Class-12th Board

The Catalyst for Physics

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Class Notes in Handwritten Format

Updated as per latest CBSE Syllabus

100% NCERT Based Notes | Detailed Theory | CBSE PYQs

Includes Competency-Based Questions | Simplified Flowcharts and Tables

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01

Electric Charges and Fields

SYLLABUS

Electric charges, Conservation of charge, Coulomb's law-force between two-point charges, forces between multiple charges; superposition principle and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

1. INTRODUCTION

Before Starting This Chapter, Just Give A Thought to the Following Points:

(i) Have you ever seen a spark or hear a cracking sound when you takes off your clothes?

(ii) Have you ever rubbed a balloon on your head and made your hair stand up?

(iii) Have you ever got a shock while opening the door of a car?

If yes then this chapter will bring a lot of interest to you.

Ans to all the above phenomenon is static charge which means charge at rest & we will be discussing about the static charge in detail in this chapter.

2. CHARGE AND ITS PROPERTIES

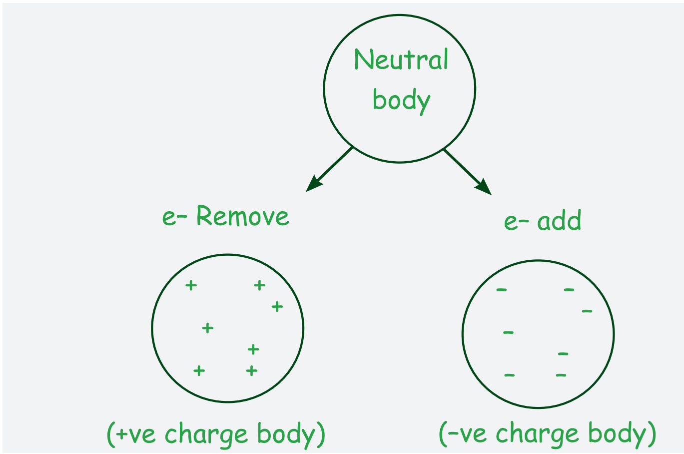
CHARGE

Charge is an intrinsic property of matter due to which it experiences or exerts electric & magnetic effects

Intrinsic: Independent of external factor

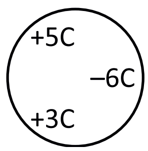
1. How does a body attain any Charge?

Ans. By transfer of e– from One body to another. (Body with equal number of positive and negative charges is neutral).



PROPERTIES OF CHARGE

1. **Additive Nature of Charge:** Total Charge on a body is algebraic sum of all the charges present on the body.



Total Charge one body = +5C – 6C + 3C = +2C

2. **Quantization of Charge:** The electric charge on a body is always integral multiple of e (charge of 1 electron).

$$Q = \pm ne$$

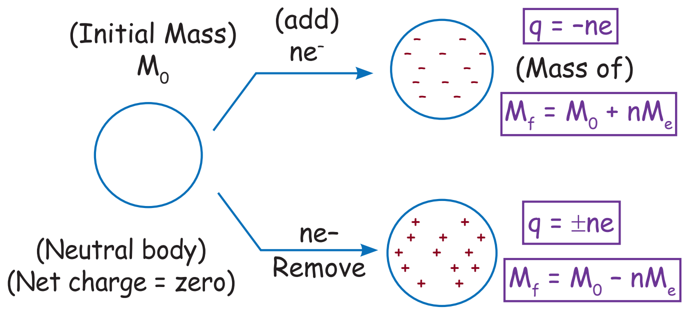
$n = 0, 1, 2, 3, 4, \ldots\ldots \infty$

$e = 1.6 \times 10^{-19}\ C$

- This is because a body gets positive charge when it loses some e– and it gets negative charge when it gains some e– & it is quite obvious that loosing or gaining of electron will always be in integer.
- Gaining or loosing of half electron will make no sense.

3. **Charge is Conserved:** Charge can neither be created nor be destroyed. It can only be transferred from one body to another body.
4. **Charge is Invariable:** Charge of a body does not depend on its state of Rest or Motion, also it is independent of the location.

   For Example: Charge of an e– is 1.6×10^{-19} C whether it is in rest or it is moving with speed of light. Whether, it is on earth or it is on moon.
5. **Charge is transferable:** Charge can be transfered to a body).
6. **Charge is always associated with mass:** A charged body will always have mass.



Charge on any body = ± ne

n = Integer

7. **Interaction of charges:**

   ⇒ Like charges Repel each other.
   ⇒ Unlike charges attract each other.

   ←⊕ ⊕→ ⊕→ ←⊖
   ←⊖ ⊖→

8. **Accelerated charge radiates energy**

v = 0 (i.e. at rest) ⊕ Q * produces $\vec{E}$ only (electric field) (Electrostats)	v = constant ⊕ → (Current) Q produces both $\vec{E}$ and $\vec{B}$ (magnetic field) but no radiation	v ≠ constant (i.e. time varying). ⊕ → Q produces both $\vec{E}$, $\vec{B}$ and radiates energy (EM Wave)

⊕ ⊖ Rest Produces Electric field.	⊕→ v = constant ←⊖ develops current ↓ (Magnetic field) + (electric field)	⊕→ accelerated EM Radiations

9. **Unit of charge** = Coulomb.

   Charge on electron is –e = – 1.6×10^{-19}

   Charge on proton is +e = 1.6×10^{-19}

   SI unit of charge is coulomb (C) & CGS unit of charge is electrostatic unit (esu) or stat Coulomb (stat C)

   $1C = 3 \times 10^9$ esu

2. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes- **(CBSE, 2022)**

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

Ans. (D) Initial charge = 1 C

Charge Added = – $(1.6 \times 10^{-19} \times 5 \times 10^{+18})$ = – 0.8 C

Final charge = (1 – 0.8)C = 0.2 C

option (d) is correct answer.

3. Name any two basic properties of electric charges.

Ans. **Quantization of Charge:** Electric charge exists in discrete packets rather than being continuous.

Conservation of Charge: The total electric charge in an isolated system remains constant over time.

4. If 10^9 electrons move out of a body to another body every second, how much time is required to get a total charge of 1 C on the other body?

Ans. In one second 10^9 electrons move out of the body. Therefore the charge given out in one second is $1.6 \times 10^{-19} \times 10^9 C = 1.6 \times 10^{-10}$ C.

The time required to accumulate a charge of 1 C can then be estimated to be

$$\frac{1C}{1.6 \times 10^{-10} C/s} = 6.25 \times 10^9 s = 198 \text{ years}$$

5. How much positive and negative charge is there in a cup of water? **(NCERT Intext)**

Ans. Let us assume that the mass of one cup of water is 250 g. The molecular mass of water is 18 g. Thus, one mole (= 6.02×10^{23} molecules) of water is 18 g. Therefore the number of molecules in one cup of water is $(250/18) \times 6.02 \times 10^{23}$.

Each molecule of water contains two hydrogen atoms and one oxygen atom, i.e., 10 electrons and 10 protons. Hence the total positive and total negative charge has the same magnitude. It is equal to $(250/18) \times 6.02 \times 10^{23} \times 10 \times 1.6 \times 10^{-19}$ C $= 1.34 \times 10^{7}$ C.

6. How many electrons should be removed from a metal sphere to give it a positive charge of 1×10^{-7} C?

(A) 6.25×10^{-11}

(B) 6.25×10^{-12}

(C) 6.25×10^{11}

(D) 6.25×10^{14}

Ans. (C) According to quantisation of charge

$$q = ne$$

$$\therefore\ n = \frac{1 \times 10^{-7}}{1.6 \times 10^{-19}} = 6.25 \times 10^{11}$$

3. METHOD OF PRODUCING CHARGES

(A) CHARHING BY FRICTION:

When two objects are rubbed together, the friction between them leads to the transfer of electrons from one object to another. Consequently, both acquire an electrical charge. The object that loses electrons becomes positively charge, and the object which gained electrons becomes negatively charged.

When the following pair will rub against each other then the charge attained by the bodies is given as:

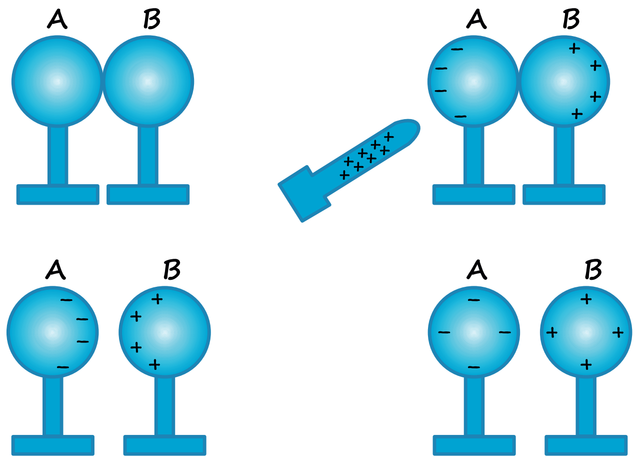
Positively Charged	Negatively Charged
Glass	Silk
Hair	Comb
Wool	Rubber
Cat skin	Ebonite Rod

(B) CHARGING BY INDUCTION

Induction is a process of charging a body without any physical contact between charged body and uncharged body.

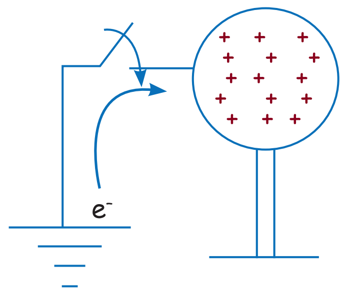
Let's grasp the concept of charging by induction with an illustration:

- Consider two metallic spheres, A and B, placed on insulating stands, and bring them close together.
- Next, position a positively charged rod near the left side of sphere A, without making physical contact.
- The positive charge on the rod attracts the electrons in sphere A, resulting in an excess of negative charge on the left side of A. Simultaneously, there will be positive charge at end B because e^- of those atoms are attracted by Rod & has moved to side A.
- Consequently, if we separate both the spheres and Remove the rod both spheres get charged. Both spheres become charged by the end of this process. This phenomenon is termed charging by induction.

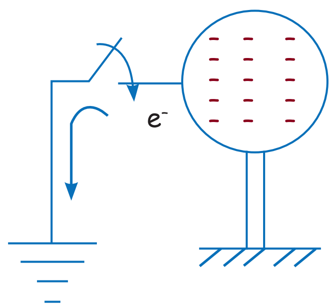


We can use Earthing also to charge a body. Lets understand what is Earthing it is process of connecting a body to Earth by a wire due to which potential of body becomes zero.

If we Earth a positive and Negative charge.

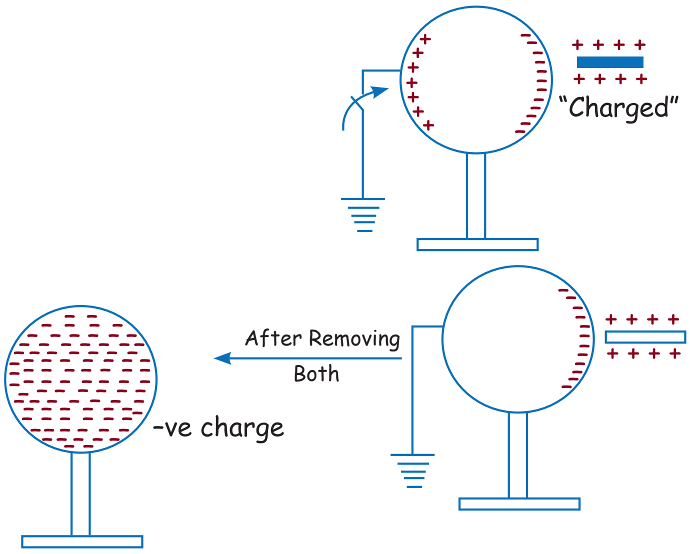


Electron move from Earth to body

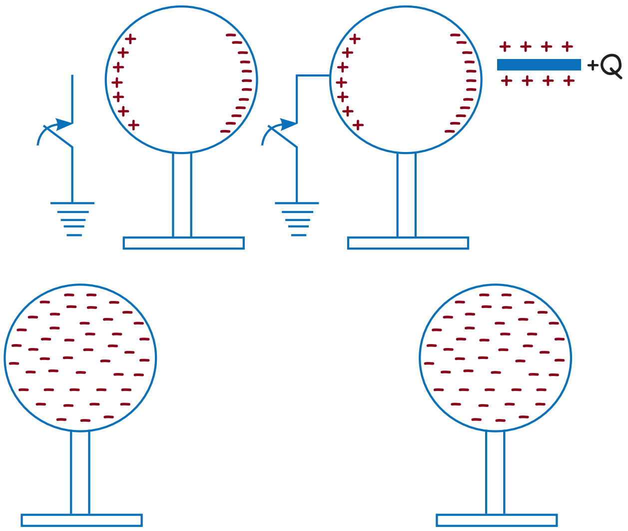


e^- move from body to earth.

Charging by Induction using Earthing



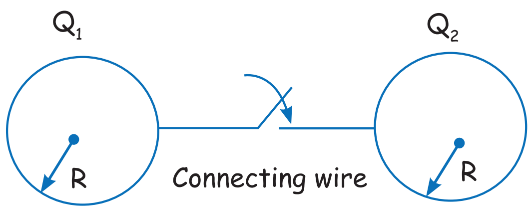
(Conducting sphere)



(C) BY CONTACT

If we connect two identical conducting spheres with wire, the charge is shared between them and after removal of wire final charges on both sphere is $\frac{Q_1 + Q_2}{2}$

When there is a contact between charged and uncharged



"Identical spheres"

Initial charge:- Q_1 Q_2

after connection $Q_T = Q_1 + Q_2$

When connection = $\frac{Q_1 + Q_2}{2}, \frac{Q_1 + Q_2}{2}$

is broken

7. Can you charge an insulator by the method of conduction?

Ans. No, insulator can only be charged by method of Rubbing/friction.

8. A negatively charged object *X* is repelled by another charged object *Y*. However, an object *Z* is attracted to object *Y*. Which of the following is the best possibility for the object *Z*? **(CBSE, 2022)**

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

Ans. (C) neutral or positive charged

As the charge Z is attracted by the charge Y, the charge Z can be positive. Neutral or positively charged object attracts negatively charged object. And neutral charge is attracted by any charged particle. So Z can be positive or neutral.

9. In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3e, +5e and –3e respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres? **(CBSE, 2022)**

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

Ans. (B) +6e, +6e, –7e

Total charge of all spheres before making contact

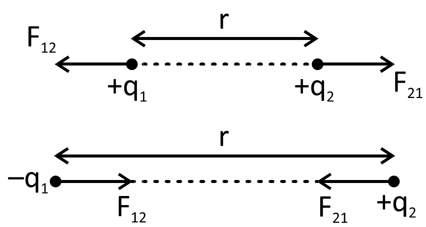
= +3e + 5e – 3e = +5e

So as per conservation of charge, total charge of all spheres after making contact should be +5e as well which is possible only in option (b).

= +6e + 6e – 7e = 5e

4. COULOMB'S LAW

The strength of the electrostatic force between two point charges is directly proportional to the product of their changes and inversely proportional to the square of the distance separating them.



F_{12} = Force on charge 1 due to charge 2

F_{21} = Force on charge 2 due to charge 1

$|F_{21}| = |F_{12}| = |F|$

|F| = Magnitude of force on either charge due to other charge

$$|F| = \frac{K|q_1||q_2|}{r^2}$$

K = Electrostatic constant.

r = separation between the charges

- ❑ ε_0 = permittivity of free space/vacuum
- ❑ $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$
- ❑ K depends on medium space
- ❑ Value of $K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$

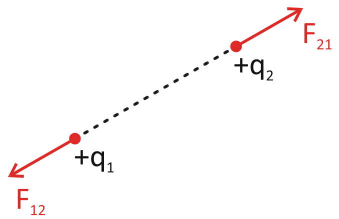
IMPORTANT POINT:

(i) Coulomb's force between two charges depends on the medium present between two charges.

(ii) Coulomb's force always acts along the line joining the centres of two charges.

(iii) Coulomb's force is a conservative force i.e., work done by Coulomb's force is path independent.

(iv) Coulomb's force is action-reaction pair forces i.e. force on 1 Charge due to 2nd Charge is equal and opposite to the force on 2nd charge due to 1st charges



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

10. The sum of two point charges is 7 μC. They repel each other with a force of 1 N when kept 30 cm apart in free space. Calculate the value of each charge. **[PYQ 2 Marks]**

Ans. Let one of two charges is x μC. Therefore, other charge will be $(7 - x)\mu C$.

By Coulomb's law, $F = F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

$$1 = 9 \times 10^9 \times \frac{(x)(10^{-6})(7-x) \times 10^{-6}}{(0.3)^2}$$

$9 \times 10^{-2} = \times\ 9 \times 10^{-3}\ (x)(7 - x) \Rightarrow 10 = x\ (7 - x)$

$\therefore x^2 - 7x + 10 = 0 \Rightarrow (x - 2)(x - 5) = 0$

$x = 2\ \mu C$ or $5\ \mu C$

11. When the distance between the charged particles is halved, the force between them becomes

(A) One-fourth (B) Half

(C) Double (D) Four times

Ans. (D) $F \propto \frac{1}{r^2}$; so when r is halved the force becomes four times.

5. COULOMB'S LAW IN MEDIUM

The Force between two charges is

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

where $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ Nm^2$ is Permitivity of free space.

Lets understand Permitivity first. when charges are placed in medium, the charges of medium disrupt the force of Interaction between charges.

Permitivity is defined as the Capability of a medium to disrupt the coulombian force.

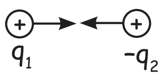
$\therefore$ More is the permitivity less is the coulombian force between charges.

$\therefore$ Every medium has its own permitivity.

Since we cannot learn all permitivities, we define Relative permitivity (ε_r) or dielectric constant.

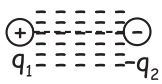
$$K = \frac{\varepsilon_{medium}}{\varepsilon_{vaccum}}$$

$\therefore$ If we know dielectric constant = 4, we can understand the permitivity of medium is 4 times ε_0.



If medium is Vaccum

$$F_0 = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$



If medium has dielectric constant k

$$F_{med} = \frac{1}{4\pi\varepsilon_m} \frac{q_1 q_2}{r^2}$$

$$k = \frac{\varepsilon_m}{\varepsilon_0}, \boxed{\varepsilon_m = k\varepsilon_0}$$

$$F_{med} = \frac{1}{4\pi\varepsilon_0 K} \frac{q_1 q_2}{r^2}$$

$$F_{med} = \frac{F_{vaccum}}{K}$$

$\therefore$ This states that when charge pair is dipped in polar liquid (having + and – polarities) Force reduces by k times.

∴ Dielectric constant of water ≈ 80

∴ Dielectric constant of conductor ≈ ∞

∴ Dielectric constant of air ≈ 1.

∴ This is the Reason why salt is dissolvable in water (Polar liquid) but not in non-polar liquid.

∴ When conductor is placed between charge pairs the force reduce to zero. This phenomenon is called Electrostatic shielding.

12. Two point charges having equal charges separated by 1 m distance experience a force of 8 N. What will be the force experienced by them, if they are held in water at the same distance? (Given, K_{water} = 80) **[PYQ 1 Mark]**

Ans. Two point charges system is taken from air to water keeping other variable (e.g. distance, magnitude of charge) unchanged. So, only factor which may affect the interacting force is dielectric constant of medium. Force acting between two point charges

$$F = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1q_2}{r^2} \text{ or } F \propto \frac{1}{K}$$

$$\Rightarrow \frac{F_{air}}{F_{medium}} = K \Rightarrow \frac{8}{F_{water}} = 80$$

$$\Rightarrow F_{water} = \frac{8}{80} \Rightarrow F_{water} = \frac{1}{10}\text{N}$$

6. VECTOR FORM COULOMB'S LAW

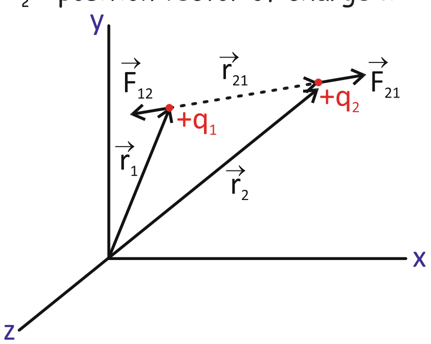
According the vector law of addition

$\vec{r}_1 + \vec{r}_{21} = \vec{r}_2$

$\vec{r}_{21} = \vec{r}_2 - \vec{r}_1$

$\vec{r}_1$ = position vector of charge 1

$\vec{r}_2$ = position vector of charge 2



$$\vec{F}_{21} = |\vec{F}_{21}|, \hat{F}_{21} = \frac{Kq_1q_2}{r^2}$$

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\hat{r}$$

$$\boxed{\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\frac{\vec{r}}{|\vec{r}|} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^3}\vec{r}}$$

$$\boxed{\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{|\vec{r}^3|}(\vec{r}_2 - \vec{r}_1)} \quad \left[|\vec{r}| = |\vec{r}_{21}| = |\vec{r}_2 - \vec{r}_1|\right]$$

Put q_1 & q_2 with sign

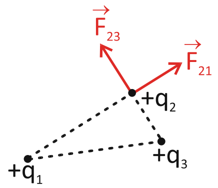
Similarly,

$$\boxed{\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{|\vec{r}_{12}|^3}\vec{r}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{|\vec{r}_{12}|^3}(\vec{r}_1 - \vec{r}_2)}$$

PRINCIPLE OF SUPERPOSITION

(i) Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to other charges.

(ii) The individual force between two charges are unaffected due to the presence of other charges.



Net Force on charge 2

$$\left(\vec{F}_2\right)_{net} = \vec{F}_{23} + \vec{F}_{21}$$

Similarly if n charges are present

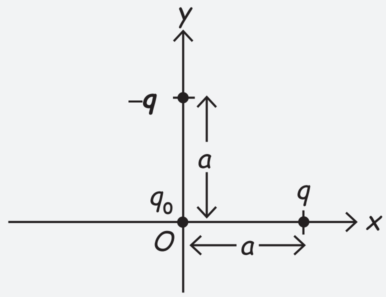
Net force on 1st charge will be

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots\ldots + \vec{F}_n$$

$$\boxed{\vec{F}_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{r_{12}^2}\hat{r}_{12} + \frac{q_1q_3}{r_{13}^2}\hat{r}_{13} + \ldots\ldots + \frac{q_1q_n}{r_n^2}\hat{r}_n\right]}$$

13. Three charges q, $-q$, q_0 are placed as shown in figure. The magnitude of the net force on the charge q_0 at point O is $\left[k = \frac{1}{(4\pi\varepsilon_0)}\right]$

(CBSE, 2022)



(A) 0

(B) $\frac{2kqq_0}{a^2}$

(C) $\frac{\sqrt{2}kqq_0}{a^2}$

(D) $\frac{1}{\sqrt{2}}\frac{kqq_0}{a^2}$

Ans. (C) $\vec{F_1} = \frac{kqq_0}{a^2}$

$\vec{F_1} = \frac{kqq_0}{a^2}\hat{j}$

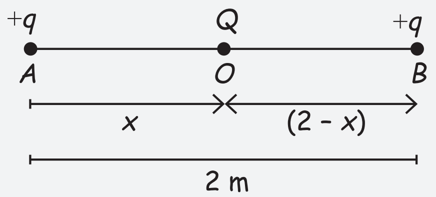
$\vec{F_2} = \frac{kqq_0}{a^2}(-\hat{i})$

$\therefore \vec{F} = \vec{F_1} + \vec{F_2} = \frac{kqq_0}{a^2}(-\hat{i} + \hat{j})$

$\therefore |\vec{F}| = \frac{kqq_0}{a^2}(\sqrt{2})$

14. Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

Ans. Let us suppose that the third charge 'Q' is placed on the line joining the first and second charge such that $AO = x$ and $OB = (2 - x)$.



Net force on each of the three charges must be zero for the system of charges to be in equilibrium.
If we assume that 'Q' is positive in nature then it will experience forces due to other two charges in opposite direction and the net force on 'Q' becomes zero. But, the repulsive force acting on either 'q' will not be zero as the forces acted in same direction.
However, if charge 'Q' is taken as negative then, on a charge q forces due to other two charges will act in opposite directions. Hence, the third charge must be negative in nature.
For charge –Q to be in equilibrium, the force acting on –Q due to +q at A and +q at B should be equal and opposite.

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

$\Rightarrow x^2 = (2 - x)^2$

$x = \pm (2 - x)$

$x = 1$ m

i.e., the position of third charge is at 1 m from either charge

'q'.

For equilibrium of q at A, Force due to Q & q at B should be balanced.

$$\frac{1}{4\pi\epsilon_0}\frac{qQ}{1^2} = \frac{1}{4\pi\epsilon_0}\frac{qq}{2^2}$$

$\Rightarrow Q = \frac{-q}{4}$

So, nature of Q is negative.

15. Two charged particles having each charge $2 \times 10^{-8} C$ each are joined by an insulating string of length 1m and the system is kept on a frictionless horizontal table, what is the tension in the string?

(A) 3.6×10^{-6} N
(B) 3.4×10^{-6} N
(C) 4×10^{-7} N
(D) 4×10^{-4} N

Ans. (A) $q_1 = q_2 = 2\times 10^{-8}$ C, $r = 1$ m
Tension in the string is equal to the force between the two charges.
According to Coulomb's law,

$$F = \frac{Kq_1q_2}{r^2}$$

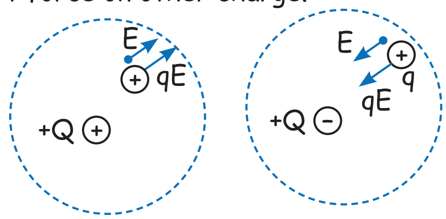
$$= \frac{9\times10^9 \times (2\times10^{-8})^2}{(1)^2} = 3.6 \times 10^{-6} \text{ N}$$

7. ELECTRIC FIELD AND FORCE ON PARTICLE

(A) Electric Field

What is field?

- It is a 3D space around a charge in which it can exert force on other charge.



- "Electric field of a isolated charge extends to infinity"

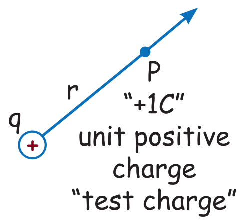
(B) Electric Field Intensity "$\vec{E}$ or $\vec{I}$"

Intensity of electric field due to point charge

- Electric field intensity is defined as "force on unit test charge"

"Kisi bhi charge ki Capacity kya hai +1C ke upar force lagane ki → Electric field Intensity."

$$\vec{E} = \frac{\vec{F}}{q}$$



$$\boxed{\vec{E} = \frac{kq(1)}{r^2}} \quad \boxed{|E| = \frac{kq}{r^2}}$$

$\therefore$ $|\vec{E}|$ due to +q charge at distance r.

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

Unit: (N/C) & (V/m)

Note: It is a Vector Quantity

Dimension : $\frac{MLT^{-2}}{AT} = [MLT^{-3}A^{-1}]$

TRICK:

Jahan E.F. nikalna ho vahan 1 C charge rakh kar us par force nikal do vahi E.F. hoga, keval unit ka dhyan rakho

IMPORTANT POINT:

q_0 is having its own electric field so to neglect that q_0 is taken as very very small, hence E.F. can be redefined as

$$\boxed{E.F. = \lim_{q_0 \to 0}\left[\frac{F}{q_0}\right]}$$

(C) Electric Field in Cartesian Form (x, y, z)

Vector quantity

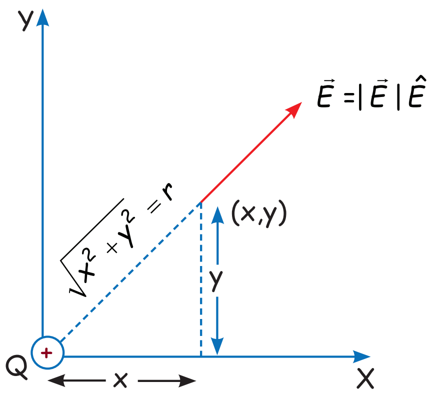
(Magnitude & direction)

Magnitude of $\vec{E} = \frac{kQ}{r^2} = \frac{kQ}{\left(\sqrt{x^2+y^2}\right)^2} = \frac{kQ}{(x^2+y^2)}$

direction of $\overrightarrow{EF} = \hat{E} = \hat{r} = \frac{x\hat{i}+y\hat{j}}{\left(\sqrt{x^2+y^2}\right)}$

(direction $\hat{E} = \hat{r}$)

$$\hat{r} = \frac{\vec{r}}{|r|}$$



$$\vec{E} = \frac{kQ}{(x^2+y^2)} \frac{(x\hat{i}+y\hat{j})}{(x^2+y^2)^{\frac{1}{2}}} = \frac{kQ(x\hat{i}+y\hat{j})}{(x^2+y^2)^{\frac{3}{2}}}$$

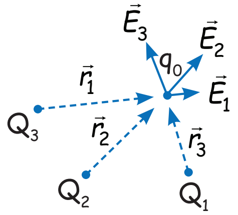
(D) EF is a vector quantity and follow Superposition principle

Electric Field due to System of Charges:

$$\vec{E}_P = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

$$\vec{E}_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1^2}\hat{r}_1 + \frac{Q_2}{r_2^2}\hat{r}_2 + \frac{Q_3}{r_3^2}\hat{r}_3\right]$$

Put Q_1, Q_2, Q_3 with sign



(E) Force on a charge particle in External field

If charge q is present in Electric Field ($\vec{E}$) then for $\vec{F}$ on q charge will be

$\boxed{\vec{F} = q\vec{E}}$ Put q with sign

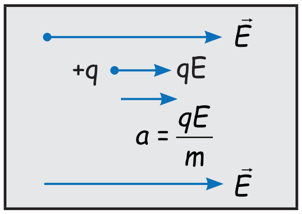
If q is +ve then force will be in the direction of $\vec{E}$

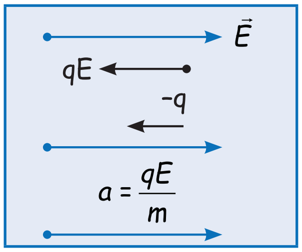
If q is –ve then force will be in the opposite direction of $\vec{E}$

- acc of charge particle $|a| = \frac{F}{m} = \frac{qF}{m}$ in $\vec{E}$

  If a charge is placed in electric field y definition:-

$$\boxed{\vec{E} = \frac{\vec{F}}{q} \Rightarrow \vec{F} = q\vec{E}}$$





- **Stopping distance and stopping time**

  |F| = qE

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

Stopping time

v = u + at

$0 = v_0 - \frac{qEt}{m}$

$t = \frac{mv_0}{qE}$

Stopping distance

$v^2 - u^2 = 2as$

$0^2 - v_0^2 = 2\left(\frac{-qE}{m}\right)x$

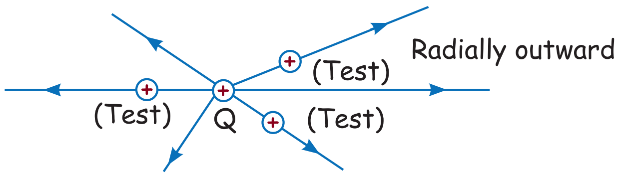
$x = \frac{mv_0^2}{2qE}$

8. ELECTRIC FIELD LINES

What are Electric Filed Lines?

3D space around a charge in which it can exert force

We use imaginary lines to represent the direction in which force will act.

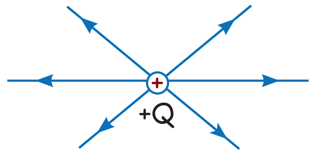


EFL = EF lines are the lines tangent to which we get the direction of EF.

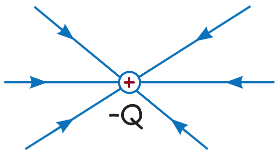
ELECTRIC FIELD LINES PROPERTIES

1. Origination and Termination

EFL always originate from +ve charge & termiante at –ve charge



Originate

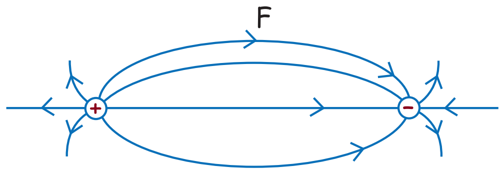


Terminate

2. Looping

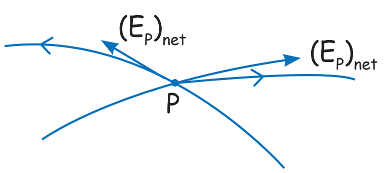
It never form close loop always Originate = +ve

Terminate = – ve

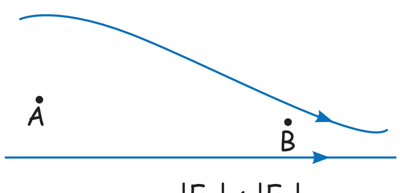


3. No intersection

No two electric field lines can intersect each other. If they do so then their will be two direction of net electric field at the intersection point which is not possible



4. Relative spacing between lines



$|E_A| < |E_B|$

EF intensity $\propto \frac{1}{\text{spacing}}$

Spacing↑ $|\vec{E}|$ ↓

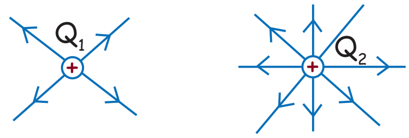
Spacing ↓ $|E|$ ↑

5. Line density

The charge with larger magnitudes will have more number of EF lines.

Ex:-

(charge ∝ no. of lines)



No. of lines = 4   No. of lines = 8

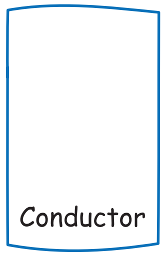
$Q_2 > Q_1$

EF inside conductor:- (always zero) (only e– can move)

Conductor → Material in which outer e^- is free to move

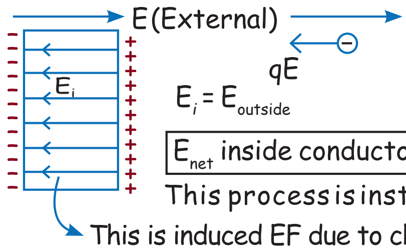
(If has infinite no of free e^-)

(a)



Neutral Conductor

(b)



$E_i = E_{outside}$

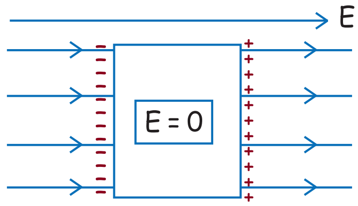
E_{net} inside conductor = 0

This process is instantaneous

This is induced EF due to charge distribution.

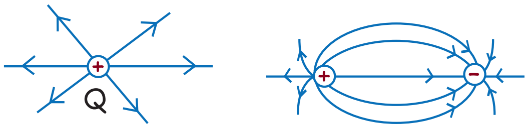
Field perpendicular to surface of conductor:-

EF is always ⊥ to surface of conductor.



Continuity and differentiability:-

EFL should be continuous & differentiable equations



1 Electric Charges and Fields

MOST RELEVANT BOARD LEVEL PROBLEMS

Multiple Choice Questions (MCQ)

1. Two charged particles having each charge $2 \times 10^{-8} C$ each are joined by an insulating string of length 1m and the system is kept on a frictionless horizontal table, what is the tension in the string?

(*a*) $3.6 \times 10^{-6} N$ (*b*) $3.4 \times 10^{-6} N$
(*c*) $4 \times 10^{-7} N$ (*d*) $4 \times 10^{-4} N$

Sol. (*a*) $q_1 = q_2 = 2 \times 10^{-8}$C, $r = 1$ m

Tension in the string is equal to the force between the two charges.

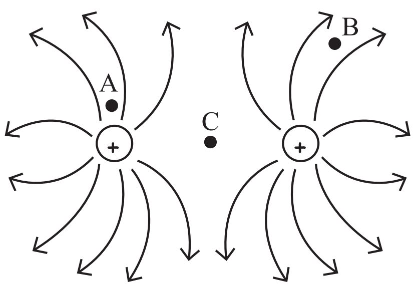
According to coulomb's law

$$F = \frac{k q_1 q_2}{r^2} = \frac{9\times10^9 \times (2\times10^{-8})^2}{(1)^2}$$

$= 3.6 \times 10^{-6}$ N.

2. Electric field lines are pictorial representations of electric fields due to static charges on the plane of a paper.

(CBSE CFPQ, 2023)



Study the given electric field representation and identify one INCORRECT qualitative impression given by this representation.

(*a*) The electric field at point *A* is stronger than at point *B*.
(*b*) The electric field distribution is two-dimensional.
(*c*) The electric field at point *C* is zero.
(*d*) The electric field always points away from a positive charge.

Sol. (*b*) The electric field distribution is not two-dimensional. It exist in 3D space around change.

3. Amount of work done in moving an electric charge Q_1 once round a circle of radius R with a charge Q_2 at the center of the circle is

(*a*) $\frac{Q_1Q_2}{4\pi\varepsilon_o R}$ (*b*) ∞
(*c*) $\frac{Q_1Q_2}{4\pi\varepsilon_o R^2}$ (*d*) Zero

Sol. (*d*) Electrostatic force is a conservative force so work done in carrying an electric charge Q, once around a circle is zero.

4. An electric dipole has a dipole moment of 3×10^{-9} C m and is positioned in a uniform electric field. If the electric field strength is 2×10^3 N/C and the dipole is initially in an unstable equilibrium, how much work is required to move it to a stable equilibrium?

(*a*) Zero (*b*) 1.2×10^{-5} J
(*c*) 2.4×10^{-5} J (*d*) -1.2×10^{-5} J

Sol. (*d*) -1.2×10^{-5}J

The work done is rotating an electric dipole from an unstable equilibrium to a stable equilibrium in a uniform electric field is given by the formula:

Work done (W) = PE $\cos(\theta_1 - \theta_2)$

where,

Dipole moment (P) = 3×10^{-9} cm

Electric field (E) = 2×10^3 N/C

θ_1 is the angle at unstable equilibrium, which is 180.

θ_2 is the angle at stable equilibrium which is 0.

Plugging in these values,

Work Done (W) = PE $(\cos\theta_1 - \cos\theta_2)$N/C

Work Done (W) = $3 \times 10^{-9} \times 2 \times 10^3$ (cos 180° – cosθ°)

$= 3 \times 10^{-9} \times 2 \times 10^3 [(-1) - (1)]$

$= 6 \times 10^{-6} [(-1) - (1)] = -1.2 \times 10^{-5}$T

So, the work done is rotating the dipole to a position of stable equilibrium is -1.2×10^{-5} J

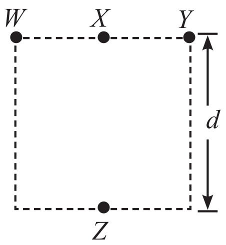
5. Force between two unit pole strength placed at a distance of one metre is

(*a*) 1 N (*b*) $\frac{10^{-7}}{4\pi}N$

(*c*) 10^{-7} N (*d*) $4\pi \times 10^{-7}$ N

Sol. (*c*) $F = 10^{-7} \times \frac{m^2}{r^2} = \frac{10^{-7}(1)^2}{(1)^2} = 10^{-7}$ N

6. For object W, X, Y and Z each with charge +q are held fixed at four points of a square of side d as shown in the figure. Objects X and Z are on the midpoints of the sides of the square. The electrostatic force exerted by object W on object X is F. Then the magnitude of the force exerted by object W on Z is **(CBSE, 2021-22)**



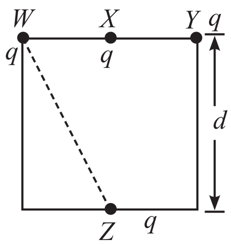
(*a*) $\frac{F}{7}$ (*b*) $\frac{F}{5}$

(*c*) $\frac{F}{3}$ (*d*) $\frac{F}{2}$

Sol. (*b*) Force on X by W is F.

Force on X by W is F.

$$F = \frac{Kq^2}{\left(\frac{d}{2}\right)^2} = \frac{4Kq^2}{d^2} \quad ...(i)$$



Force on Z by W,

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

$$F' = \frac{Kq^2}{\left(\sqrt{\frac{5d^2}{4}}\right)^2} = \frac{Kq^2 \times 4}{5d^2} = \frac{1}{5}F \quad \text{(Using (}i\text{))}$$

7. An electric dipole placed in a non-uniform electric field can experience **(CBSE, 2020)**

(*a*) a force but not a torque

(*b*) a torque but not a force

(*c*) always a force and a torque

(*d*) neither a force nor a torque

Sol. (*c*) An electric dipole in a non-uniform electric field always experience a force and a torque.

8. The electric flux through a closed Gaussian surface depends upon **(CBSE, 2020)**

(*a*) net charge enclosed and permittivity of the medium

(*b*) net charge enclosed, permittivity of the medium and the size of the Gaussain surface

(*c*) net charge enclosed only

(*d*) permittivity of the medium only.

Sol. (*a*) Net charge enclosed and permittivity of the medium.

Assertion and Reason Type Questions

Direction: The following questions consist of two statements– Assertion (A) and Reason (R). Answer these questions by selecting the appropriate option given below:

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

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

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

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

9. **Assertion (A):** A charged metallic shell may have charged particle inside it.

Reason (R): There can't exist electric field lines inside the conductor.

Sol. (*b*) A charge conductor may initially have a charged particle inside it but since E field inside it is always zero so it gets redistributed on the outer surface.

10. **Assertion (A):** Charge is invariant.

Reason (R): Charge does not depend on speed or frame of reference.

Sol. (*a*) Charge is invariant as it is independent of frame of reference. It is a fixed quantity.

Very Short Answer Type Questions

11. What does the statement, "The electric field of a point charge exhibits spherical symmetry, while that of an electric dipole displays cylindrical symmetry," signify?

Sol. The electric field produced by a point charge q at a distance r is described by the formula $E = -\frac{q}{4\pi\varepsilon_0 r^2}$

Importantly, this fields magnitude remains constant at all points along the surface of a sphere with a radius of r centered around the point charge. It is independent of the direction of the vector r. Consequently the field lines created by a point charge exhibit spherical symmetry.

For an electric dipole, the electric field at a distance r along the equitorial line, denoted by p, is expressed as $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{P}{(r^2 + a^2)^{\frac{3}{2}}}$

The electric field $\vec{E}$ remains uniform at all location situated along a cylinder with a radius r aligned along the dipoles axis. Additionally the field's appearance remains consistent within all planes intersecting the dipole axis. This observation leads us to describe the electric field generated by an electric dipole as possessing cylindrical symmetry.

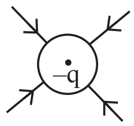
12. A point charge causes an electric flux -3×10^{-16} N-m^2/C to pass through a spherical Gaussian surface.

(*a*) Calculate the value of the point charge.

(*b*) If the radius of the Gaussian surface is doubled, how much flux would pass through the surface?

Sol. (*a*) By Gauss' theorem, total electric flux through closed Gaussian surface is

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



$\therefore \ \theta = \phi\varepsilon_0$

By electric flux passing through the surface,

$\phi = -3 \times 10^{-16}$ N–m^2/C

$\therefore \ q = (-3 \times 10^{-16}) \times 8.85 \times 10^{-12}$

$= -26.55 \times 10^{-28}$ C

(*b*) The electric flux passing through the surface remains constant, as it is solely determined by the enclosed charge and is not influenced by the size of the surface.

13. An electric dipole of length 4cm when placed with its axis making an angle of 60° with a uniform electric field, experience a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge ± 8 nC. **(Delhi 2014)**

Sol. Given, length 2a = 4 cm = 4×10^{-2} m

Angle, $\theta = 60°$

Torque, $\tau = 4\sqrt{3}$ Nm

We know that, $\tau = Q(2a)\, E \sin\theta$

$$\text{Electric field, } E = \frac{\tau}{Q(2a)\sin\theta}$$

$$= \frac{4\sqrt{3}}{8\times10^{-9}\times4\times10^{-2}\times\sin 60°}\text{ N/C}$$

$= 2.5 \times 10^{10}$ N/C

$\therefore$ Potential energy, C $= -pE\cos\theta$

$= -Q(2a)\, E\cos\theta$

$$U = -8\times10^{-9}\times4\times10^{-2}\times\frac{4\sqrt{3}\times\cos 60°}{8\times10^{-9}\times4\times10^{-2}\times\sin 60°}$$

$$= \frac{-4\sqrt{3}}{\sqrt{3}}\text{ J} = -4\text{ J}$$

Short Answer Type Questions

14. A particle of charge 2 μC and mass 1.6 g is moving with a velocity $4\hat{i}\ \text{ms}^{-1}$. At t = 0 the particle enters in a region having an electric field E (in N C^{-1}) = $80\hat{i} + 60\hat{j}$. Find the velocity of the particle at t = 5s. **(CBSE, 2020)**

Sol. Given $q = 2\mu$C, $m = 1.6$ g $= 10^{-3}$ kg.

$u = 4\hat{i}\ \text{m s}^{-1},\ \vec{E} = 80\hat{i} + 60\hat{j}$ and $t = 5\,s$

$F = m\vec{a}$

or $q\vec{E} = m\vec{a}$

$\Rightarrow \ 2\times10^{-6}(80\hat{i} + 60\hat{j}) = (1.6\times10^{-3})\vec{a}$

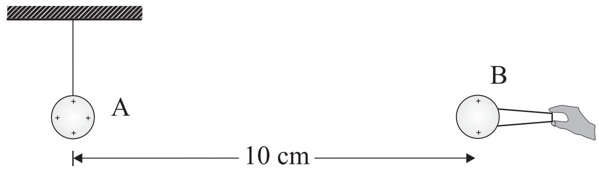
$\Rightarrow \ \vec{a} = 100\times10^{-3}\hat{i} + 75\times10^{-3}\hat{j}$

Now from equation of motion,

$\vec{v} = \vec{u} + \vec{a}t = 4\hat{i} + (100\times10^{-3}\hat{i} + 75\times10^{-3}\hat{j})5$

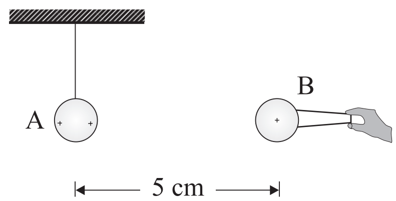
$= 4.5\hat{i} + 0.375\hat{j}$

15. A charged metallic sphere A is suspended by a nylon thread. Another charged metallic sphere B held by an insulating handle is brought close to A such that the distance between their centres is 10 cm, as shown in Fig. (a). The resulting repulsion of A is noted (for example, by shining a beam of light and measuring the deflection of its shadow on a screen). Spheres A and B are touched by uncharged spheres *C* and *D* respectively, as shown in Fig. (b). C and D are then removed and B is brought closer to A to a distance of 5.0 cm between their centres, as shown in Fig. (c). What is the expected repulsion of A on the basis of Coulomb's law? Spheres *A* and *C* and spheres *B* and *D* have identical sizes. Ignore the sizes of A and B in comparison to the separation between their centres. **(NCERT Intext)**



(a)

(b)



(c)

Sol. Let the original charge on sphere *A* be *q* and that on *B* be *q*′. At a distance *r* between their centres, the magnitude of the electrostatic force on each is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{qq'}{r^2}$$

neglecting the sizes of spheres *A* and *B* in comparison to *r*. When an identical but uncharged sphere *C* touches *A*, the charges redistribute on *A* and *C* and, by symmetry, each sphere carries a charge *q*/2. Similarly, after *D* touches *B*. the redistributed charge on each is *q*′/2.

Now, if the separation between A and B is halved, the magnitude of the electrostatic force on each is

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{(q/2)(q'/2)}{(r/2)^2} = \frac{1}{4\pi\varepsilon_0}\frac{(qq')}{r^2} = F$$

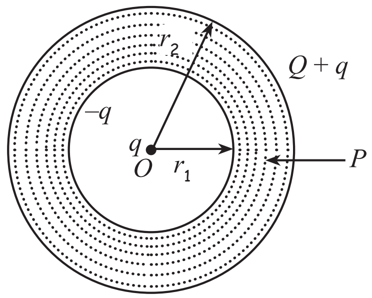
Thus the electrostatic force on A, due to B, remains unaltered.

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

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

(*b*) Is the electric field inside a cavity (with no charge) zero; independent of the fact whether the shell is spherical or not? Explain. **(CBSE, 2019)**

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



Surface charge density at the inner surface of the shell is given by the relation,

$$\sigma_1 = \frac{\text{Total charge}}{\text{Inner surface area}} = \frac{-q}{4\pi r_1^2}$$

A charge of $+q$ is induced on the outer surface of the shell. A charge of magnitude Q is placed on the outer surface of the shell. Therefore, total charge on the outer surface of the shell is $Q + q$. Surface charge density at the outer surface of the shell,

$$\sigma_2 = \frac{\text{Total charge}}{\text{Outer surface area}} = \frac{Q+q}{4\pi r_2^2}$$

(*b*) Yes

The electric field intensity inside a cavity is zero, even if the shell is not spherical and has any irregular shape. Take a closed loop such that a part of it is inside the cavity along a field line while the rest is inside the conductor. Net work done by the field in carrying a test charge over a closed loop is zero because the field inside the conductor is zero. Hence, electric field is zero, whatever is the shape.

Case Based Type Questions

17. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly, he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped Dr.Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child. **(CBSE Delhi 2013)**

Answer the following questions based on the above information.

(*i*) Why is it safer to sit inside a car during a thunderstorm?

(*ii*) Which two values are displayed by Dr. Pathak in his action?

(*iii*) Which values are reflected in parents response to Dr. Pathak?

(*iv*) Give an example of similar action on your part in the past from everyday life.

Sol. (*i*) It is safer to be set inside a car during thunderstorm because the car acts like a Faraday cage. The metal in the car will shield you from any external electric fields and thus prevent the lightning from traveling within the car.

(*ii*) Awareness and humanity

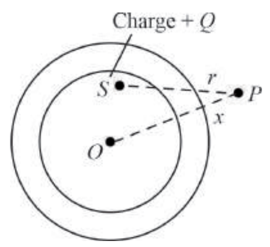
(*iii*) Gratitude and obliged

(*iv*) I once came across to a situation where a puppy was stuck in the middle of a busy road during rain and was not able to go cross due to heavy flow, so I quickly rushed and helped him.

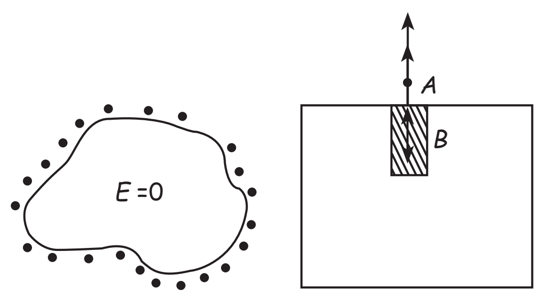
Long Answer Type Questions

18. (*a*) A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $\left(\frac{\sigma}{2\varepsilon_0}\right)\hat{n}$, where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.

(*b*) The figure shows a charge $+Q$ held on an insulating support S and enclosed by a hollow spherical conductor. O represents the centre of the spherical conductor and P is a point such that $OP = x$ and $SP = r$. Find the electric field at point P.



Sol. (*a*) Inside a charged conductor, the electric field is zero.



Physics Wallah **Set-1**

Series SR5QP/5

प्रश्न-पत्र कोड
Q.P. Code **55/5/3**

रोल नं.
Roll No.

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें।

Candidates must write the Q.P. Code on the title page of the answer-book.

नोट

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **8** हैं।

(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं।

(III) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें।

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में प्रश्न का क्रमांक अवश्य लिखें।**

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है। प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा। 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे।

NOTE

(I) Please check that this question paper contains **8** printed pages.

(II) Please check that this question paper contains **33** questions.

(III) Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(IV) **Please write down the serial number of the question in the answer-book before attempting it.**

(V) 15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

भौतिक विज्ञान (सैद्धांतिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे — *अधिकतम अंक : 70*

Time allowed : 3 hours — *Maximum Marks : 70*

The dielectric material between the two plates is made of a soft material and is compressible. The combination of the two plates and the dielectric between them constitutes a capacitor.

Each key on the keyboard when pressed is recognized due to which one of the following factors?

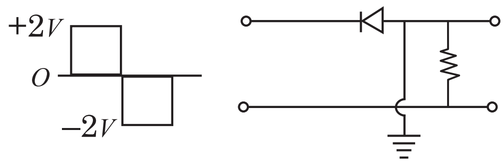
(a) The pressing of the key increases the capacitance of the capacitor below the key due to a decrease in separation between the plates.

(b) The decrease in the thickness of the soft dielectric layer decreases the capacitance of the capacitor below the key.

(c) The momentary decrease in the space between the plates of the capacitor is detected as a mechanical sound signal of a specific frequency.

(d) all of the above

2. A ideal diode and a resistor are connected to an ac source as shown.



Input Output

The input voltage is a square wave as shown above. What will be output across the resistor?

(a) Only +2 V (b) Only –2 V (c) Either 0 V or +2 V (d) Either 0 V or -2 V

3. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon the **1**

(a) rate at which current change in the two coils

(b) relative position and orientation of the coils

(c) rate at which voltage induced across two coils

(d) currents in the two coils

4. An electron is released from rest in a region of uniform electric and magnetic fields acting parallel to each other. The electron will **1**

(a) move in a straight line. (b) move in a circle.

(c) remain stationary. (d) move in a helical path.

5. Read the following statements carefully:

I. Steel has high retentivity, high coercivity, and high permeability.

II. Soft iron has higher permeability, lower retentivity, and lower hysteresis loss compared to steel.

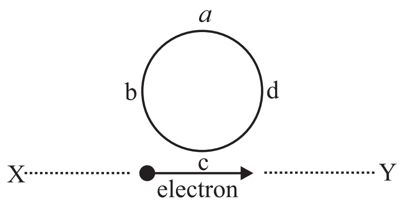
III. Amorphous metals are non-crystalline solids of very high resistivity and allow very less hysteresis losses (example: an alloy of Fe, Ni, Co and glass). Their B-H (net field Vs. magnetizing field) curve is very narrow.

Based on the above material-specific properties, identify which materials are MOST suitable for the given electrical applications. **1**

I. Steel	A. Transformer core
II. Soft iron	B. Permanent magnets
III. Amorphous metals	C. Electromagnet

(a) I-A, B : II-B, C : III-C, A
(b) I-B : II-C : III-A
(c) I-B : II-C, A : III- A, B
(d) I-A : II-C : III-B

6. An electron moves on a straight line path XY as shown. The abcd is a coil adjacent to the path of electron. What will be the direction of current, if any, induced in the coil? **1**



(a) No current induced
(b) abcd
(c) adcd
(d) The current will reverse its direction as the electron goes past the coil

7. Which of the following is not a property of a semiconductor diode? **1**
(a) It allows current to flow in one direction only.
(b) It has a high resistance in the reverse direction.
(c) It emits light when a current flows through it.
(d) It converts AC to DC.

8. An magnetic field $\vec{B}$ and electric field $\vec{E}$ exist in region. The field are not perpendicular to each other, then **1**
(a) No electromagnetic wave is passing through the region
(b) Data insufficient
(c) An electromagnetic wave may be passing through the region
(d) An electromagnetic wave is certainly passing through the region

9. Plano-concave lens having focal length –10 cm, then its focal length when its plane surface is polished is (n = 3/2) **1**
(a) 40 cm
(b) – 10 cm
(c) 5 cm
(d) None of these

10. Interference was observed in interference chamber where air was present, now the chamber is evacuated, and if the same light is used, a careful observer will see **1**
(a) No interference
(b) Interference with brighter bands
(c) Interference with dark bands
(d) Interference with larger width

11. Find average life time of radium if half life is 2000 years. **1**
(a) 1550 year
(b) 4000 year
(c) 3000 year
(d) 2886 year

12. The energy of an electron in an excited hydrogen atom is –3.4 eV. Calculate the angular momentum of the electron according to Bohr's theory. ($h = 6.6 \times 10^{-34}$ J-s) **1**
(a) 3×10^{-32} J-s
(b) 2.1×10^{-34} J-s
(c) 4×10^{-34} J-s
(d) None of these

About The Author

Rajwant Singh Sir, affectionately known to many as RJ Sir, is a distinguished alumnus of IIT Dhanbad, where he achieved both his bachelor's and master's degrees in Physics. Following his academia, he served as a meteorologist at the Indian Meteorological Department (IMD), enriching his expertise with practical experience. With over nine years dedicated to teaching JEE Main, Advanced, and Olympiad aspirants, RJ Sir's pedagogical journey is marked by a profound commitment to enriching students' understanding of physics. Drawing inspiration from the venerable HC Verma Sir, RJ Sir aspires to create a pedagogical masterpiece that transcends conventional learning. His forthcoming book is a testament to this vision, meticulously designed to challenge and cultivate critical thinking and analytical prowess among students. Through his work, RJ Sir aims to not merely educate but to inspire a perpetual passion for physics, equipping learners with the intellectual toolkit necessary for navigating the intricacies of the subject. RJ Sir's philosophy is grounded in the empowerment of students, believing firmly in unlocking their potential and kindling an enduring love for learning. His approach is emblematic of a teacher who does not just instruct but transforms, leaving a lasting impact on the minds and hearts of those he guides.

Gagan sir, from a small town of Haryana is extremely humble and grounded personality, with his generosity reflecting his family values. He completed his B.tech in Mechanical Engineering from Thapar university where his life took a turn towards teaching. Gagan sir, have mentored and taught students with a vision of providing quality education and firmly believes in simplifying the topic till the level of student. He has worked with renowned organisations and is known for his fabulous one-shots live classes, providing content for the mass audience. Currently, part of Physics Wallah he is providing quality content through his power-packed lectures and now-presenting his long time work within this book as an Author. Gagan keep rocking as a teacher and has tried to compile his life-long teaching-learning experiences through the medium of this book.

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