0{\cdot}04} = 24$$

11.
$$\mu = r_p \times g_m$$

$$\therefore g_m = \frac{\mu}{r_p} = \frac{20}{10\times10^3}$$

$$= 2 \times 10^{-3} \text{ mho}$$

12.
$$x = at^2, \; y = bt^2$$

$$v_x = \frac{dx}{dt} = 2at$$

$$v_y = \frac{dy}{dt} = 2bt$$

$$\therefore v = \sqrt{v_x^2 + v_y^2}$$

$$= \sqrt{(2at)^2 + (2bt)^2}$$

$$= 2(a^2 + b^2)^{1/2} \times t$$

13. Pressure exerted by a gas

$$\rho = \frac{1}{3}\rho v^{-2} \; ; \; v \propto \sqrt{\frac{3\rho}{\rho}}$$

$$[v] = [\rho^{1/2}, \rho^{-1/2}]$$

15. Horizontal Range = max. height reached

$$\frac{u^2 \sin 2\theta}{g} = \frac{u^2 \sin^2\theta}{2g}$$

$$2 \sin\theta \cos\theta = \frac{\sin^2\theta}{2}$$

$$4 \cos\theta = \sin\theta$$

$$\tan\theta = 4 \Rightarrow \theta = \tan^{-1} 4$$

16. $F_e = \frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r^2}$ and $F_m = \frac{\mu_0}{4\pi}\cdot\left(\frac{e^2v^2}{r^2}\right)$

$$\frac{F_m}{F_e} = \mu_0\varepsilon_0 v^2 = \frac{v^2}{c^2}$$

Since $\mu_0\varepsilon_0 = \frac{1}{c^2}$

17.
$$\alpha = \omega^2 y$$

$$\omega^2 = \frac{\alpha}{y} = \frac{12}{3} = 4$$

$$\therefore \omega = 2s^{-1}$$

NEET BASED QUESTIONS

$$T = \frac{2\pi}{\omega} = \frac{2\times 3{\cdot}14}{2} = 3{\cdot}14\ s$$

18. $$a = \sqrt{a_1^2 + a_2^2}$$

$$= \sqrt{6^2 + 8^2} = 10\ m$$

19. Electron is moving in the first orbit

$$n = 1$$

Angular momentum $= \dfrac{nh}{2\pi}$

$\therefore$ For $n = 1,\ L = \dfrac{h}{2\pi}$

$[L = mvr = 9 \times 10^{-31} \times 22 \times 10^{6} \times 0{\cdot}53 \times 10^{-10}$

$= 1{\cdot}0494 \times 10^{-34}$ J.s

Also $\dfrac{h}{2\pi} = \dfrac{6{\cdot}6\times 10^{-34}}{2\times 3{\cdot}14}$

$\therefore$ $L = \dfrac{h}{2\pi}]$

20. Power = Torque × angular speed

= 180 × 200 = 36000 W

= 36 kW

22. Magnetic dipole moment

$= IA = (qf) \times \pi r^2$

$= q\left(\dfrac{v}{2\pi r}\right)\times \pi r^2 = \dfrac{q\,vr}{2}$

23. In beta-decay $n \longrightarrow \rho + e + \bar{\upsilon}$

$\bar{\upsilon}$ denotes antineutrino

24. $$\frac{mv^2}{r} = Bq\,v \Rightarrow r = \frac{mv}{Bq}$$

The time t required by the icn to complete a semicircle is given by

$$t = \frac{\pi r}{v} = \frac{\pi}{v}\times\frac{mv}{Bq} = \frac{\pi m}{Bq}$$

25. For hydrogen like atom,

$$E_n = -\frac{13{\cdot}6}{n^2}\times Z^2$$

Thus for Li^{++} atom (Z = 3) we have

$$E_1 = \frac{-13{\cdot}6\times(3)^2}{1^2} = -122{\cdot}4\ eV$$

$$E_3 = \frac{-13{\cdot}6\times(3)^2}{3^2}$$

$$= -13{\cdot}6\ eV$$

Thus the energy required to transfer an electron from E_1 to E_3 level is.

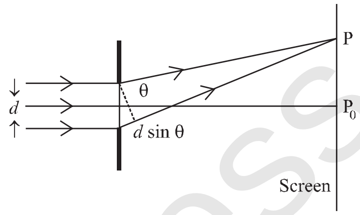
$$E = E_3 - E_1 = -13{\cdot}6 - (-122{\cdot}4)$$
$$= 108{\cdot}8\ eV$$

$$\therefore \quad \lambda = \frac{hc}{E}$$

$$= \frac{(6{\cdot}63\times10^{-34})\times(3\times10^{8})}{108{\cdot}8\times1{\cdot}6\times10^{-19}}\ m$$

$$\Rightarrow \quad \lambda = 113{\cdot}74\ \text{Å}$$

26.



Position of minima is given by

$$d\sin\theta = n\lambda$$

For first minimum, $n = 1$

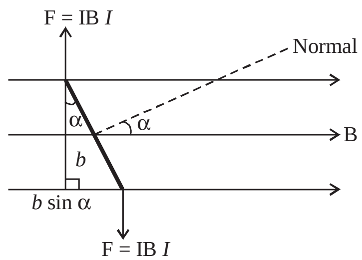
$\therefore$ $\Delta = d\sin\theta = \lambda$

Hence, phase difference

$$\Delta\varphi = \frac{2\pi\Delta}{\lambda} = \frac{2\pi}{\lambda}\cdot\lambda = 2\pi$$

27. The couple acting on a current carrying coil freely suspended in uniform magnetic field is given by

$$\tau = IBl \times b\sin\alpha = IBA\sin\alpha$$



$\Rightarrow \tau$ is maximum when $\alpha = 90°$ *i.e.*, when the plane of the coil is parallel to the magnetic field

$\Rightarrow \tau = 0$ when $\alpha = 0$ *i.e.*, when the plane of the coil is perpendicular to the magnetic field

Hence, the couple sets the coil in a position in which its plane is perpendicular to the magnetic field. It is the position of stable equilibrium of the coil.

28. Part A will act as convex lens (thicker in the middle) and part B will act as concave lens (thinner in the middle) of equal focal length. Hence taken together their power will be zero.

29. Colour sequence will follow VIBGYOR

From figure X may be BIV only. It can not be red, pink or orange.

33. $T_{1/2} = \dfrac{0{\cdot}6931}{\lambda} = \dfrac{0{\cdot}6931}{4.28\times10^{-4}}$

$= 1621$ years ≈ 1620 years

37. The maximum no. of electrons in a shell is $2n^2$

For $n = 1$, K-shell,
no. of electrons $= 2$
For $n = 2$, L-shell,
no. of electrons $= 8$
For $n = 3$, M-shell,
no. of electrons $= 18$
For $n = 4$, N-shell,
no. of electrons $= 32$
Thus, the total number of electrons = 60
Hence the number of elements will be 60

38. 1 BeV= 10^9 eV = $10^9 \times 1{\cdot}6 \times 10^{-19}$ J
$= 1{\cdot}6 \times 10^{-10}$ J

40. In case of positive rays we get a parabola when B and E are parallel because different positive ions have different velocities and they reach at different points on the parabola. If the velocities of all the ions be the same, only a point will be obtained on the screen. Since there is no velocity-distribution in cathode rays, hence no parabola is obtained.

41. For three journies of the body

$h = -ut_1 + \frac{1}{2}gt_1^2 \Rightarrow \frac{h}{t_1} = -u + \frac{1}{2}gt_1$ ...(1)

$h = ut_2 + \frac{1}{2}gt_2^2$; $\Rightarrow \frac{h}{t_2} = u + \frac{1}{2}gt_2$ ...(2)

$h = 0 + \frac{1}{2}gt_3^2$ ...(3)

Adding first two expressions

$$h\left(\frac{1}{t_1}+\frac{1}{t_2}\right) = \frac{1}{2}g(t_1+t_2)$$

Comparing it with eqn. (3)

$$t_3 = \sqrt{t_1 t_2}$$

42. In S.H.M., $\alpha = \omega^2 y$

$\Rightarrow \omega^2 = \dfrac{\alpha}{y} = \dfrac{12}{3} = 4\ \text{sec}^{-2}$

$\therefore T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{2} = \pi = 3{\cdot}14$ sec

44. $M = \dfrac{F}{t}$

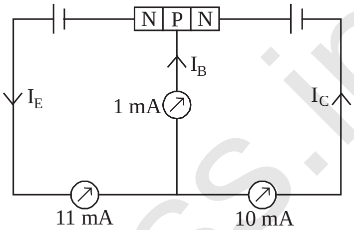
To decrease M, f should be increased

45. Resolving limit $\dfrac{\lambda}{d\lambda} = \dfrac{1{\cdot}22\lambda}{D}$

$= \dfrac{1{\cdot}22\times6000\times10^{-10}}{0{\cdot}1}$

$\approx 6 \times 10^{-6}$ rad.

50. The current distribution is as shown in the figure—



As 90% of the electrons constitute 10 mA collector current, the base current = 10% of 10 mA = 1 mA

$\because I_E = I_C + I_B = 10 + 1 = 11$ mA

51. $A_1 = A_0 e^{-\lambda t1}$,

$A_2 = A_0 e^{-\lambda t2}$

$\therefore \dfrac{A_2}{A_1} = \dfrac{e^{-\lambda t_2}}{e^{-\lambda t_1}}$

$= e^{\lambda(t_1 - t_2)}$

$\Rightarrow \dfrac{A_2}{A_1} = e^{\frac{t_1 - t_2}{T}}$

$\left(\because \lambda = \dfrac{1}{T}\right)$

$\Rightarrow A_2 = e^{(t_1-t_2)/T}$

52. K. E. $= \dfrac{Ze^2}{8\pi\varepsilon_0 r}$ and P. E.$= \dfrac{-Ze^2}{4\pi\varepsilon_0 r}$

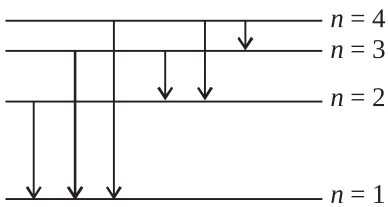
$\therefore$ K. E. + P. E. = Total Energy $= \dfrac{-Ze^2}{8\pi\varepsilon_0 r}$

$\Rightarrow \dfrac{\text{K.E.}}{\text{T.E.}} = \dfrac{-Ze^2}{8\pi\varepsilon_0 r} \times \dfrac{8\pi\varepsilon_0 r}{-Ze^2}$

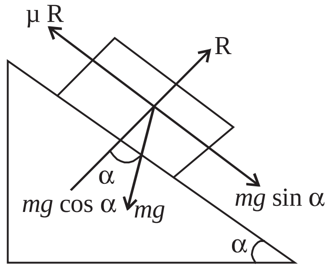
$= -1$

53. $\lambda_{min} = \dfrac{12400}{V}$ Å $\Rightarrow \upsilon_{max} \propto V$

54.



55.



Here $R = mg\cos\alpha$

and $mg\sin\alpha - \mu R = ma$

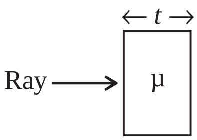
Therefore, acceleration

$$a = \frac{mg\sin\alpha - \mu R}{m} = \frac{mg\sin\alpha - \mu \times mg\cos\alpha}{m}$$

$$= g(\sin\alpha - \mu\cos\alpha)$$

56. Required time = $\dfrac{\text{Optical thickness}}{\text{Speed of light in air}}$

$$= \frac{\mu t}{c}$$



57. The springs are connected in parallel; the equivalent force constant $k = k_1 + k_2$—

$\therefore$ $$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m}{k_1 + k_2}}$$

58. $$r_e = \frac{\sqrt{2m_e k_e}}{qB};$$

$$r_p = \frac{\sqrt{m_p k_p}}{qB}$$

$\therefore$ $$\frac{r_e}{r_p} = \sqrt{\frac{m_e k_e}{m_p k_p}} = \sqrt{\frac{m_e}{m_p}}$$

$(\because k_e = k_p)$

$\therefore$ $r_p > r_e$

Hence the path of proton will be less curved.

59. $h\upsilon = h\,\upsilon_0 + E_k \Rightarrow E_k = h\,\upsilon - h\,\upsilon - h\,\upsilon_0$

63. Magnetic induction $$B = \frac{2.4\times10^{-5}}{0.2\times10^{-4}}$$

$= 1.2$ wb/m^2

Magnetic permeability $$\mu = \frac{B}{H} = \frac{1.2}{1600}$$

$= 7.5 \times 10^{-4}$ N/A^2

$\therefore$ Suceeptibility $$K = \frac{\mu}{\mu_0} - 1$$

$$= \frac{7.5\times10^{-4}}{4\pi\times10^{-7}} - 1 = 596$$

64. $$W = \int_0^\theta \tau d\theta = \int_0^\theta MB\sin\theta\, d\theta$$

$$= MB[-\cos\theta]_0^\theta = MB\,[1 - \cos\theta]$$

65. Self-inductance of toroid

$$L = N\frac{\phi}{i}$$

Energy of toroid $$E = \frac{1}{2}Li^2 = \frac{1}{2}\left(\frac{N\phi}{i}\right)i^2$$

$$= \frac{1}{2}N\phi i$$

66. $L = \dfrac{\mu_0\, n^2\, \pi r}{2}$; $L = \dfrac{\mu_0 (2n)^2\, \pi (r/2)}{2}$

$$= 2\left[\frac{\mu_0\, n^2 \pi r}{2}\right] = 2L$$

(When the number of turns in a coil is doubled without changing the length of the coil, the radius of the coil is reduced to half)

67. $B = \mu_0 ni$; when current is doubled, the magnetic field is also doubled as n is unchanged.

68. The given spring system is equal to a spring of spring constant

$$\frac{K}{2}\left[\frac{1}{K'} = \frac{1}{K} + \frac{1}{K} \Rightarrow K = \frac{K}{2}\right]$$

$$T = 2\pi\sqrt{\frac{M}{K/2}} = \sqrt{2}\left[2\pi\sqrt{\frac{M}{K}}\right] = \sqrt{2}\,T'$$

$\Rightarrow$ $$T' = \frac{T}{\sqrt{2}}$$

where T' is the period if a single spring is used.

69. Velocity of simple pendulum

$$v = a\,\omega\cos\omega t = 10\times\frac{2\pi}{T}\cos\frac{2\pi}{T}.1$$

$$= \frac{20\pi}{4}\cos\frac{2\pi}{4}.1 = 0$$

70. 1 nanometer = 10^{-9} m

1 angstrom = 10^{-10} m

1 fermi = 10^{-15} m

1 attometer = 10^{-18} m

72. For $\vec{A}$ and $\vec{B}$ to be perpendicular,

$$\vec{A}.\vec{B} = 0$$

$$= (5\hat{i} + 2\hat{j} - s\hat{k}).(3\hat{i} + \hat{j} - 2\hat{k})$$

$$= 15 + 2 - 2s = 0$$

$\Rightarrow$ $s = 8.5$

Physics

73. $K = C + 273$

$\therefore \quad 4 = C + 273$

$\Rightarrow \quad C = 4 - 273$

$= -269$

Now, $\dfrac{F-32}{9} = \dfrac{C}{5}$

or, $\dfrac{F-32}{9} = -\dfrac{269}{5}$

$\Rightarrow \quad F = -452$

74. The density of water is maximum at 4ºC; therefore, the volume of a given amount of water will be minimum at 4ºC.

75. $\dfrac{V_2}{V_1} = \sqrt{\dfrac{T_2}{T_1}} = \sqrt{\dfrac{327+273}{27+273}}$

$= \sqrt{\dfrac{600}{300}} = \sqrt{2}$

$\therefore \quad V_2 = \sqrt{2}\,V_1 = 1{\cdot}414 \times 141{\cdot}4$

$\simeq 200$ m/s

76. $M.P. = \dfrac{25\,\text{cm}}{f}$

$\Rightarrow \quad f = \dfrac{25}{12{\cdot}5}$

$= 2$ cm

78. $\dfrac{\sin c}{\sin 90^\circ} = \dfrac{\mu_1}{\mu_2}$

$\Rightarrow \quad \sin c = \dfrac{\mu_1}{\mu_2}$

where μ_1 is the refractive index of rarer medium.

79. In (B) and (C) the central maxima is brightest.

80. The angular momentum of allowed orbits is $\dfrac{h}{2\pi}, \dfrac{2h}{2\pi}, \dfrac{3h}{2\pi}, \ldots$ Thus difference between successive allowed orbits is—

$\dfrac{h}{2\pi} = \dfrac{6{\cdot}64 \times 10^{-34}}{2\pi}$

$= 1{\cdot}06 \times 10^{-34}$ kg × m²/s

82. Since both the atomic number and number of nucleons must be conserved, α-particles must carry (92 + 0) – (54 + 36 + 0) = 2 protons and (235 + 1) – (142 + 89 + 1) = 4 nucleons. These are contained in one α-particle.

83. Naturally occurring uranium contains only 0·7% of $_{92}U^{235}$. Thus, the amount of U^{235} in a 20g sample

$= 20 \times \dfrac{0{\cdot}7}{100}$

$= 0{\cdot}14$ g

84. By definition, fermi energy is the energy corresponding to the highest energy level in the conduction band occupied by electrons at absolute zero.

85. The ionic crystals are usually insulators and are transparent.

86. Mach 2 corresponds to twice the speed of sound. Thus, it is

$= 2 \times 330$ m/s

$= 2 \times \dfrac{330 \times 60 \times 60}{1000}$ km/hr

$= 2376$ km/hr

87. $E = \dfrac{1}{2} m\omega^2 a^2$. Thus percentage change in energy is

$\dfrac{\Delta E}{E} = \dfrac{20^2 - 15^2}{20^2} \times 100 \simeq 44\%$

88. If I is the initial intensity, the sound level in decibels,

$db_1 = 10 \log \dfrac{I}{I_0}$

Also $db_2 = 10 \log \dfrac{I}{I_0}$

$= 10 \log 2 + 10 \log \dfrac{I}{I_0} \simeq 3 + db_1$

89. $I = 2\pi^2 v d f^2 A^2 \therefore I \propto f^2$

90. An ammeter is a galvanometer with a small resistance in parallel with it, while a voltmeter is made by connecting a high resistance in series with it.

91. $(\vec{A} + \vec{B}).(\vec{A} - \vec{B}) = 0$

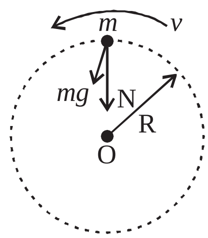
$\vec{A}^2 + \vec{B}.\vec{A} - \vec{A}.\vec{B} - \vec{B}^2 = 0$

$\vec{A}^2 - \vec{B}^2 = 0$

(Since $\vec{A}.\vec{B} = \vec{B}.\vec{A}$)

$A^2 = B^2 \quad \Rightarrow \quad A = B$

92.



At highest point

$$mg + N = \frac{mv^2}{R}$$

For V_{min}, N = 0 $\Rightarrow$ $V_{min} = \sqrt{gR}$

93. While sliding down with an acceleration α, the force exerted by the man on the rope is

$$T = m(9 - \alpha) = \frac{2}{3}mg$$

$$\Rightarrow \quad \alpha = \frac{1}{3}g$$

94. Work done = Energy stored

$$= \frac{1}{2}kx^2$$

For second spring x will be more, whose square is involved in above expression.

95.

$$\frac{mv^2}{r} = \frac{k}{r^2}$$

$$K.E. = \frac{1}{2}mv^2 = \frac{k}{2r}$$

$$P.E. = -\int_{\infty}^{r} F dr = \int_{\infty}^{r} \frac{k}{r^2} dr$$

$$= -\frac{k}{r}$$

Total energy E = KE + PE

$$= \frac{k}{2t} - \frac{k}{r} = -\frac{k}{2r}$$

96.

$$\text{Power} = \frac{\text{Work done}}{\text{Time}}$$

$$= \frac{\text{Force} \times \text{Displacement}}{\text{Time}}$$

$$= \frac{80 \times 9{\cdot}8 \times 20 \times 0{\cdot}2}{10} = 313{\cdot}6 \text{ W}$$

97. $\vec{L} = \vec{r} \times \vec{p} = m\vec{r} \times \vec{v}$

L = $rp \sin\theta = mvr \sin\theta = mr(v\sin\theta)$

As vertical component of velocity (v sin θ) initially decreases and after its highest point increases

⇒ L, initially decreases and after highest point it increases.

98.

$$mgh = \frac{1}{2}kx^2$$

$$\Rightarrow \quad x = \sqrt{\frac{2mgh}{k}}$$

99. For rolling motion

(Translational + Rotational)

Acceleration $f = \dfrac{g\sin\theta}{1 + \dfrac{K^2}{R^2}}$

For sphere, $K = R\sqrt{\dfrac{2}{5}}$

$$\Rightarrow \quad f_1 = \frac{g\sin\theta}{1{\cdot}4}$$

For disc, $K = R \times \dfrac{1}{\sqrt{2}}$

$$\Rightarrow \quad f_2 = \frac{g\sin\theta}{1{\cdot}5}$$

For shell, $K = R\sqrt{\dfrac{2}{3}}$

$$\Rightarrow \quad f_3 = \frac{g\sin\theta}{1{\cdot}66}$$

For ring, K = R

$$\Rightarrow \quad f_4 = \frac{g\sin\theta}{2{\cdot}0}$$

$\therefore f_1 > f_2 > f_3 > f_4$

100.

$$\overrightarrow{r_{C.M.}} = \frac{m_1\vec{r} + m_2\vec{r_2}}{m_1 + m_2}$$

$$= \frac{10(\hat{i}+\hat{j}+\hat{k}) + 30(-\hat{i}-\hat{j}-\hat{k})}{10+30}$$

$$= -\frac{20(\hat{i}+\hat{j}+\hat{k})}{40}$$

$$= -\frac{\hat{i}+\hat{j}+\hat{k}}{2}$$

☆☆☆