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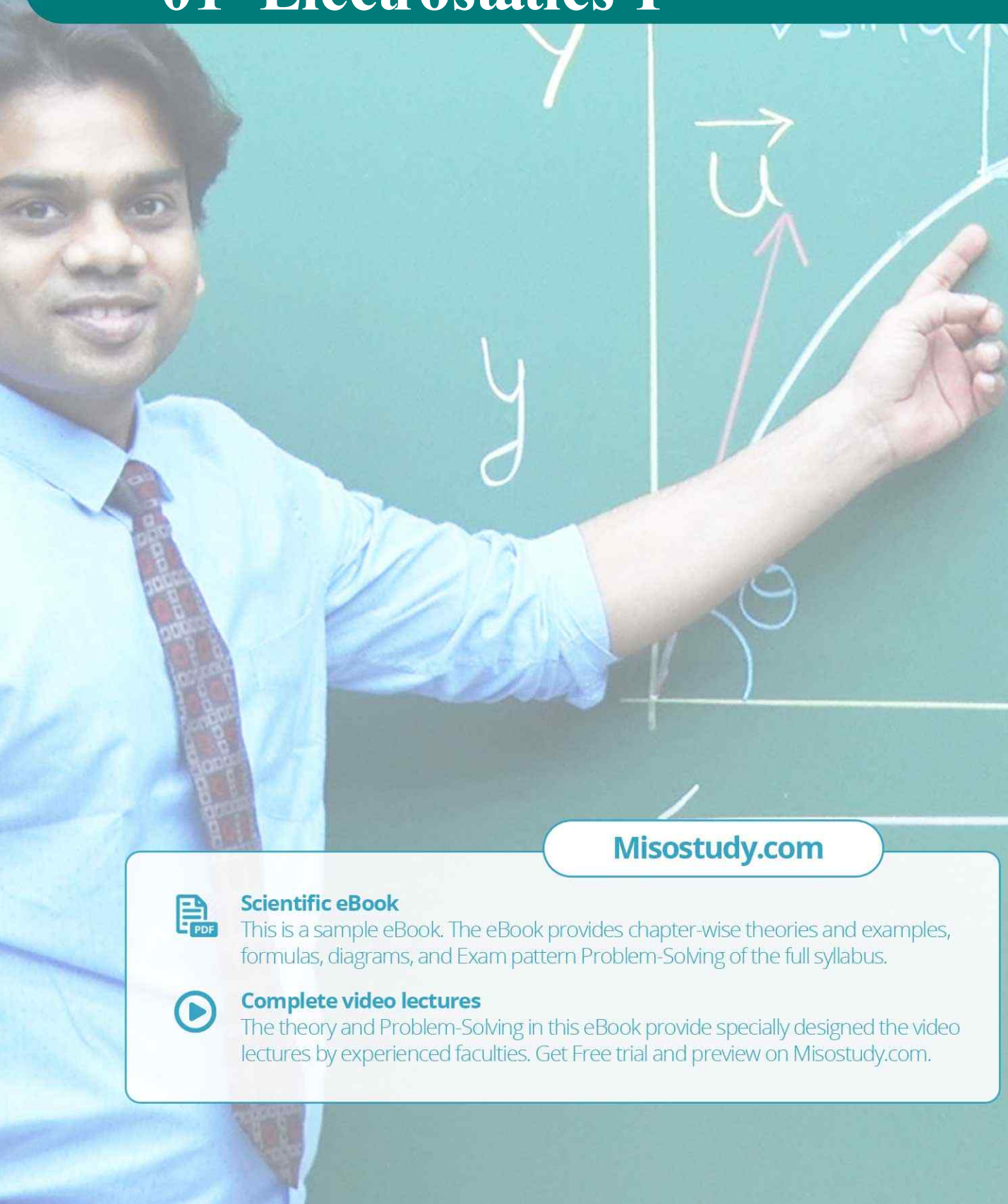
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Class 12 | Physics

01 Electrostatics-I

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01. Introduction

Electrostatics, deals with the study of charges in rest. These stationary charges occurs due to friction of two insulting bodies, therefore it is often called frictional electricity.

Important points

(i)   Gravitational force is the weakest while nuclear force is the strongest force of the nature

(ii) Nuclear force does not depend upon charge, it acts equally between proton-proton, proton neutron and neutron-neutron.

(iii) There are weak forces acting in β-degradiation in radio-activity.

(iv) A stationary charge produces electric filed while a moving charge produce electric as well as magnetic field.

(v)   Moving charge produce electric field as well as magnetic field but does not radiate energy while uniform acceleration.

(vi) Accelerated charge produce electric field as well as magnetic field and radiate energy.

02. Charge

Property of a substance by virtue of which it can repel or attract another charged substance.

Charges are of two types

(a) Positive charge : Lesser number of electrons than number of protons.

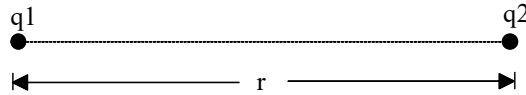**(b) Negative charge :** More number of electrons than number of protons

Importants Points : Only, electron is responsible for a substance to be charged and not the proton.

Properties of Charge

(i)   Like charges repel while unlike charges attract each other.

(ii) Charge is quantized in nature i.e. The magnitude of charge possessed by different objects is always and integral multiple of charge of electron (or proton) i.e. $q = \pm ne$ where n = 1, 2, 3 ....

(iii) The minimum possible charge that can exist in nature is the charge of electron which has a magnitude of e $= 1.60207 \times 10^{-19}$ coulomb. This is also known as quantum of charge or fundamental charge.

(iv) In an isolated system the algebraic sum of total charge remains constant. This is the law of 'Conservation of charge'.

03. Coulomb's Las

The force of attraction or repulsion between two stationary point charges is directly proportional to the product of charges and inversely proportional to the square of distance between them. This force acts along the line joining the two. If q_1 & q_2 are charges in consideration r, the distance between them and F, the force acting between them

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Then, $F \propto q_1 q_2$

$\qquad F \propto 1/r^2$

$\therefore \qquad F \propto \dfrac{q_1 q_2}{r^2}$

$\Rightarrow \qquad F = K \dfrac{q_1 q_2}{r^2}$, where $k =$ constant.

$\qquad K = \dfrac{1}{4\pi\varepsilon_0\varepsilon_r} = \dfrac{9 \times 10^9}{\varepsilon_r} N\,m^2 C^{-2}$

where,

$\quad \varepsilon_0 =$ Electric permittivity of vacuum or air

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

$\quad K$ or $\varepsilon_r =$ Relative permittivity or Dielectric constant or Specific inductive capacity
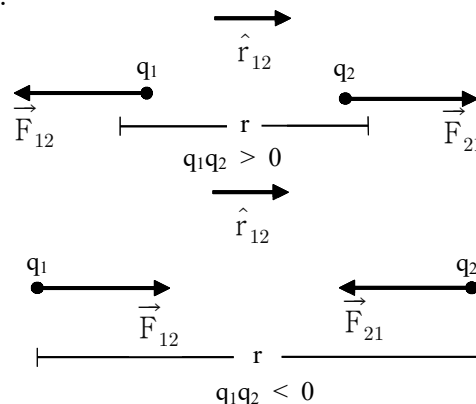
$\quad \varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0} \Rightarrow \varepsilon = \varepsilon_0\varepsilon_r$

[Newton's law for particles is analogous to coulomb's law for rest charge. The difference is that Newton's law gives attraction force while coulomb's law gives attraction as well as repulsion force]

NOTE ☞   (i)   Coulomb's law is applicable to point charges only. But it can be applied for distributed charges also

         (ii)   This law is valid only for stationary charges and cannot be applied for moving charges.

         (iii)   This law is valid only if the distance between two charges is not less than 10^{-15} m

Direction

Direction of the force acting between two charges depends upon their nature and it is along the line joining two charges.

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$\vec{F}_{21}$ = force on q_2 due to q_1

$$\vec{F}_{21} = \frac{q_1 q_2}{4\pi\varepsilon_0\varepsilon_r r_{12}^2}\hat{r}_{12} \qquad ....(A)$$

(where $\hat{r}_{12}$ is a unit vector pointing from q_1 to q_2)

$\vec{F}_{12}$ = Force on q_1 due to q_2

$$\vec{F}_{12} = \frac{q_1 q_2}{4\pi\varepsilon_0\varepsilon_r r_{12}^2}\hat{r}_{21} \qquad ....(B)$$

(where $\hat{r}_{21}$ is a unit vector pointing from q_2 to q_1)

$\Rightarrow$ Electric force between two charges not depends on neighbouring charges.

$\Rightarrow$ If a dielectric slab $(\in_r)$ of thickness 't' is placed between two charges (distance d), force decreases.

$$F = \frac{Q_1 Q_2}{4\pi\in_0 r^2} \qquad \text{where } r = d - t + t\sqrt{\in_r}$$

04. Electric Field

A charge produces something called and electric field in the space around it and this electric field exerts a force on any charge placed in it.
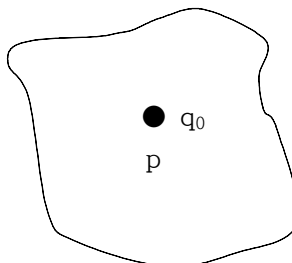

NOTE ☞ The electric field does not exert force on source charge.

Electric field Intensity

Force experienced by a unit positive charge placed in and electric field at a point is called electric field intensity at that point. It is also known as electric field simply. Let q_0 be the positive test charge placed in an electric field. If $\vec{F}$ is the force experienced by this charge, then

$$\vec{E} = \lim_{q_0 \to 0}\frac{\vec{F}}{q_0}$$

(i)   Unit : N/C or volt/metre

(ii) This is a vector quantity and its direction is the same as force on the positive test charge.

(iii) Since $\vec{E}$ is the force on unit charge, force on charge q is. $\vec{F} = q\vec{E}$.

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(iv) Dimension is $[M^1L^1T^{-3}A^{-1}]$

(v) Electric field due to a point charge is

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

(vi) Direction of electric field due to positive charge is away from charge while direction of electric field due to negative charge is towards the charge.
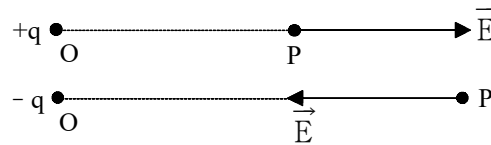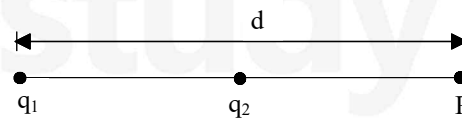

Special point

(a) If q_1 and q_2 are at a distance r and both have the same type of charge, then the distance 'd' of the point from q_1 where electric field is zero is given by $d = \dfrac{\sqrt{q_1}\, r}{\left(\sqrt{q_1} + \sqrt{q_2}\right)}$. This point will lie between line joining q_1 & q_2.
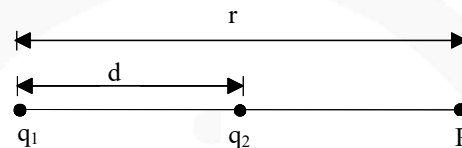
(b) If q_1 and q_2 have opposite charges then distance 'd' of the point 'p' from q_1 where electric field is zero is given by

$$d = \frac{\sqrt{q_1}\, r}{\sqrt{q_1} - \sqrt{q_2}}, \qquad \left[|q_1| > |q_2|\right]$$

(c) There charges $+Q_1$, $+Q_2$ and q are placed on a straight line. If this system of charges is in equillibrium, charge q should be a given

$$q = \frac{Q_1 Q_2}{\left(\sqrt{Q_1} + \sqrt{Q_2}\right)^2}$$

$\Rightarrow$ For measuring $\vec{E}$ practically a test charge (+ve) of magnitude much less than the source charge should be used.

$\Rightarrow$ Electric force on a charge in uniform E is constant and hence acceleration is constant, so equations of motion can be used

(acceleration $a = \dfrac{qE}{m}$)

$\Rightarrow$ Electric field due to linear charge distribution (a) Finite wire

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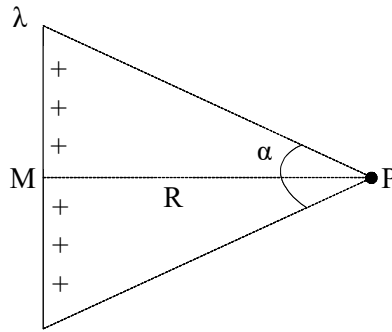
(d) Finite wire

$$E_p = \frac{2k\lambda}{R} \sin\frac{\alpha}{2}$$

(e) Infinite wire ($\alpha = 180°$)
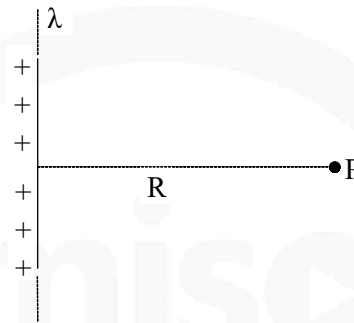
$$E_P = \frac{2k\lambda}{R}$$

(f) Charged arc
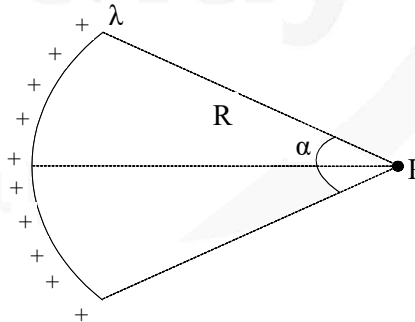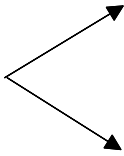
$$E_P = \frac{2k\lambda}{R} \sin\left(\frac{\alpha}{2}\right)$$

(g) Charged ring of radius R

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at and axial point $E_P = \dfrac{kQx}{(R^2+x^2)^{3/2}}$;

$$x >> R \implies E_P = \dfrac{kQ}{x^2}$$

If

$$x \ll R \implies E_P = \dfrac{kqx}{R^2}$$

As x is increases: $\vec{E}$ due to ring first ↑ then ↓ and at $X = \dfrac{R}{\sqrt{2}}$ it is maximum.

Electric lines of forces : (ELF)
The electric field in a region can be represented by drawing certain curves known as electric lines of force.
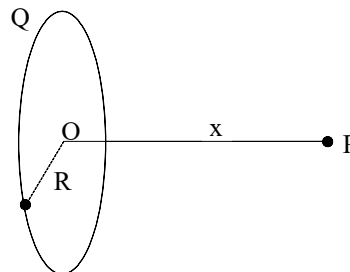An electric line of force is that imaginary smooth curve drawn in an electric field along which a free isolated unit positive charge moves.

Properties
(i)   Imaginary
(ii) Can never cross each other
(iii) Can nerver be closed loops
(iv) The number of lines originating or terminating on a charge is proportional to the magnitude of charge. In rationalised MKS $\left(\dfrac{1}{\varepsilon_0}\right)$ system electric lines are associated with unit charge, so if a body encloses q, total lines of force associated with it (called flux) will be q/ε_0.
(v)   Total lines of force may be fractional as lines of force are imaginary.
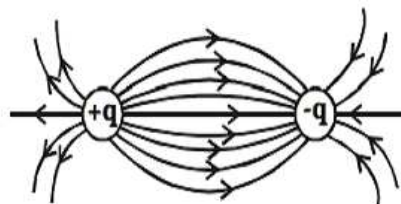
(vi)   Lines of force ends or starts normally at the surface of a conductor.
(vii) If there is no electric field there will be no lines of force.
(viii) Lines of force per unit area normal to the area at a point represents magnitude of intensity, crowded lines represent strong field while distant weak field.
(ix)   Tangent to the line of force at a point in an electric field gives the direction of intensity. So a positive charge free to move follow the line of force.

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05. Electric Dipole

(i) An system consisting of two equal and opposite charges separated by a small distance is termed and electric dipole.
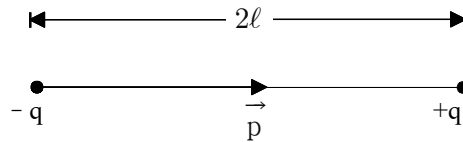
Example : Na^+Cl^-, H^+ Cl^- etc.

(ii) An isolated atom is not a dipole because centre of positive charge coincides with centre of negative centres. But if atom is placed in an electric field, then the positive and negative centres are displaced relative to each other and atom become a dipole.

(iii) DIPOLE MOMENT: The product of the magnitude of charges and distance between them is called the dipole moment.

It is denoted by $\vec{p}$ and $|\vec{p}| = q \times 2\ell$

(a) This is a vector quantity which is directed from negative to positive charge.

(b) Unit : C-m

(c) Dimension : $[M^0L^1T^1A^1]$

Electric field due to a dipole

(i) There are two components of electric field at any point

(a) $E_r \rightarrow$ in the direction of $\vec{r}$

(b) $E_\theta \rightarrow$ in the direction perpendicular to $\vec{r}$

$$E_r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p\cos\theta}{r^3}$$

$$E_\theta = \frac{1}{4\pi\varepsilon_0} \cdot \left(\frac{p\sin\theta}{r^3}\right)$$
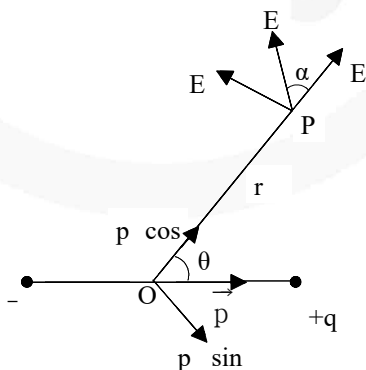
(i) Resultant

$$E = \sqrt{E_r^2 + E_\theta^2} = \frac{p}{4\pi\varepsilon_0 r^3}\sqrt{1 + 3\cos^2\theta}$$

(ii) Angle between the resultant $\vec{E}$ and $\vec{r}$, α given

by $\alpha = \tan^{-1}\left(\frac{E_\theta}{E_r}\right) = \tan^{-1}\left(\frac{1}{2}\tan\theta\right)$

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(iii) If $\theta = 0$, i.e point is on the axis -

$$E_{axis} = \frac{2kp}{r^3} \qquad (r \gg \ell)$$

(iv) If $\theta = 90^\circ$, i.e. point is on the line bisecting the dipole perpendicularly

$$E_{equatorial} = \frac{kp}{r^3} \qquad (r \gg \ell)$$

(v) So, $E_{axis} = 2E_{equatorial}$ (for same r)

(vi) $\qquad E_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\,pr}{\left(r^2 - \ell^2\right)^2}$

$$E_{equatorial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{\left(r^2 + \ell^2\right)^{3/2}}$$

where $p = q \cdot (2\ell)$

(vii)
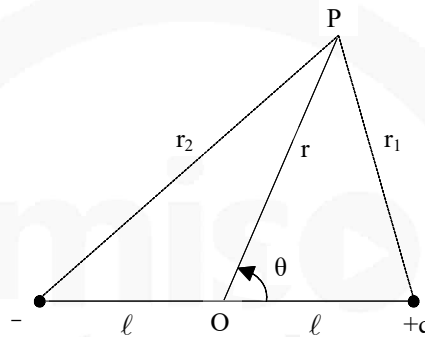
potential at a general point.

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

(viii) If $\theta = 0^\circ$, $V_{axis} = \dfrac{kp}{r^2}$

(ix) If $\theta = 90^\circ$, $V_{equator} = 0$

(x) Here we see that $V = 0$ but $E \neq 0$ for points at equatorial position.

(xi) Again, if $r \gg d$ is not true and $d = 2\ell$,

$$V_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{\left(r^2 - \ell^2\right)}$$

$$V_{equator} = 0$$

NOTE ☞ (i) **This is not essential that at a point, where E = 0, V will also be zero there eg. inside a uniformly charged sphere, E = 0 but V ≠ 0**

(ii) **Also if V = 0, it if not essential for E to be zero eg. in equatorial position of dipole V = 0, but E ≠ 0**

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Electric Dipole In an Electric Field – Uniform Electric Field

(i) When an electric dipole is placed in a uniform electric dipole, A torque acts on it which subjects the dipole to rotatory motion. This τ is given by $\tau = pE\sin\theta$ or $\vec{\tau} = \vec{p} \times \vec{E}$

(ii) Potential energy of the dipole
$$U = -pE\cos\theta = -\vec{p}.\vec{E}$$
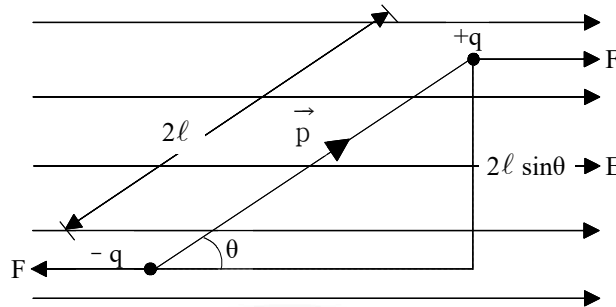
Cases

(a) If $\theta = 0º$, i.e. $\vec{p} \parallel \vec{E}, \tau = 0$ and $U = -pE$, dipole is in the minimum potential energy state and no torque acting on it and hence it is in the stable equilibium state.

(b) For $\theta = 180º$, i.e. $\vec{p}$ and $\vec{E}$ are in opposite direction, then $\tau = 0$ but $U = pE$ which is maximum potential energy state. Although it is in equilibium but it is not a stable state and a slight perturbation can disturb it.

(c) $\theta = 90°$, i.e. $\vec{p} \perp \vec{E}$, then
$\tau = pE$ (maximum) and $U = 0$

Work done in rotating an electric dipole in and electric field

(i) To rotate the dipole by an angle θ from the state of stable equilibrium $W = PE$ $(1 - \cos\theta)$.

(ii) Work done in rotating the dipole from θ_1 to θ_2 in an uniform electric filed
$$W = pE\ (\cos\theta_1 - \cos\theta_2)$$

(iii) Work done in rotating the dipole through 180º from stable equilibrium state
$$W = 2pE = 2\ (\text{potential energy})$$

06. Electric Flux

(i) It is denoted by 'ϕ'.

(ii) It is a scalar quantity.

(iii) It is defined as the total number of lines of force passing normally through a curved surface placed in the field.

(iv) It is given by the dot product of $\vec{E}$ and normal infinitesimal $\vec{ds}$ area integrated over a closed surface.
$$d\phi = \vec{E}.\vec{ds}$$
$$\phi = \oint \vec{E}.\vec{ds} = \oint Eds\cos\theta$$

where θ = angle between electric field and normal to the area

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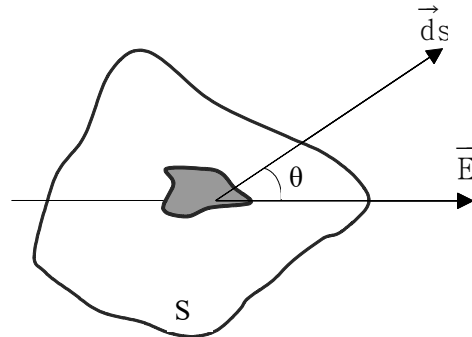
(v) Unit : (a) N-m^2/C (b) volt – meter

(vi) Dimension : $[ML^3T^{-3}A^{-1}]$

(vii) Flux due to a positive charge goes out of the surface while that due to negative charge comes into the surface.

(viii) Value of electric flux is independent of shape and size of the surface.

(ix) If only a dipole is present in the surface then net flux is zero.

(x) Net flux from a surface is zero does not imply that intensity of electric field is also zero.

07. Gauss's Law

This law states that electric flux ϕ_E through any closed surface is equal to $1/\varepsilon_0$ times the net charge 'q' enclosed by the surface i.e

$$\phi_E = \oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$$

Important point about flux

(i) Independent of distances between charges inside the surface and their distribution.

(ii) Independent of shape, size and nature of surface.

(iii) Net flux due to a charge outside the surface will be zero.

(iv) Gauss law is valid only for the vector fields which obey inverse square law

Example   A hemispherical surface of radius R is kept in a uniform electric field E such that E is parallel to the axis of hemi-sphere, Net flux from the surface will be
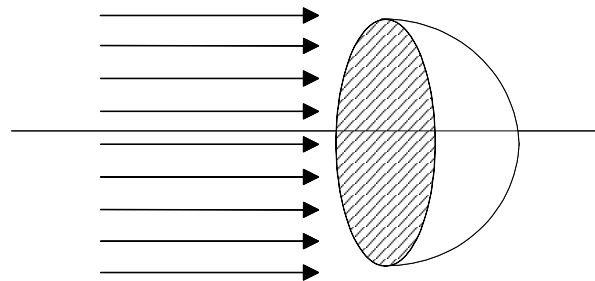
Solution $\phi = \oint \vec{E}.\vec{ds} = E.\pi R^2.$

= (E) (Area of surface perpendicular to E)

= E. πR^2.

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08. Application of Gauss's Law

Electric field due to a solid conducting sphere/Hollow conducting sphere.
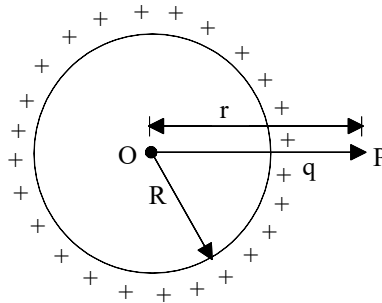
(i) **Case: 1** $r > R$ $\qquad \vec{E} = \dfrac{kq}{r^2}\hat{r} = \dfrac{1}{\varepsilon_0}\dfrac{\sigma R^2}{r^2}\hat{r}$

Case: 2 $r = R$ $\qquad \vec{E} = \dfrac{\sigma}{\varepsilon_0}\hat{r}$

Case: 3 $r < R$ $\qquad \vec{E} = 0$

i.e. At point interior to a conducting or a hollow sphere, electric field intensity is zero.

(ii) For points outside the sphere, it behaves like all the charge is present at the centre.

(iii) Intensity of electric field is maximum at the surface

Imp.

(iv) Electric field at the surface is always perpendicular to the surface.

(v) For points, near the surface of the conductor, $E = \dfrac{\sigma}{\varepsilon_0}$ perpendicular to the surface

Electric field due to infinitely long charge

(i) A long wire is given a line charge density λ. If wire is positively charged, direction of $\vec{E}$ will be away from the wire (outward ⊥) while fro a negatively charged wire, direction of $\vec{E}$ will be (inward ⊥) towards the wirde.

(ii) E at point p

$$\vec{E} = \dfrac{\lambda}{2\pi\varepsilon_0 r}\hat{r} \qquad \text{or} \qquad E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$$
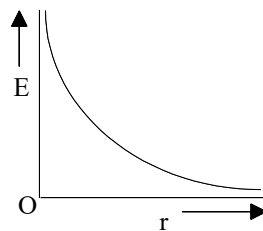
(iii) Potential difference between points A (r_1) & $B(r_2) = V_2 - V_B = \dfrac{\lambda}{2\pi\varepsilon_0}\ell n\left(\dfrac{r_2}{r_1}\right)$

(iv) Potential difference between points A (r_1) & $B(r_2) = V_2 - V_B = \dfrac{\lambda}{2\pi\varepsilon_0}\ell n\left(\dfrac{r_2}{r_1}\right)$

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Electric field at a point due to an infinite sheet of charge

(i) If σ = surface charge density. Intensity at points near to the sheet $\vec{E} = \dfrac{\sigma}{2\varepsilon_0}\hat{r}$

(ii) Direction of electric field is perpendicular to the sheet of charge.

(iii) Intensity of electric field does not depend upon the distance of points from the sheet for the points in front of sheet i.e. There is an equipotential region near the charged sheet.

(iv) Potential difference between two points A & B at distances r_1 & r_2 respectively is

$$V_A - V_B = \dfrac{\sigma}{2\varepsilon_0}\left(r_2 - r_1\right)$$

Electric field due to infinite charged metal plate

(i) Intensity at points near the plate $\vec{E} = \dfrac{\sigma}{\varepsilon_0}\hat{r}$
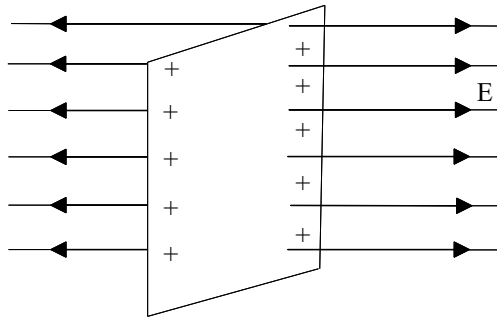
where σ = surface charge density

(ii) $\vec{E}$ is independent of distance of the point from the plate and also of the area of sheet i.e. There is an equipotential region near the plate.
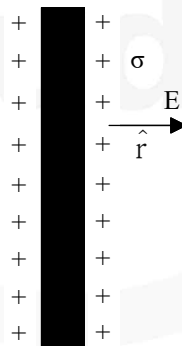
(iii) Direction of electric field is perpendicular to the palate.

(iv) Potential difference between two point A (r_1) and B (r_2) ($r_1 < r_2$) near the plate is

$$\triangle V = V_A - V_B = \dfrac{\sigma}{\varepsilon_0}\left(r_2 - r_1\right)$$

Electric field due to charged ring : Q charge is distributed over a ring of radius R.

(i) Intensity of electric field at a distance x from the centre of ring along it's axis-

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q\cos\theta}{r^2} = \frac{Qx}{4\pi\varepsilon_0 r^3} \quad (\because \cos\theta = x/r)$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Qx}{\left(R^2 + x^2\right)^{3/2}} \quad \left[\because r = \sqrt{R^2 + x^2}\right]$$

and it's direction will be along the axis of the ring.

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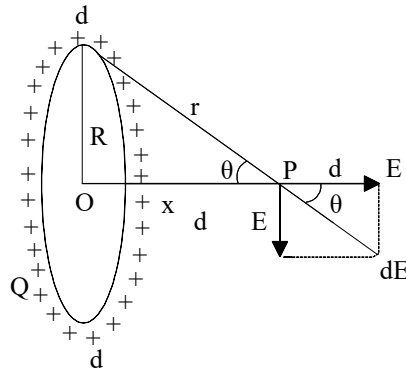
(ii)   Intensity will be zero at the centre of the ring.

(iii) Intensity will be maximum at a distance $R/\sqrt{2}$ from the centre and

$$E_{max} = \frac{2}{3\sqrt{3}} \cdot \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2}$$

(iv) Electric potential at a distance x from centre,

$$V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{\sqrt{(x^2 + R^2)}}$$

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Exercise (1)

1. The force between two charges situated in air is F, The force between the same charges if the distance between them is reduced to half and they are situated in a medium having dielectric constant 4 is
   (a) $F/4$
   (b) $4\ F$
   (c) $16\ F$
   (d) F

2. If charge q is placed at the centre of the line joining two equal charges Q, the system of three charges will be in equilibrium if q is
   (a) $-Q/2$
   (b) $-Q/4$
   (c) $-4\ Q$
   (d) $+Q/2$

3. Two equally charged identical metal spheres A and B repel each other with a force 3×10^{-5} N. Another identical unchanged sphere C is touched with A and then placed at the mid-point between A and B. Net force on C is
   (a) 1×10^{-5} N
   (b) 2×10^{-5} N
   (c) 1.5×10^{-5} N
   (d) 3×10^{-5} N

4. The electric strength of air is 2×10^7 N/C. The maximum charge that a metallic sphere of diameter 6 mm can hold is
   (a) $3\ nC$
   (b) $20\ nC$
   (c) $1.5\ nC$
   (d) $2\ nC$

5. An electric dipole is placed at an angle of 60º with an electric field of intensity 10^5 NC^{-1}. It experiences a torque equal to $8\sqrt{3}\ Nm$. Calculate the charge on the dipole, if the dipole length is 2 cm.
   (a) -8×10^3 C
   (b) 8.54×10^{-4} C
   (c) 8×10^{-3} C
   (d) 0.85×10^{-6} C

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6. An electric field exists in the space around a point charge $+Q$. A positive charge $+q$ is carried from A to B and A to C, where B and C lie on a circle with $+Q$ at the centre, Work done is

Figure
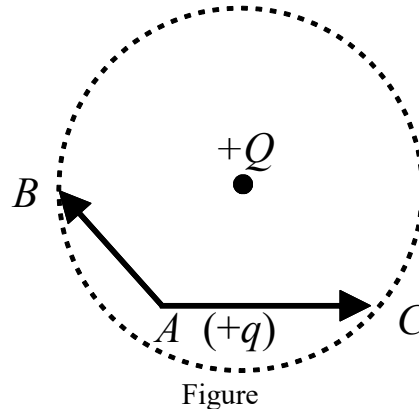
(a) greater along the path AC than along AB
(b) greater along the path AB than along AC
(c) same in both the cases
(d) zero in both the cases.

7. An α-particle and a proton are accelerated through same potential difference from rest. Find the ratio of their final velocity
(a) $\sqrt{2} : 1$
(b) $1 : 1$
(c) $1 : \sqrt{2}$
(d) $1 : 2$

8. A, B and C are three points in a uniform electric field, in Figure. The electric potential is :
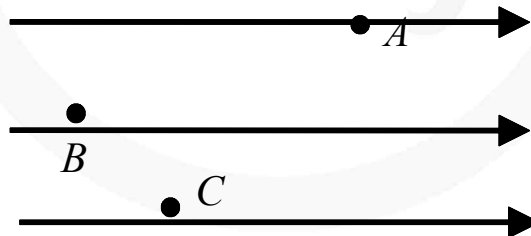
(a) Same at all the three points A, B and C
(b) Maximum at A
(c) Maximum at B
(d) Maximum at C

9. n small drops of same size are charged to V volt each. If they coalesce to form a single large drop, then the potential will be
(a) Vn
(b) Vn^{-1}
(c) $Vn^{1/3}$
(d) $Vn^{2/3}$

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10. A long string with a charge of λ per unit length passes through an imaginary cube of edge a. The maximum flux of the electric field through the cube will be

   (a) $\lambda a/\in_0$

   (b) $\sqrt{2}\ \lambda a/\in_0$

   (c) $6\lambda\ a^2/\in_0$

   (d) $\sqrt{3}\lambda\ a/\in_0$

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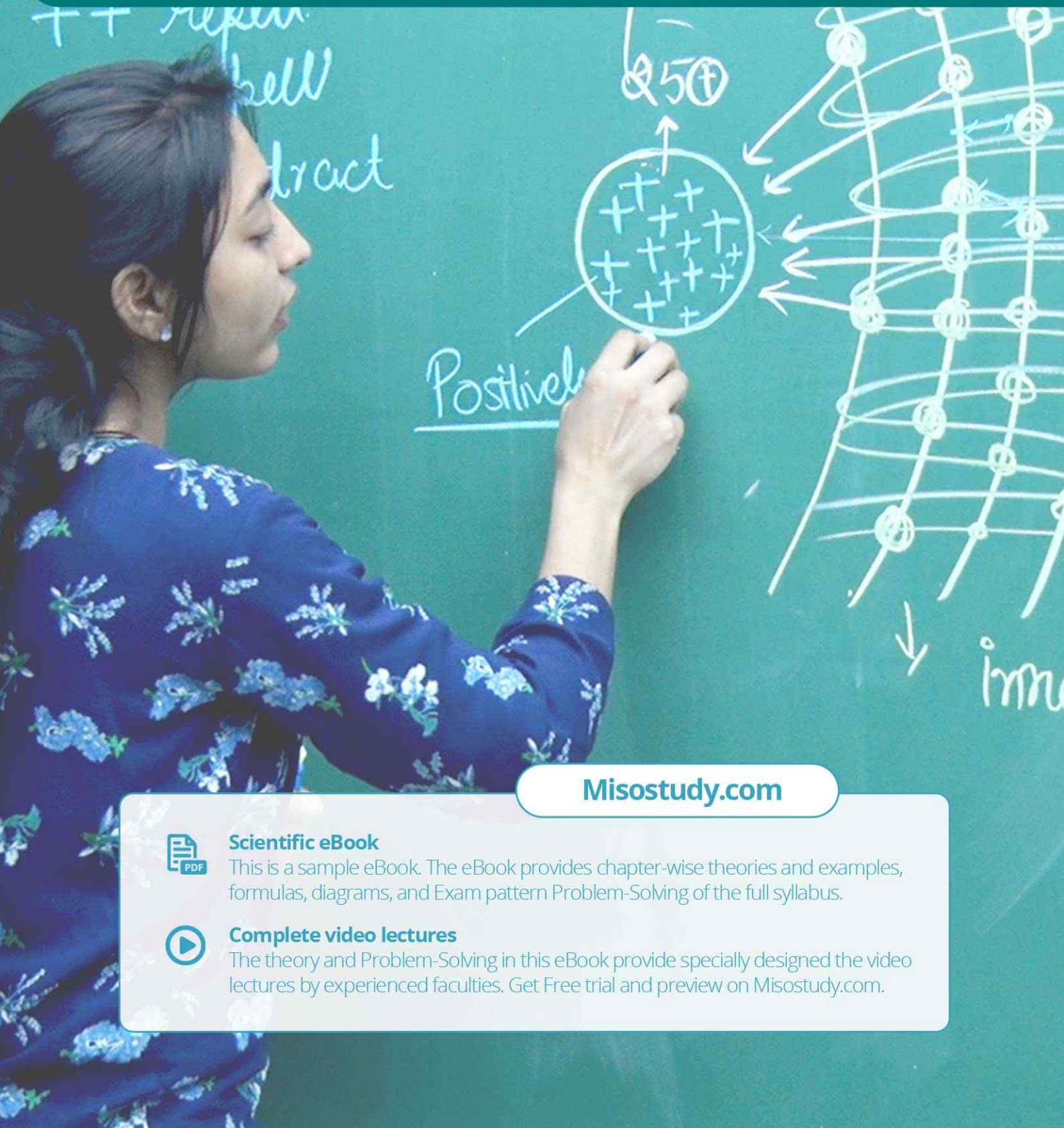
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Class 12 | Chemistry

02 Solid State

01. The Solid State

The solid are characterized by incompressibility, rigidity and mechanical strength. The molecules, atoms or ions in solids are closely packed i.e they are held together by strong forces and can not move about at random. Thus solids have definite volume, shape, slow definite, low vapour pressure and possesses the unique property of being rigid. Such solids are known as true solids e.g. NaCl, KCl, Sugar, Ag, Cu etc. On the other hand the solid which loses shapes on long standing, flows under its own weight and easily distorted by even mild distortion forces are called pseudo solids e.g. glass, plastic etc.

Some solids such as NaCl, Sugar, Sulphur etc. have properties not only of rigidity and incompressibility but also of having typical geometrical forms. These solids are called as crystalline solids. In such solids there is definite arrangements of particles (atoms, ions or molecules) throughout the entire three dimensional network of a crystal. This is named as long-range order. This three dimensional arrangement is called **crystal lattice or space lattice.** Other solids such as glass, rubber, plastics etc. have rigidity and incompressibility to a certain extent but they do not have definite geometrical forms or do not have long range order are known as amorphous solids.

02. Differences Between Crystalline and Amorphous Solids

(i). **Characteristic Geometry**

In the crystalline solids the particles (atoms, ions, or molecules are definitely and orderly arranged thus these have characteristic geometry while amorphous solids do not have characteristic geometry.

Melting Points

A crystalling solids has a sharp melting point i.e. it changes into liquid state at a definite temperature. On the contrary an amorphous solid does not has a sharp melting point.

Cooling curve

Amorphous solids show smooth cooling curve while crystalline solids show two breaks in cooling curve. In the case of crystalline solids two breaks points 'a' and 'b' are appear. These points indicate the beginning and the end of the process of crystallization. In this time interval temperature remains constant. This is due to the fact that during crystallization process energy is liberated which compensates for the loss of heat thus the temperature remains constant.

Cooling curve of an amorphous solid

Cooling curve of an crystalline solid

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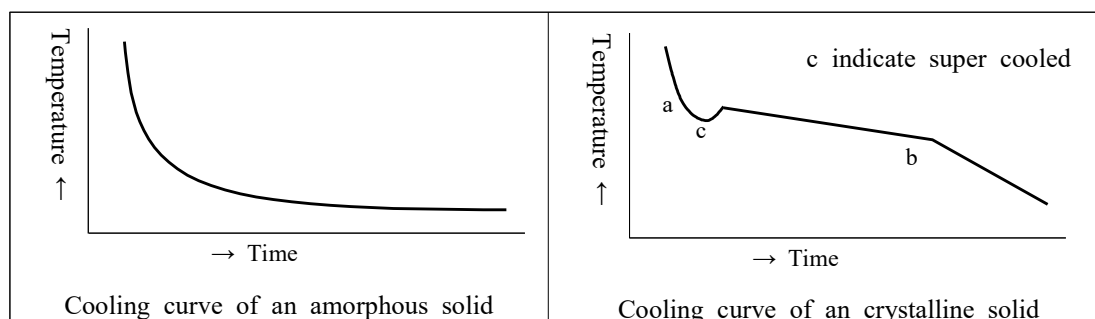
(i). **Isotropy and Anisotropy**

Amorphous solids differ from crystalline solids and resemble liquids in many respects. The properties of amorphous solids, such as electrical conductivity, thermal conductivity, mechanical strength, refractive index, coefficient of thermal expansion etc. are same in all directions. Such solids are known as isotropic. **Gases and liquids are also isotropic.** On the other hand crystalline solids show these physical properties different in different directions. Therefore crystalline solids are called anisotropic.

03. Crystalline State

"A crystal is a solid composed of atoms (ions or molecules) arranged in an orderly repetitive array"

"The smallest geometrical position of the crystal which can be used as repetitive unit to build up the whole crystal is called a unit cell." The unit cell should have same symmetry elements as the crystal and there should be no gaps between unit cells.

The angle between the two perpendiculars to the two intersecting faces is termed as the interfacial angle which may be same as the angle between the unit cell edges. Goniometer is used to measure the interfacial angle. It is important to note that interfacial angle of a substance remains the same although its shape may be different due to conditions of formation.

Interfacial angles of crystal
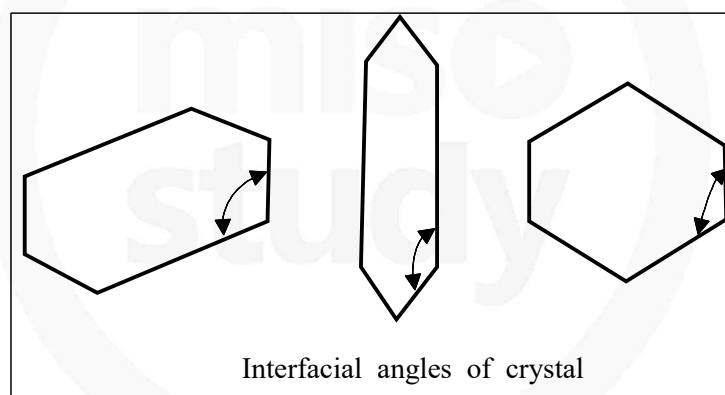
04. Types of the Crystals

Crystals are divided into four important types on the basis of chemical bonding of the constituent atoms.

(i) **Ionic Crystals**

These are formed by a combination of highly electro-positive ions (cations) and highly electronegative ions (anions). Thus strong electrostatic force of attraction acts with in the ionic crystals. Therefore, a large amount of energy is required to separate ions from one another.

e.g. NaCl, KF, CsCl etc.

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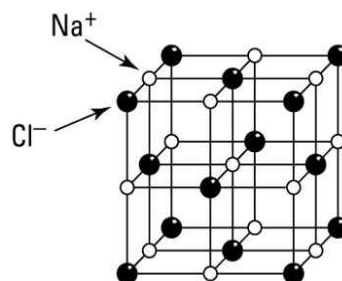
(ii) **Covalent Crystals**

These are formed by sharing of valence electrons between two atoms resulting in the formation of a covalent bond. The covalent bonds extend in two or three dimensions forming a giant interlocking structure called network. Diamond and graphite are the good examples of this type.

(iii) **Molecular Crystals**

In these crystals, molecules occupy the lattice points of the unit cells, except in solidified noble gases in which the units are atoms, where the binding is due to vander Waal's' forces and dipole-dipole forces. Since vander Waal's' forces are non-directional hence structure of the crystal is determined by geometric consideration only. Solid H_2, N_2, O_2, CO_2, I_2, sugar etc. are well known examples of such crystal in which vander Waal's' forces are acting.

(iv) **Metallic Crystals**

These are formed by a combination of atoms of electropositive elements. These atoms are bound by metallic bonds. It may be defined as:
The force that binds a metal ion to a number of electrons within its sphere of influences is known as metallic bond.

05. Isomorphism

The occurrence of a given substance in more than one solid crystalline forms have different physical properties is known as polymorphism. This property when occurs in elements is known as allotropy.

Sometimes we come across examples of chemically different solids which crystalline in the crystalline shape. Such substances are said to be Isomorphous (same shape). Their chemical constitutions are very similar and in some cases crystals of one substance may continue to grow when placed in a saturated solution of the other e.g. potash alum and chrome alum crystals have the same shape and can be grown in each other's solutions.

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06. SPACE LATTICE/CRYSTALLINE LATTICE/3-D LATTICE

Space lattice is a regular arrangement of lattice points showing how the particles are arranged at different sites in 3D-view.

"The three dimensional distribution of component particles in a crystal can be found by X-ray diffraction of different faces of the crystal. On the basis of the classification of symmetry, the crystals have been divided into seven systems. These can be grouped into 32 classes which in turn can be regrouped into 7 crystal systems. These seven systems with the characteristics of their axes (angles and intercepts) along with some examples of each are given in the following table.

The Seven Crystal System

	Name of system	Axes	Angles	Bravais Lattices
1.	Cubic [Isometric]	a = b = c	$\alpha = \beta = \Upsilon = 90^\circ$	Primitive, Face-centred, Body centred = 3
2.	Tetragonal	a = b ≠ c	$\alpha = \beta = \Upsilon = 90^\circ$	Primitive, Body centred = 2
3.	Rhombohedral or Trigonal	a = b = c	$\alpha = \beta = \Upsilon \neq 90^\circ$	Primitive = 1
4.	Orthorhombic or Rhombic	a ≠ b ≠ c	$\alpha = \beta = \Upsilon = 90^\circ$	Primitive, Face-centred, Body centred End centred = 4
5.	Monoclinic	a ≠ b ≠ c	$\alpha = \Upsilon = 90^\circ$; $\beta \neq 90^\circ$	Primitive, End – centred = 2
6.	Triclinic	a ≠ b ≠ c	$\alpha \neq \beta \neq \Upsilon \neq 90^\circ$	Primitive = 1
7.	Hexagonal	a = b ≠ c	$\alpha = \beta = 90^\circ$ $\Upsilon = 120^\circ$	Primitive = 1 Total = 14

07. Types of Unit Cells

There are four types of unit cells (among the cubic system).
(a) Simple or primitive. Particles are only at the comers of the unit cell.
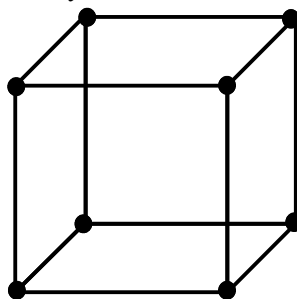
(b) Face-centred cubic unit cell. A particle is present at the centre of each face of the unit cell.
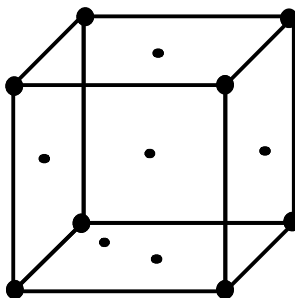
(c) End-face-centred cubic unit cell. A particle is present at each comer plus particles are present on the end faces of the unit cell.
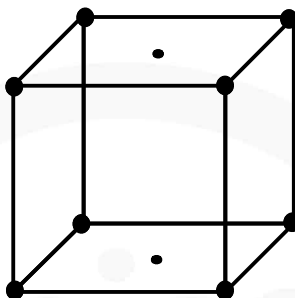
(d) Body-centred cubic unit cell. In addition to the particles at the corners, there is one particle in the body-centre of the unit cell.
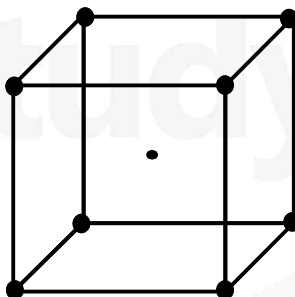
08. Coordination Number

If atoms are represented by spheres, the number of spheres which are touching a particular sphere is called *coordination number* of that sphere. In ionic crystals, the coordination number may be defined as the number of the oppositely charged ions surrounding a particular ion.

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09. The number of particles per Unit Cell

    (i)   An atom at the corner is shared by 8 unit cells. Therefore, its contribution is = 1/8.

    (ii)   An atom at the face is shared by 2 unit cells. Therefore, its contribution is = 1/2.

    (iii) An atom present in the body is unshared. Therefore, its contribution is 1.

    (iv) An atom present on the edge is shared by four unit cells. Therefore, its contribution is = 1/4. Thus, in

    (v)   a primitive or simple cubic unit cell, the total number of particles is 1/8×8=1.

    (vi) a face-centred cubic unit cell; the total number of particles is 1/8×8+1/2×6=4.

    (vii) a body-centred cubic unit cell, the total number of particles is 1/8×8+1=2.

The number of atoms per unit cell are in the same ratio as the stoichiometry of the compound or the ratio of the number of particles A and B present per unit cell gives the formula of the compound formed between A and B.

10. LENGTH OF FACE DIAGONAL AND CUBE DIAGONAL
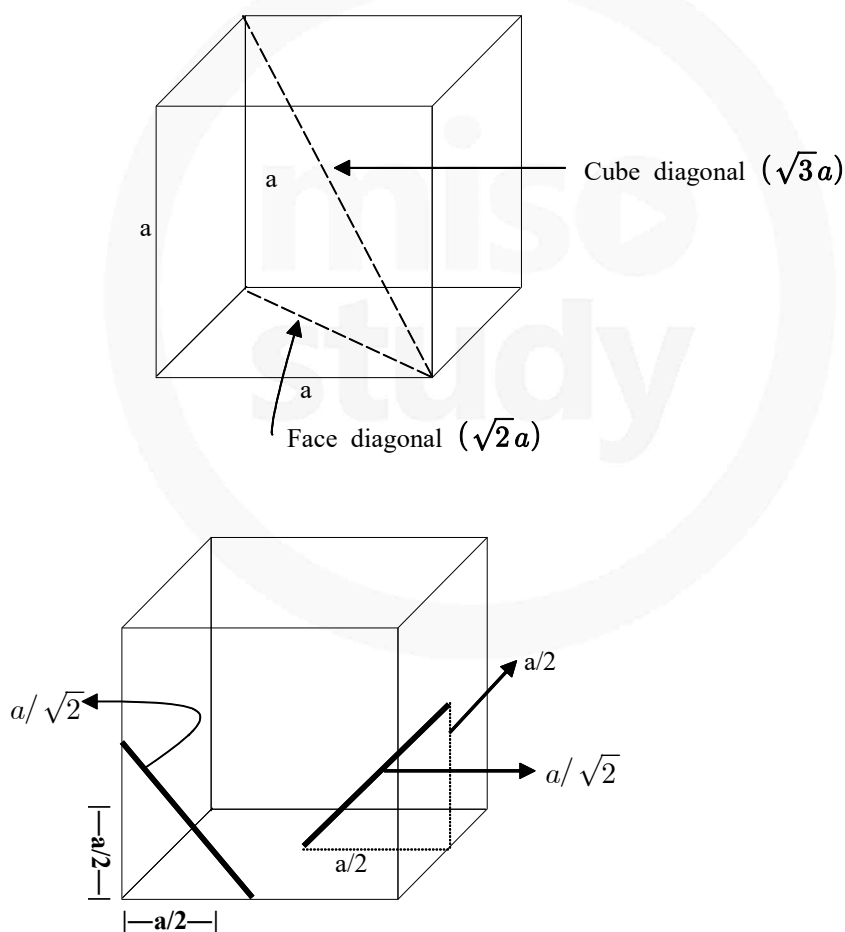
Consider the triangle ABC, with the help of pythagoras theorem

$$AC = \sqrt{AB^2 + BC^2} = \sqrt{a^2 + a^2} = \sqrt{2}\,a \quad \text{(length of face diagonal.)}$$

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02 Solid State

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Consider the triangle DAC, with the help of pythagoras theorem

$DC = \sqrt{DA^2 + AC^2} = \sqrt{a^2 + (\sqrt{2}\,a)^2} = \sqrt{3}\,a$ (length of cube diagonal)

TYPES OF UNIT CELL (BRAVAIS LATTICE)

The distance between successive lattice planes of the same type is called the spacing of planes or inter planar distance between the planes. On the basis of this aspect, the lattices may be divided in following classes.

11. Simple/Primitive/Basic Unit cell

A unit cell having lattice point only at corners called as primitive or simple unit cell. i.e. in this case there is one atom at each of the eight corners of the unit cell considering an atom at one corner as the centre, it will be found that this atom is surrounded by six equidistant neighbours (atoms) and thus the co-ordination number will be six. If 'a' is the side of the unit cell, then the distance between the nearest neighbours shall be equal to 'a'.

1/8 ATOM
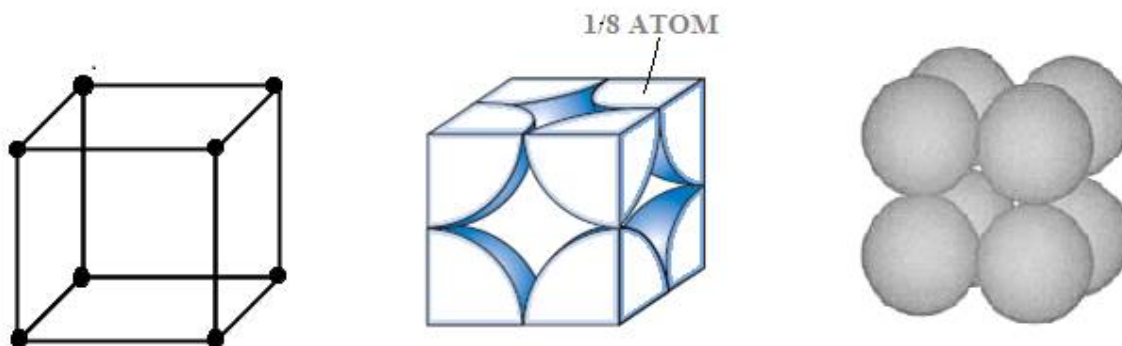
(a) **Relationship between edge length 'a' and atomic radius 'r' :**
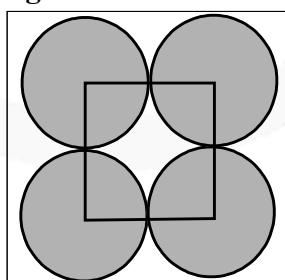
a=2r   i.e. $r = \dfrac{a}{2}$ (One face of SCC)

(b) **Number of atoms present in unit cell**

In this case one atom or ion lies at the each corner. Hence simple cubic unit cell contains a total of $\dfrac{1}{8} \times 8 = 1$ atom or ion/unit cell.

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(c) Packing efficiency(P. E.)

$$P.E.= \frac{\text{Volume occupied by atoms present in unit cell}}{\text{Volume of unit cell}}$$

$$= \frac{n \times \frac{4}{3}\pi r^3}{V} \quad [\because \text{Volume of atom} = \frac{4}{3}\pi r^3]$$

For SCC : $$P.E. = \frac{1 \times \frac{4}{3} \times \pi \times \left(\frac{a}{2}\right)^3}{a^3} \quad [\because r = \frac{a}{2} \text{ and } V = a^3, n = 1]$$

$$= \frac{\pi}{6} = 0.524 \quad \text{or} \quad 52.4\%$$

12. Body centred cubic (b.c.c.) cell:

A unit cell having lattice point at the body centre in addition to the lattice point at every corner is called as body centered unit cell.

Here the central atom is surrounded by eight equidistant atoms and hence the co-ordination number is eight. The nearest distance between two atoms will be $\frac{a\sqrt{3}}{2}$
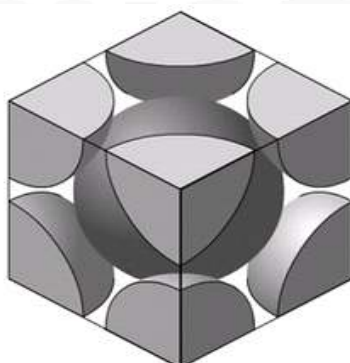
(a) Relationship between edge length 'a' and atomic radius 'r' :
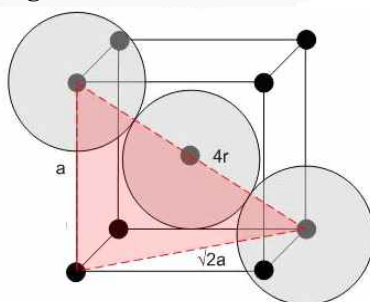
In BCC, along cube diagonal all atoms touches each other and the length of cube diagonal is $\sqrt{3}\,a$

So, $\sqrt{3}\,a = 4r$ i.e. $r = \frac{\sqrt{3}\,a}{4}$

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(b) **Number of atom present in unit cell:**

$\left(\frac{1}{8} \times 8\right) + (1 \times 1) = 1 + 1 = 2$ atoms/unit cell

In this case one atom or ion lies at the each corner of the cube. Thus contribution of the 8 corners is $\left(\frac{1}{8} \times 8\right) = 1$, while that of thee body centred is 1 in the unit cell. Hence total number of atoms per unit cell is 1 + 1 = 2 atoms (or ions)

(c) **Packing efficiency:**

$$\text{P.E.} = \frac{n \times \frac{4}{3}\pi r^3}{V} = \frac{2 \times \frac{4}{3} \times \pi \left(\frac{\sqrt{3}\,a}{4}\right)^3}{a^3} = \frac{\sqrt{3}\,\pi}{8} = 0.68 \quad \left[\because n = 2, r = \frac{\sqrt{3}\,a}{4}, V = a^3\right]$$

In B.C.C. 68% of total volume is occupied by atom or ions.

13. Face centred cubic (f.c.c.) cell:

A unit cell having lattice point at every face centre in addition to the lattice point at every corner called as face centred unit cell. i.e. in this case there are eight atoms at the eight corners of the unit cell and six atoms at the centre of six faces. Considering an atom at the face centre as origin, it will be found that this face is common to two cubes and there are twelve points surrounding it situated at a distance which is equal to half the face diagonal of the unit cell. Thus the co-ordination number will be twelve and the distance between the two nearest atoms will be $\frac{a}{\sqrt{2}}$.
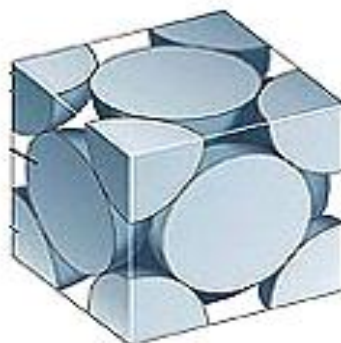
(a) **Relationship between edge length 'a' and atomic radius 'r' :**
In FCC, along the face diagonal all atoms touches each other and the length of face diagonal is $\sqrt{2}\,a$.

So $\quad 4r = \sqrt{2}\,a \qquad$ i.e. $\quad r = \frac{\sqrt{2}\,a}{4} = \frac{a}{2\sqrt{2}}, \qquad r = \frac{2}{2\sqrt{2}}$

Face diagonal

$\leftarrow$ a $\rightarrow$
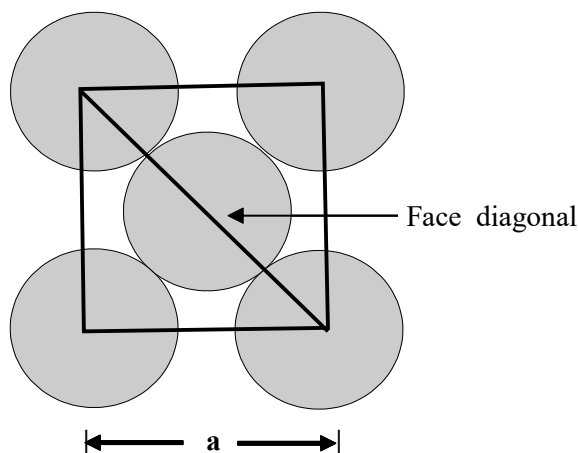
(b) **Number of atoms per unit cell :**

$$\left(\frac{1}{8}\times 8\right)+\left(6\times\frac{1}{2}\right) = 1+3 \ = 4 \ \text{atoms /unit cell}$$

In this case one atom or ion lies at the each corner of the cube and one atom or ion lies at the centre of each face of the cube. It may noted that only $\frac{1}{2}$ of each face sphere lie with in the unit cell and there are six such faces. The total contribution of 8 corners is $\left(\frac{1}{8}\times 8\right) = 1$, while that of 6 face centred atoms is $\left(\frac{1}{2}\times 6\right) = 3$ in the unit cell. Hence total number of atoms per unit cell is 1+3 = 4 atoms (or ions).

(c) **Packing efficiency :**

$$\text{P.E.} = \frac{n\times\frac{4}{3}\pi r^3}{V} \qquad \left[\because \text{for FCC } n = 4, \ r = \frac{a}{2\sqrt{2}}, \ V = a^3\right]$$

$$= \frac{4\times\frac{4}{3}\pi\times\left(\frac{a}{2\sqrt{2}}\right)^3}{a^3} \ = \ \frac{\pi}{3\sqrt{2}} \ = 0.74 \quad \text{or } 74\%$$

i.e. In FCC, 74% of total volume is occupied by atoms.

14. End Centered Unit Cell:

A unit cell having lattice point at the centres of only. one set of opposite faces in addition to the lattice point at every corner called as end centered unit cell.

NOTE ☞ This type of Bravais lattice is obtained only in orthorhombic and monoclinic type unit call.

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02 Solid State

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15. CRYSTAL DENSITY OF THE CRYSTAL

If the length of edge of the unit cell is known we can calculate the density of the crystal as follow: Let length of edge of the unit cell be ℓ.

$\therefore$ Volume of the unit cell = ℓ^3 = V cm^3

$$\text{Density of the unit cell} = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$$

Mass of the unit cell = Number of atoms present in a unit cell $\times$ Mass of one atom = n$\times$m g

$$\text{But mass of one atom (m)} = \frac{\text{Atomic mass}}{\text{Avogadro Number}} = \frac{M}{N_A}$$

$$\text{Mass of the unit cell} = n \times \frac{M}{N_A} \text{ g}$$

$$\text{Density of the unit cell} = \frac{n \times \dfrac{M}{N_A}}{V} \text{ gm cm}^{-3}$$

$$\text{Density of the unit cell} = \frac{n \times M}{V \times N_A} \text{ g cm}^{-3} = \text{ Crystal density (p)}$$

Example   An element (atomic mass = 60) having face centred cubic crystal has a density of 6.23 g cm^{-3}. What is the edge length of the unit cell (Avogadro constant, N_A = 6.02×10^{23} mol^{-1}).

Solution   Density = $\dfrac{Z \times M}{a^3 \times N_A}$ Z = 4 (for *fcc*)

$6.23 = \dfrac{4 \times 60}{a^3 \times 6.022 \times 10^{23}}$ $a^3 = \dfrac{4 \times 60}{6.23 \times 6.022 \times 10^{23}}$

$\qquad\qquad\qquad\qquad\qquad\qquad = 64 \times 10^{-24}$

$\qquad\qquad\qquad\qquad a = 4 \times 10^{-8}$cm

$\qquad\qquad\qquad\qquad\quad = \mathbf{4 \times 10^{-10}m = 400\ pm.}$

16. Close packing

It is type of packing with maximum packing fraction & space utilization. The constituent particles of a solid are like hard spheres. These spheres can pack in space in various manner to form a packing. To clearly understand the packing of these spheres, the packing can be categorised as :

   (i)   Close packing in one dimension.
   (ii) Close packing in two dimension.
   (iii) Close packing in three dimension.

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17. Close packing in one dimension :

In one dimension, only one arrangement of spheres is possible as shown in fig.
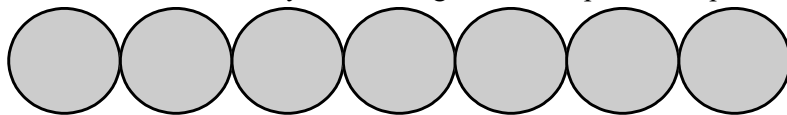
Close packing of spheres in one dimension

Two dimensional packing of spheres :

Two possible types of two dimensional packing are.
  (i)   Square close packing in two dimension.
  (ii) Hexagonal close packing in two dimension.

18. Two dimensional square packing of spheres :

When two rows are placed in such a manner, that spheres of one row are placed immediately below of the other, the resulting packing is called two dimensional square close packing.

  (i) Since all the rows are identical the packing is called AAA ...... type packing.
  (ii) Each sphere is touched by four other hence coordination number is four.
  (iii) Of centres of spheres are connected, square cells are formed, hence also called two dimensional square packing.
  (iv) This type of packing is not very effective in terms of utilization of space.
  (v) Packing efficiency in $2-D = \dfrac{1 \times \pi r^2}{a^2} = \dfrac{1 \times \pi (a/2)^2}{a^2} = \dfrac{\pi}{4} = 0.74$.

  (vi) Packing efficiency in $3-D = \dfrac{1 \times \dfrac{4}{3} \pi \left(\dfrac{a}{2}\right)^3}{a^3} = 0.52$ [In 3-D its unit cell is simple cubic]

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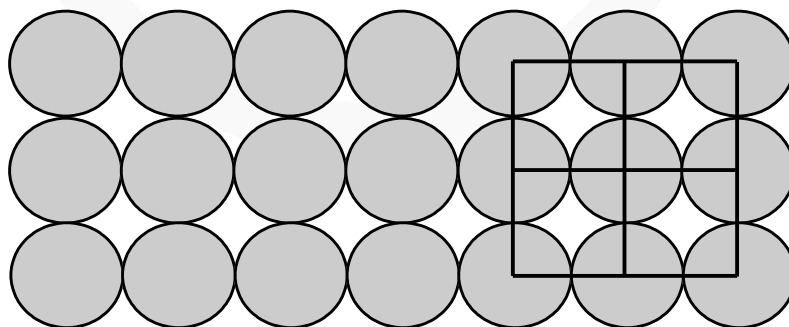
19. Two dimensional hexagonal packing :

If various one dimensional close pack rows are placed in such a way that spheres of top row fits in depression of bottom row spheres, the resulting packing is called two dimensional close packing structure.

(i)   Every third row sphere comes exactly at top of first row sphere, hence the packing is called ABABAB packing.

(ii) If centres are joined, hexagonal unit cells are formed. Hence this is called two dimensional hexagonal close packing.

(iii) This packing is most efficient in utilizing space in two dimensional arrangement.

(iv) Each sphere is touched by six other, hence coordination number is six.

(v)   Packing efficiency in $2-\mathrm{D} = \dfrac{3\times\pi\left(\dfrac{a}{2}\right)^2}{\dfrac{a^3\sqrt{3}}{4}\times 6} = \dfrac{\pi}{2\sqrt{3}} = 0.91$

(vi) Packing efficiency in $3-\mathrm{D} = \dfrac{3\times\dfrac{4}{3}\pi\left(\dfrac{a}{2}\right)^3}{\dfrac{a^2\sqrt{3}}{4}\times 6\times a} = \dfrac{\pi}{3\sqrt{3}} = 0.60$
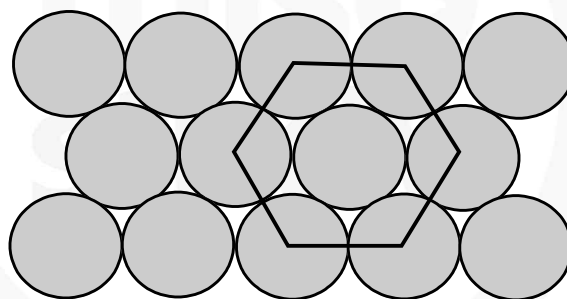
20. Close packing in three dimensions :

When two dimensional packing structure are arranged one above the other, depending upon type of two dimensional arrangement in a layer, and the relative positions of spheres in above or below layer, various types of three dimensional packing results. To define 3-D lattice six lattice parameters are required – 3 edge lengths & 3 angles.

(i)   Simple cubic packing (A A A A)

(ii) Hexagonal close packing (AB AB AB .....)

(iii) Cubic close packing or face centered cubic (...ABC ABC...)

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21. Simple cubic packing in three dimension :

The two dimensional square close packed layer are placed, in such a manner that spheres in each layer comes immediately on top of below layer, simple cubic packing results. Important points.

    (i)   Atoms all aligned vertically and horizontally in all directions.
    (ii) The unit cell for this packing is simple cubic unit cell.
    (iii) In this packing, only 52% of available space is occupied by atoms.
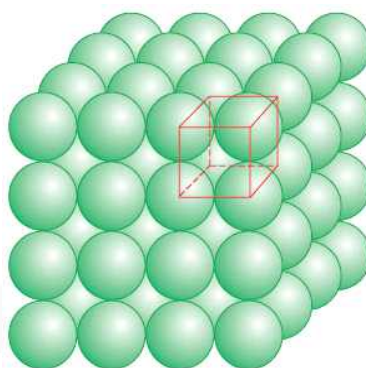
22. Three Dimensionally close packing :

In hexagonal close packing, there are two types of the voids (open space or space left) which are divided into two sets 'b' and 'c' for convenience. The spaces marked 'c' are curved triangular spaces with tips pointing upwards whereas spaces marked 'b' are curved triangular spaces with tips pointing downwards. Now we extend the arrangement of spheres in three dimensions by placing second close packed layer (hexagonal close packing) (B) on the first layer (A). The spheres of second layer may placed either on space denoted by 'b' or 'c'. It may be noted that it is not possible to place sphered on both types of voids (i.e. b and c). Thus half of the voids remain unoccupied by the second layer. The second layer also have voids of the types 'b' and in order to build up the third layer,
there are following two ways :

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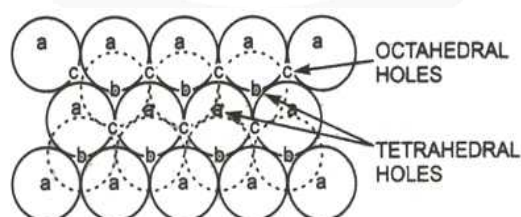
23. Hexagonal close packing (HCP) AB-AB-AB .... Type :

(i) In one way, the spheres of the third layer lie on spaces of second layer (B) in such a way that they lie directly above those in the first layer (A). In other words we can say that the layer becomes identical to the first layer. If this arrangement is continued idefinitely in the same order this represented as A BA BA B .....
This type of arrangement represent hexagonal close packing (hcp) symmetry (or structure), which means that the whole structure has only one 6-fold axis of symmetry i.e. the crystal has same appearance on rotation through an angle of 60°.

(ii) Every third layer sphere lies on top of first layer sphere. (ABABAB ..... packing)

(iii) Maximum possible spade is occupied by spheres.

(iv) Each sphere is touched by 12 other spheres in 3D
(6 is one layer, 3 in top layer and 3 in bottom.)

(v) The unit cell for hexagonal close packing is hexagonal unit cell.

(vi) For every atom forming hcp there are effectively two tetra voids and one octa void. That why this generate ABAB ..... AB pattern. One type of void always remain on unoccupied.

Unit cell : a = 2r = b; $\Upsilon = 120^{\circ}$

Hexagonal
closest packed
structure
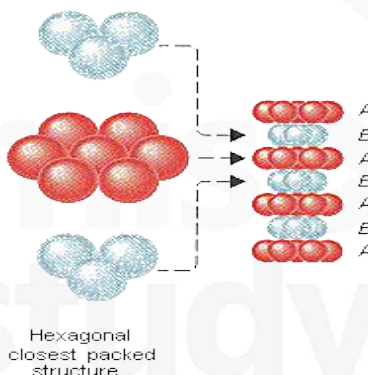
(vii) **Packing efficiency of HCP units**
Relation between a, b, c and R :
a = b = 2R
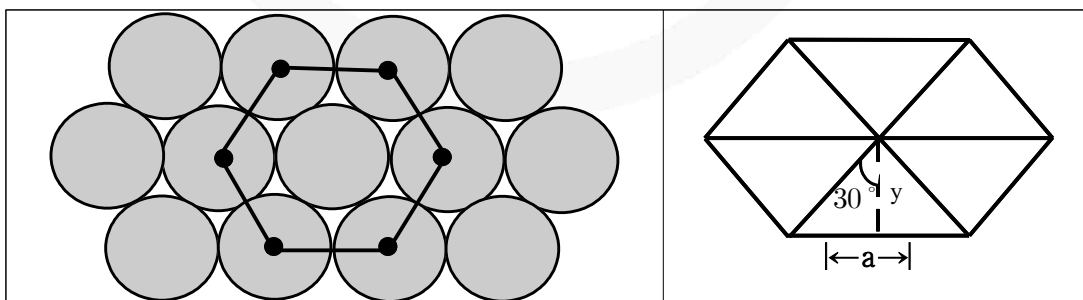
$$\tan 30 = \frac{a}{2 \times y} \qquad\qquad \text{so} \qquad\qquad y = \frac{a \times \sqrt{3}}{2 \times 1} = \frac{\sqrt{3}}{2} a.$$

$$\text{Area} = 6\left[\frac{1}{2}\frac{a}{2} \times \frac{\sqrt{3}}{2}a\right] = \frac{6\sqrt{3}a^2}{4}$$

Calculation of c :

$$\cos 30^\circ = \frac{a}{2 \times x} \qquad x = \frac{2a}{2 \times \sqrt{3}} = \frac{a}{\sqrt{3}}$$

Applying pythogoras theorem : $x^2 + h^2 = a^2$

So $\quad h^2 = a^2 - x^2 = a^2 - \frac{a^2}{3} = \frac{2}{3}a^2$

$h = \frac{2}{\sqrt{3}}a \qquad$ so $\qquad c = 2h = 2\sqrt{\frac{2}{3}}\,a$
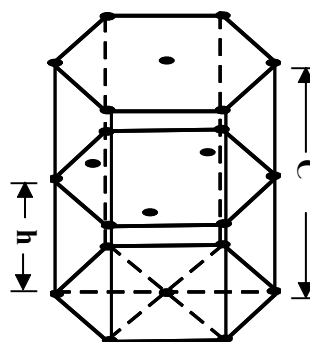
24. ABC – ABC arrangement (Cubic close packing (FCC)

In second way, the spheres of the third layer (C) lie on the second layer (B) in such a way that they lie over the unoccupied spaces 'C' of the first layer(A). If this arrangement is continuous in the same order this is represented as ABC ABC ABC..... This type of arrangement represent cubic close packed (ccp) structure. This structure has 3-fold axes of symmetry which pass though the diagonal of the cube. since in this system, there is a sphere at the centre if each face of the unit cell and hence this structure is also known as face-centred cubic (fcc) structure. It may be noted that in ccp (or fcc) structures each sphere is surrounded by 12 spheres hence the coordination number of each sphere is 12. The spheres occupy 74% of the total volume and 26% of is the empty space in both (hcp and ccp) structure.
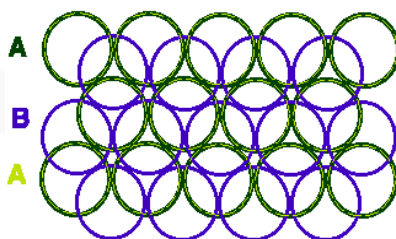
- IIIrd layer will be different from I^{st} layer as well as IInd layer.
- It is also known as cubical close packing (CCP), unit cell chosen is face centered unit cell (FCC).

Relation between 'a' and 'R' :

$a \neq 2R \qquad \sqrt{2}\,a = 4R$ (Sphere are touching along the face diagonal)

Effective no. of atoms per unit cell (Z) = $Z = \frac{1}{8} \times 8 + \frac{1}{2} \times 6 = 4$

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Packing fraction

$$\text{P.F.} = \frac{4 \times \frac{4}{3}\pi \ R^3}{4 \times 4 \times 4 \ R^3} \times \sqrt{2} \times 2 = \frac{\pi}{3\sqrt{2}} = 0.74 \ (74\%)$$

Coordination number , (CN) = 12

$$\text{Density (d)} = \frac{Z \times M}{N_A \ . \ a^3}$$

INTERSTICES OR VOIDS OR HOLES IN CRYSTALS

It has been shown that the particles are closely packed in the crystals even than there is some empty space left in between the spheres. This is known as interstices (or interstitial site or hole empty space or voids). In three dimentional close packing (CCP & HCP) the interstices are of two types : (i) tetrahedral interstices and (ii) octahedral interstices.
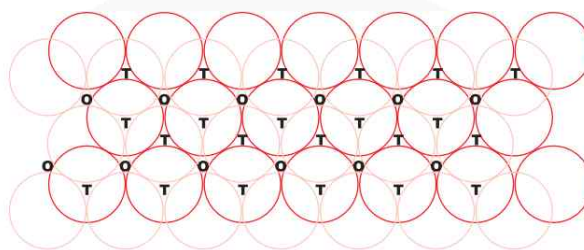
25. Tetrahedral Interstices :

We have seen that in hexagonal close packing (hcp) and cubic close packing (ccp) each sphere of second layer touches with three spheres of first layer. Thus they, leave a small space in between which is known as **tetrahedral site or interstices.** or The vacant space between 4 touching spheres is called as tetrahedral void. Since a sphere touches three spheres in the below layer and three spheres in the above layer hence there are two tetrahedral sites associated with one sphere. It may by noted that a tetrahedral site does not mean that the site is tetrahedral in geometry but it means that this site is surrounded by four spheres and the centres of these four spheres lie at the apices of a regular tetrahedron.

Tetrahedral void

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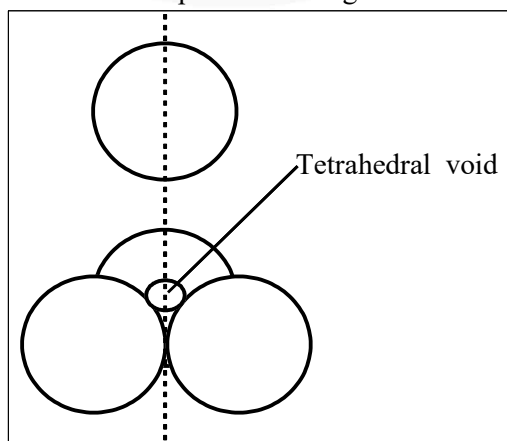
In FCC, one corner and its three face centred atom of faces meeting at that corner form a tetrahedral void.

In FCC, two tetrahedral voids are obtained along one cube diagonal. So in FCC 8 tetrahedral voids are present.

In FCC total number of atoms = 4

In FCC total number of tetrahedral voids = 8

So, we can say that, in 3D close packing 2 tetrahedral voids are attached with one atom.

Tetrahedral void
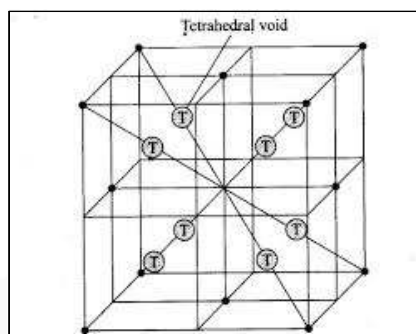
26. Octahedral – Interstices :

Hexagonal close packing (hcp) and cubic close packing (ccp) also form another type of interstices (or site) which is called octahedral site (or interstices). or The vacant space between 6 touching spheres is called as octahedral void.

In the figure two layers of close packed spheres are shown. The spheres of first layer are shown by full circles while that of second layer by dotted circles. Two triangles are drawn by joining the centres of three touching spheres of both the layers.

In FCC, 6 face centres form a octahedral void at body centre.

The apices of these triangles point are in opposite directions. On super imposing these triangles on one another a octahedral site is created. It may be noted that an octahedral site does not mean that the hole is octahedral in shape but it means that this site is surrounded by six nearest neighbour lattice points arranged octahedrally.

Octahedral

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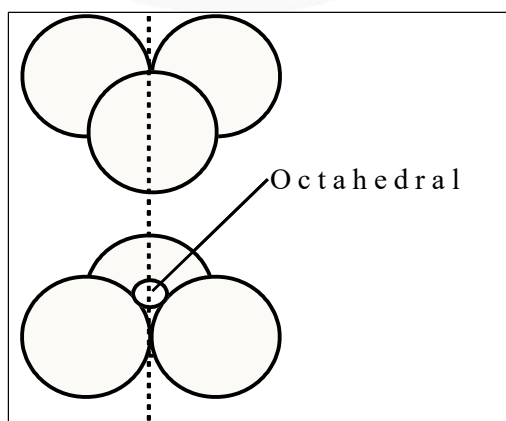
27. Positions of Tetrahedral Voids in an fcc Unit Cell :

The centre of tetrahedral void is located on the centre of body diagonal of each small cube of volume $\left(\dfrac{a^3}{8}\right)$.

Total number of atoms per unit cell $= \dfrac{1}{2} \times 6 + 8 \times \dfrac{1}{8} = 4$

Total number of tetra void $= 8$
Effective number of tetra void per atom forming close pack$=2$.
If a fcc unit cell is divided into eight equal mini-cubes (edge$=a/2$) then centre of tetra voids lies at the centres of each of there mini-cubes. In FCC center of tetra void is at perpendicular distance of $a/4$ from nearest face.

28. Positions of Octahedral Voids in an fcc Unit Cell :

Position of octa void is at mid-point of each edge (total 12 edges in a cube) and at the centre of cube. Each octa void located at mid point of edge contributes $1/4$ to the unit cell. The octa void situated at the centre contributes 1.
In FCC, total number of octahedral voids are

$(1 \times 1) \quad + \quad (12 \times \dfrac{1}{4}) = 1 + 3 = 4$

(Cube centre)   (edge)
In FCC, number of atoms $= 4$
In FCC, number of octahedral voids $= 4$
So, we can say that, in any type of close packing one octahedral void is attached with one atom.

29. Limiting Radius Ratios

An ionic crystal contains a large number of cations and anions. Generally cations are smaller in size than anions. The cations are surrounded by anions and they touch each other. These ions are arranged in space in such a way to produce maximum stability. The stability of the ionic crystal may be described in terms of radius ratio i.e. the ratio of the radius of cation (r) to that of anion (R) is (r/R). The range of (r/R) may be expressed as limiting radius ratio. This value is important to determine the arrangement of the ion in different types of crystals.

Limiting radius ratio for various types of sites

Limiting radius ratio = r/R	Coordination Number of cation	Structural Arrangement (Geometry of voids)	Example
0.155 – 0.225	3	Plane Trigonal	Boron Oxide
0.225 – 0.414	4	Tetrahedral	ZnS, SiO_2
0.414 – 0.732	4	Square planar	– .
0.414 – 0.732	6	Octahedral	$NaCl$, MgO_2
0.732 – 1.000	8	Cubic	$CsCl$

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Example   A solid $A^+ B^-$ has NaCl type close packed structure. If the anion has a radius of 250 pm, what should be the ideal radius for the cation ? Can a cation C^+ having a radius of 180 pm be slipped into the tetrahedral site of the crystal $A^+ B^-$? Give reason for tour answer.

Solution   NaCl = FCC Closed packed structure

$$\frac{r_+(C^+)}{r_-(B^-)} = \frac{180pm}{250pm} = 0.72$$

It does not lie in the range 0.225–0.414. Hence, C^+ cannot be slipped into the tetrahedral site.

30. STRUCTURE of NaCl :

The bigger Cl^- forms cubic close packing and small Na+ occupy positions of all octahedral voids. The radius ratio $\dfrac{r^+}{r^-}$ lie in the range 0.414 – 0.73.

(i)   Each Na^+ is surrounded by six Cl^- is surrounded by six Na^+ ion. [6:6 coordination]

(ii)   Total no. of Na^+ and Cl^- in each limit cell is 4.

(iii) Number of formula units of NaCl per unit cell is equal to 4.

(iv)   The density of NaCl crystal is given by $d = \left(\dfrac{4 \times M_{NaCl}}{N_A \times a^3} \right)$

N_A = Avogadro's number   ;   a = Edge length

The edge length of NaCl unit cell is given by $(2r^+ + 2r^-) \Rightarrow \dfrac{a}{2} = r^+ + r^-$ (FCC & Octa void)

31. Zinc Blende (Sphalerite) Structure :

Larger anions form ccp arrangement and smaller cations filling half of alternate tetrahedral voids.

(i)   C.N. of Zn^{2+} = 4 ;   C.N. of S^{2-} = 4   [4 : 4 coordination]

(ii)   Formula units of $\frac{3}{c}$ per unit cell = 4.

(iii) $d_{ZnS} = \dfrac{4 \times M_{ZnS}}{N_A \times a^3}$

(iv) $r_{Zn^{2+}} + r_{S^{2-}} = \dfrac{a\sqrt{3}}{4}$

32. Cesium Halide Structure :

(CsCl) Cl^- at the corners of cube and Cs^+ in the center.

(i) C.N. of Cs^+ = 8 ; C.N. of Cl^- = 8 [8 : 8 coordination]

(ii) Formula units of CsCl per cube = 1

(iii) $d_{CsCl} = \dfrac{M_{CsCl}}{N_A \times a^3}$

(iv) $r_{Cs+} = r_{Cs-} = \dfrac{a\sqrt{3}}{2} \Rightarrow r^+ + r^- = \dfrac{a\sqrt{3}}{4}$ (FCC & tetra void)

33. Fluorite Structure :

(CaF_2) Ca^{2+} forming ccp arrangement and F^- filling all tetrahedral voids.

(i) C.N. of F^- = 4 ; C.N. of Cs = 8 [8 : 4 coordination]

(ii) Formula units of CaF_2 per unit cell = 4

(iii) $d_{CaF_2} = \dfrac{4 \times M_{CaF_2}}{N_A \times a^3}$

(iv) $r_{Ca^{2+}} + r_{F^-} = \dfrac{a\sqrt{3}}{4}$

34. Imperfections In Solid

Any deviation from the perfectly ordered arrangement constitutes a defect or imperfection. These defects sometimes called thermodynamic defect because the number of these defects depends on the temperature. Crystals may also possess additional defect due to the presence of impurities. Imperfection not only modify the properties of solids but also give rise to new properties.

35. Stoichiometric Defects

Those compounds in which the number of positive and negative ions are exactly in the ratio indicated by their chemical formula are called stoichiometric compounds. eg NaCl (1:1). These solids show following types of defects :

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36. Schottky Defect :

This type of defect is created when same number of positive ion and negative ion are missing from their respective positions leaving behind a pair of holes. Schottky defect is more common in ionic compounds with high co-ordination number and where the size of positive and negative ions are almost equal. The presence of large number of schottky defects in crystal results in significant decrease in its density. Eg. NaCl, KCl, CsCl, KBr etc.

SCHOTTKY DEFECT OF CRYSTALS
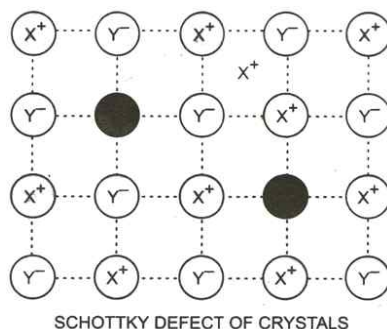
37. Interstitial Defect :

This type of defect is caused due to the presence of ions in the normally vacant interstitial sites in the crystal.

38. Frenkel Defect :

This type of defect is created when an ion leaves its correct lattice site and occupies an interstitial site. Frenkel defects are common in ionic compounds which have low co-ordination number and in which there is large difference in size between positive and negative ions. Eg. ZnS, AgCl, AgBr, Ag etc.

39. Non Stoichiometric Defect Frenkel Defect :

There are many compound in which the ratio of positive and negative ions present in the compound differs from that required by ideal formula of the compound. Such compounds are called Non stoichiometric compounds. eg. VO_x (Where x can vary between 0.6 to 1.3.) In these compounds balance of positive and negative charges is maintained by having extra electrons or extra positive charge. So, these defects are of following types:

40. Metal Excess Defects Due to Anion Vacancies

A compound may have excess metal ion if a negative ion is absent from its lattice site, leaving a hole which is occupied by electron to maintain electrical neutrality. The holes occupied by electrons are called F-centres and are responsible for the colour lf the compound. Eg.

• The excess sodium in NaCl makes the crystal appears yellow.
• Excess potassium in KCl makes it voilet.
• Excess lithium in LiCl makes it Pink.
• Greater the number of F-centres greater is the intensity of colour. This type of defects are found in crystal which are likely to possess schottky defects.

Metal excess defects
due to anion vacancies
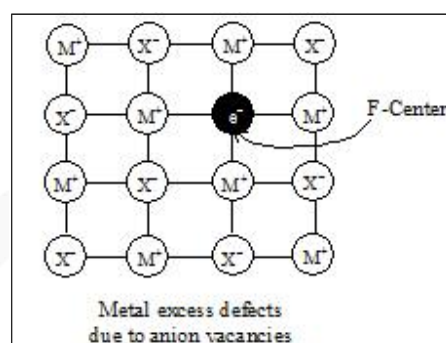
41. Metal Excess Defects Due to Interstitial Cations

It may occur if an extra positive ion is present in an interstitial site, Electrically neutrality is maintained by the presence of an electron in the interstitial site. This type of defects are exhibited by the crystals which are likely to exhibit "Frenkel defects". Eg. Yellow colour of ZnS.

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02 Solid State

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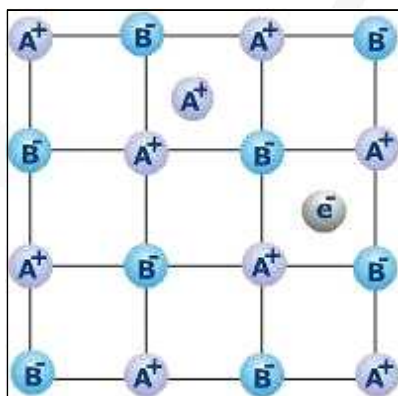
42. Metal Deficiency Due to Cation Vacancies

The non-stoichiometric compound may have metal deficiency due to the absence of a metal ion from its lattice site. The charge is balanced by an adjacent ion having higher positive charge. This type of defects are generally shown by compounds of transition metals.

Metal deficiency
due to cation vacancies
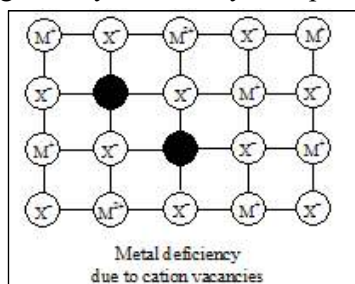
Example   Analysis shows that nickel oxide has the formula $Ni_{0.98}O$. What fractions of the nickel exist as Ni^{2+} and Ni^{3+}?

Solution   Let Ni^{2+} be x so that Ni^{3+} will be 0.98–x. Total charge on the compound must be zero so that

$+ 2x + 3(0.98 - x) - 2 = 0$

$2x + 2.94 - 3x - 2 = 0$

$-x = - 0.94$

or $x = 0.94$

$\% \text{ of } Ni^{2+} = \dfrac{0.94}{0.98} \times 100 = 96\%$

% of Ni^{3+} = 4%

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NEET Pattern
Exercise (1)

Q1. A metal crystallizes with a face-centered cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is
(a) 144 pm
(b) 204 pm
(c) 288 pm
(d) 408 pm

Q2. Percentage of free space in a body centred cubic unit cell is
(a) 28%
(b) 30%
(c) 32%
(d) 34%

Q3. If a is the length of the side of a cube, the distance between the body centered atom and one corner atom in the cube will be

(a) $\dfrac{2}{\sqrt{3}}a$

(b) $\dfrac{4}{\sqrt{3}}a$

(c) $\dfrac{\sqrt{3}}{4}a$

(d) $\dfrac{\sqrt{3}}{2}a$

Q4. Structure of a mixed oxide is cubic close packed (ccp). The cubic unit cell of mixed oxide is composed of oxide ions. One fourth of the tetrahedral voids are occupied by divalent metal A and the octahedral voids are occupied by a monovalent metal B. The formula of the oxide is
(a) ABO_2
(b) A_2BO_2
(c) $A_2B_3O_4$
(d) AB_2O_2

Q5. The number of octahedral void(s) per atom present in a cubic close-packed structure is
(a) 2
(b) 4
(c) 1
(d) 3

Q6. Lithium metal crystallizes in a body centred cubic crystal. If the length of the side of the unit cell of lithium is 351 pm, the atomic radius of the lithium will nearly be
(a) 152 pm
(b) 75 pm
(c) 300 pm
(d) 240 pm

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Q7. AB crystallizes in a body centred cubic lattice with edge length 'a' equal to 387 pm. The distance between two oppositely charged ions in the lattice is
 (a) 335 pm
 (b) 250 pm
 (c) 200 pm
 (d) 300 pm

Q8. If 'a' stands for the edge length of the cubic systems : simple cubic, body centred cubic and face centred cubic, then the ratio of radii of the spheres in these systems will be respectively

 (a) $1a : \sqrt{3}\,a : \sqrt{2}\,a$

 (b) $\dfrac{1}{2}a : \dfrac{\sqrt{3}}{4}a : \dfrac{1}{2\sqrt{2}}a$

 (c) $\dfrac{1}{2}a : \sqrt{3}\,a : \dfrac{1}{\sqrt{2}}a$

 (d) $\dfrac{1}{2}a : \dfrac{\sqrt{3}}{2}a : \dfrac{\sqrt{2}}{2}a$

Q9. A given metal crystallizes out with a cubic structure having edge length of 361 pm. If there are four metal atoms in one unit cell, what is the radius of one atom?
 (a) 108 pm
 (b) 40 pm
 (c) 127 pm
 (d) 80 pm

Q10. The packing efficiency of two-dimensional square unit cell shown below is

 (a) 39.27%
 (b) 68.02%
 (c) 74.05%
 (d) 78.54%

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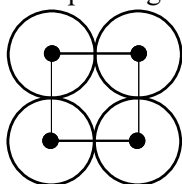
Answer & Solution

ANSWER

Q1	Q2	Q3	Q4	Q5
(c)	(c)	(d)	(d)	(c)
Q6	Q7	Q8	Q9	Q10
(a)	(a)	(b)	(c)	(d)

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Class 12 | Biology

03 Reproduction in Organisms

has both unicellular

? When is a fungu

unicellular

Multi cellular

Penci

01. Introduction

A vast number of plant and animal species have existed on the earth for several thousand of years. The process in living organisms that ensures this continuity is Reproduction. Reproduction is one of the most characteristic feature of living organisms. Life will not exist on the earth if plants and animals do not reproduce to make offsprings.

02. Life span

Life span can be defined as the period from birth to the natural death of an organism. It can vary from as short as few days to as long as a number of years.

Maximum Life Span : Maximum life span is the maximum number of years survived or the greatest age reached by any member of a species. The average life span refers to the average number of years survived or age reached by the members of a population. The maximum life span of a domestic dog is about 20 years and that of a laboratory mouse is 4.5 years. The maximum life span of humans has been estimated to be about 121 years. This rests on the fact that a man in Japan, Shirechiyo lzymi, reached the age of 120 years and 237 days in 1986. He died after developing pneumonia. Average life span and life expectancy of humans have grown dramatically. In general the rate of mortality of humans has gone down and the life span has increased. It is 56 in India whereas in the United State, it is 78.

03. Reproduction

Reproduction is the means of self perpetuation of a race in which new, young, similar looking individuals are formed by the grown up or adult individuals. The adults which give rise to young ones are called parents.

Functions of Reproduction :
(i)   It replaces the individuals dying due to senescence or ageing.
(ii)   Individuals removed from population due to predation or disease are replaced through reproduction.
(iii) It introduces variations essential for adaptability and struggle for existence.

Basic Features of Reproduction :
(i)   Replication of DNA.
(ii)   Division of cells. It may or may not involve meiosis.
(iii) Growth due to synthesis of more protoplasm.
(iv)   Formation of reproductive units.
(v)   Elaboration and development of reproductive units to form new young individuals.

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04. Types of Reproduction

Broadly speaking, there are two types of reproduction, asexual and sexual. Asexual reproduction does not involve gamete formation and fusion. It is uniparental. On the other hand, sexual reproduction consists of formation and fusion of gametes of opposite sexes. It is mostly biparental with two types o parents of different sexes but can be single/uniparental also, as in case of bisexual or hermaphrodite animals.

I. Asexual Reproduction

It is the mode of reproduction in which new individuals develop directly from specialised or unspecialised parts of a single parent without involving fusion of gametes or sex cells. Asexual reproduction occurs in both single celled and multicelled individuals. The parent individual splits, buds or fragments to form identical daughter cells or individuals, e.g., Amoeba, Paramoecium, Euglena (acellular protists), Sycon, Hydra, Tubularia, Planaria, Ascidia (metazoans). Asexual reproduction is also called agamogenesis or agamogeny. In this mode of reproduction, somatic cells undergo mitosis during the formation of a new individual. Therefore, it is also called somatogenic reproduction. Young ones resulting from asexual reproduction are exactly identical with the parent except in size and are called clones. Each individual of a clone is referred to as a ramet.

Asexual reproduction occurs by fission, budding and fragmentation.

(A) Fission : It is a mode of asexual reproduction in which the body of a mature individual divides into two or more similar and equal sized daughter individuals. Fission can be binary fission or multiple fission.

   (a) **Binary Fission :** It is the division of the body of an individual into two equal halves, each of which functions as an independent daughter individual. In unicellular organisms, binary fission is accompanied by mitotic division of nucleus followed by cytokinesis. In metazoans. The organisms which undergo binary fission seldom die of senescence or old age because as soon as they mature, they divide into two daughters. They are, therefore, nearly immortal. Depending on the plane of division, binary fission is of the following types:

   (i) **Simple Binary Fission (Irregular Binary Fission) :** Division can occur through any plane e.g., Amoeba.

   (ii) **Longitudinal Binary Fission :** The plane of fission passes along the longitudinal axis of the organism, e.g., Euglena, Vorticella.

   (iii) **Oblique Binary Fission :** The plane of binary fission lies at an angle to the transverse axis e.g., Ceratium, Gonyaulax.

   (iv) **Transverse Binary Fission :** The plane of binary fission runs along the transverse axis of the individual, e.g., Paramoecium, diatoms, bacteria. In Paramoecium, transverse binary fission is preceeded by a mitotic division of meganucleus and mitotic division of micronucleus. In it, binary fission produces two dissimilar daughters, one proter (anterior) and the other opisthe (posterior). Both develop the deficient components and become similar.

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(b) **Multiple Fission :** The nucleus divides several times by amitosis to produce many nuclei, without involving any cytokinesis. Later, each nucleus gathers a small amount of cytoplasm around it and the mother individual splits into many tiny daughter cells (e.g., Amoeba, Plasmodium, Monocystis, etc). In course of time, each of these daughter cells starts a free life and transforms into an adult individual. This kind of fission is called multiple fission.

Cyst formation : In response to unfavourable living conditions, an Amoeba withdrawn its pseudopodia and secretes a three-layered hard covering or cyst around itself. This phenomenon is termed as **encystation.** During favourable conditions, the encysted Amoeba divides by multiple fission and produces many minute amoubae or pseudopodiospores; the cyst wall bursts out and the spores are liberated in the surrounding medium to grow up into many Amoebae. This phenomenon is known as sporulation. Acellular protists like sporozoans (e.g., Monocystis, Plasmodium, etc.) typically exhibit sporulation in their life cycles.

(B) **Budding :** In budding, new individuals are formed by mitosis. Initially, a small outgrowth of the parent's body develops into a miniature individual. It then separates from the mother to lead a free life (e.g., Hydra). This type of budding is known as exogenous budding. Sometimes, the buds do not get separated from the mother individual and form a colony. For example, in Obelia, the colony consists of a number of individuals jor zooids that perform different functions. In all fresh water sponges (e.g., Spongilla) and some marine sponges (e.g., Sycon), the parent individual releases a specialized mass of cells enclosed in a common opaque envelope, called the gemmule. On germination, each gemmule gives rise to offspring and the archeocytes present in it give rise to various cells of the body of sponge as they are **totipotent**. Gemmules are thought to be **internal buds**.

(C) **Fragmentation :** The body of the parent breaks into distinct pieces, each of which can produce an offspring (e.g., Hydra, some marine worms, sea-stars).

Advantages of Asexual Reproduction :
(a) It is uniparental.
(b) It is a rapid mode of reproduction.
(c) The young ones are exact replicas of their parent.
(d) Asexual reproduction is simpler than sexual reproduction.

Disadvantages of Asexual Reproduction :
(a) As there is rapid multiplication, a large number of young ones are formed which causes overcrowding.
(b) There is no mixing of genetic material, so no new combination or variation takes place.
(c) There is no crossing over, hence hew linkages are not formed.
(d) It has no role in evolution.
(e) Adaptability to changes in environment is low due to absence of new variations.

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05. Sexual Reproduction

Sexual reproduction involves formation and fusion of gametes to form the zygote which develops to form a new organism.

Characteristics :
(a) Two fusing gametes can be produced by same individual or different individuals.
(b) Offsprings produced are not identical to parents.
(c) It involves meiosis and syngamy (fusion or gametes).
(d) It is a slow, elaborate or complex process, so multiplication is not so rapid.

06. Phases in Life Cycle

(a) Juvenile phase
(b) Reproductive phase
(c) Senescent phase

(a) **Juvenile phase/Pre-reproductive phase :** During this phase organism will show growth so that it can attain certain maturity to perform the sexual reproduction. This phase is known as vegetative phase in plants. It is of variable durations in different organisms.
(b) **Reproductive phase :** Reproductive organs develop and mature during this phase. In the higher plants (Angiosperms). end of juvenile phase or onset of reproductive phase is easily marked. In the higher plants during this phase, there is formation of reproductive structures i.e., flowers.
(c) **Senescent phase :** It is a post-reproductive phase. It involves structural and functional deterioration of body by accumulation of waste metabolites which ultimately leads to death.

07. Events in Sexual Reproduction

After attainment of maturity, all sexually reproducing organisms exhibit events and processes that have remarkable fundamental similarity, even though the structures associated with sexual reproduction are indeed very different. These sequential events may be grouped into three distinct stages, namely, the pre-fertilization, fertilization and the post-fertilization events.

A. Pre-fertilization Events
These are events in sexual reproduction which occur prior to the process of fertilization. The two main pre-fertilization events are **gametogenesis** and **gamete transfer.**
(a) **Gametogenesis :** It refers to the process of formation of gametes – male and female.
Categories of Gametes :
(i) **Isogametes :** When the fusing gametes are morphologically similar they are known as isogametes or homogametes. They are produced in some algae and fungi.

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- Algae : Cladophora, Chlamydomonas debaryana, Ulothrix
- Fungi : Synchytrium, Rhizopus

(ii) **Heterogametes :** When the fusing gametes are morphologically distinct types, they are known as heterogametes. It is the feature of majority of sexually reproducing organisms. e.g.

(a) Algae : Fucus, Volvox, Chara

(b) All Bryophytes, Pteridophytes, Gymnosperms and Angiosperms.
In such organisms, male gamete is called antherozoid or sperm and the female gamete is called egg or ovum

Cell Division During Gamete Formation : Gametes are always haploid i.e., they possess only one set of chromosomes or genome though the parent body producing gametes may be either haploid or diploid. As gametes are always haploid so surely in haploid parent, gametes are produced by mitotic division.

In plants belonging to group pteridophytes, gymnosperms and angiosperms and animals the parental body is diploid. Here reductional division occurs before or at the time of gamete formation. The cells which undergo meiosis ar called meiocyte. If meiocyte is indulged in gamete formation, then it is called gamete mother cell.

In haploid organisms, gametes are produced through mitosis but you must not think that meiosis never occurs in life cycle of haploid organisms. This could be made clear from what you have learnt in previous classes. In these organisms like haploid algae and some fungi, meiosis occurs in zygote or zygospore which is called zygotic meiosis.

08. Sexuality in Organisms :

Lower Organisms : In most of the lower sexually reproducing organisms, two fusing gametes are morphologically similar. If these gametes belong to the same parent then such organisms are called homothallic, e.g., fungi (Mucor mucedo). When these gametes belong to different parents then these organisms are called heterothallic.

Higher Organisms : In higher plants there are well-developed sex organs and there is clear distinction between male and female sex organs. Angiosperms possess flowers as reproductive structures. The male sex organ is called stamen and female sex organ is carpel or pistil. If male and female sex organs occur in the same flower then these plants are called bisexual, e.g., China rose. If flowers possess only stamen or carpel then these plants are called unisexual. When male flower (staminate) and female flower (pistillate) are present on same plant body such plants are monoecious, e.g., cucurbits, coconut and maize. However, if they are present on separate plant body then these plants are known as dioecious, e.g., date palm and papaya.

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09. Gamete Transfer :

After the formation of male and female gametes, compatible gametes must be physically brought together to facilitate fusion (fertilisation or syngamy). In few fungi and algae, both types of gametes are motile. But in majority of organisms male gamete is motile and the female gamete is non-motile. So there is a need of a medium through which the male gametes move.

In seed plants both male and female gametes are non-motile. Here pollen grains are the carrier of male gametes and ovule has the egg. As the male gamete is non-motile so it cannot swim through water medium to reach female gamete rather pollen tube serve this purpose.

For this pollen grain produced in anther ($\male$ part) are transferred to the stigma of female organ i.e., carpel through the process of pollination. Pollination is of two type i.e., self pollination and cross pollination. Self pollination is the transfer of the pollen grains from anther of a flower to the stigma of same flower or different flower of the same plant. Cross pollination is transfer of the pollen grain from anther of one flower to the stigma of different flower of other plant.

10. Fertilization

The most vital event of sexual reproduction is the fusion of gametes. This process is called syngamy or fertilization which results in the formation of a diploid zygote.

(a) **External fertilization :** Syngamy occurs outside the body of organism in external medium (water). It is shown by majority of aquatic organisms like most of algae, fishes as well as amphibians.

(b) **Internal fertilization :** Syngamy occurs inside the body of organisms. It is present in majority of plants like bryophytes, pteridophytes, gymnosperms and angiosperms. It occurs in few algae like spirogyra. In all these organisms egg is formed inside the female body where syngamy occurs.

11. Post-Fertilization Events

Events in sexual reproduction after the formation of zygote are called post-fertilization events.
Zygote : It is the first cell of the new generation in all sexually reproducing organisms. Zygote is always diploid. It is formed in the external aquatic medium in those organisms which perform external fertilization. Zygote is produced inside the body in cases where fertilization in internal.

In many algae and fungi, the zygote secretes a thick wall that is resistant to desiccation and damage, which help organisms to tide over unfavourable conditions. During unfavourable conditions it undergoes a period of rest until a swing back to sustainability occurs.
Embryogenesis : Embryogenesis is the process of development of embryo from zygote. Embryo is a multicellular stage in the life cycle of a plant or animal prior to formation of an independent individual.

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In embryogenesis, the zygote undergoes repeated cell divisions through mitosis. Cell differentiation occurs at specific locations resulting in production of different tissues, organs and organ systems. Development of different external and internal structures is called morphogenesis. Embryo formation is present in all plant groups, except algae. In flowering plants, zygote develops into embryo. The food for development of embryo comes from a special tissue known as endosperm. Ultimately, the fertilized ovule matures into a seed. Inside the mature seed is the progenitor of the next generation, the embryo. A number of seeds develop in an ovary depending upon the number of ovules. Meanwhile, wall of the ovary also proliferates. It produces pericarp or fruit wall. The pericarp can be dry or fleshy. The ripened ovary with pericarp and seeds is called fruit.

Differences between Asexual and Sexual Reproduction	
Asexual Reproduction	**Sexual Reproduction**
i. New individuals are formed from a single parent.	i. Commonly two parents are involved in the formation of new individuals through sexual reproduction.
ii. Asexual reproduction does not require the production of sex organs.	ii. Formation of sex organs is a pre-requisite for sexual reproduction.
iii. It does not involve meiosis. All divisions are mitotic.	iii. Sexual reproduction involves meiosis at one or the other stage. In higher plants, it occurs at the time of spore formation or sporogenesis.
iv. Asexual reproduction does not involve fusion of cells or gametes.	iv. It involves fusion of gametes.
v. New individual develops from one cell or a part of one parent.	v. New individual develops from zygote i.e., fusion product of two gametes.
vi. New individuals are genetically similar to the parents.	vi. Offspring or new individuals are genetically different from either of the two parents.
vii. It does not introduce variability. Hence, asexual reproduction has no evolutionary importance.	vii. It introduces variability and is, hence of evolutionary importance.
viii. It is quick method of multiplication.	viii. Sexual reproduction is a slower method of multiplication.
ix. It is simple process.	ix. It is elaborate or complex process.

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NEET Pattern
Exercise (1)

1. Which one of the following shows isogamy with non-flagellate gametes?
   - (a) Sargassum
   - (b) Ectocarpus
   - (c) Ulothrix
   - (d) Spirogyra

2. Select the wrong statement.
   - (a) Isogametes are similar in structure, function and behaviour
   - (b) Anisogametes differ either in structure, function and behaviour
   - (c) In oomycetes female gamete is smaller and motile, while male gamete is larger and non-motile
   - (d) Chlamydomonas exhibits both isogamy and anisogamy and Fucus shows oogamy

3. Product of sexual reproduction generally generates
   - (a) longer viability of seeds
   - (b) prolonged dormancy
   - (c) new genetic combination leading to variation
   - (d) large biomass

4. Which one of the following is correctly matched?
   - (a) Onion   -   Bulb
   - (b) Ginger   -   Sucker
   - (c) Chlamydomonas -   Conidia
   - (d) Yeast   -   Zoospores

5. The 'Eyes' of the potato tuber are
   - (a) flower buds
   - (b) shoot buds
   - (c) axillary buds
   - (d) root buds

6. Why is vivipary an undesirable character for annual crop plants?
   - (a) It reduces the vigour of the plant
   - (b) It adversely affects the fertility of the plant
   - (c) The seeds exhibit long dormancy
   - (d) the seeds cannot be stored under normal conditions for the next season

7. During regeneration modification of an organ to other organ is known as
   - (a) morphogenesis
   - (b) cpimorphosis

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    (c) morphallcixis

    (d) acretopmaruy growth

8. The process of series of changes from larva to adult after embryonic development is called

    (a) regeneration

    (b) metamorphosis

    (c) growth

    (d) ageing

9. A population of genetically identical individuals, obtained from asexual reproduction is

    (a) callus

    (b) clone

    (c) deme

    (d) aggregate

10. New banana plants develop from

    (a) rhizome

    (b) sucker

    (c) stolon

    (d) seed

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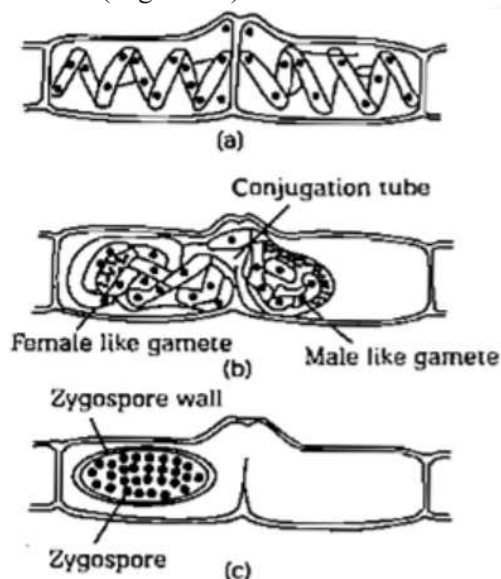2ND FLOOR 65-A, OMPRO TOWER, KALU SARAI, NEW DELHI, DELHI 110016

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Answer & Solution

1. **(d)**

   Isogamy with non-flagellated of gametes is seen is *Spirogyra* can reproduce both by sexual and asexual (vegetative) means.

   They reproduce sexually by conjugation in which two non-flagellated morphologically similar but physiologically different gemetes (isogamous) fuse together. One filament acts as male like gamete and passes through the conjugation tube of another filament which acts as female like gamete.

2. **(c)**

   Oomycetes include water moulds, white rusts and downy mildews. In these female gamete is larger and non-motile, wherease, male gamete is smaller and motile. whereas, male gamete is algae like Uiothrix, Chalmydomonas, Spirogyra etc., which are similar in structure, function and behaviour. Anisogametes are found in Chlamydomonas in which one gamete is larger and non-motile and the other one is motile egg with motile sperm. The gametes, differ both morphologically as well as physiologically It occurs in chalamydomonas, Fucus, Chara, volvox etc.

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3. (c)

Sexual reproduction leads to new genetic combination leading to variation in new products. Longer viability of seeds prolonged dormancy and large biomass are not related to sexual reproduction.

4. (a)

The correctly matched pair to onion-bulb. Onion is a simple tunicated layered bulb while ginger is a straggling rhizome having uniparous cyme reproduces by budding and Chlamydomonas by zoospores,

5. (c)

Tuber is oval or spherical swollen underground modified stem lacking adventitious roots. It possesses a number of spirally arranged depression called eyes. Each eye represents node and consists of 1-3 axillary bus in the axils of small scally leaves.

6. (d)

Vivipary is the condition when seeds germinate on the plant, It an undesirable character for annual crop plants because germinated seeds cannot be stored under normal condition for the next season.

7. (b)

Epimorphosis is the replacement of a lost organ of the body by proliferating new cells from the surface of the wound or injured part. Morphogenesis (Gr. morhe = form and genesis = origin) is the growth, shaping and arrangement of body parts according to genetically predefined patterns. The extent direction and rate of morphogenesis depend on genetic controls and environmental factors.

8. (b)

Matamorphosis (meta = change, morphe = form) is a process by which an animal undergoes a comparatively rapid change from larval to adult form Regeneration is regrowth of the part of body which has been removed due to the injury or other causes Growth is an increase in dry mass of an organism. Ageing is progressive deteriortion in activity of cell tissues organs, etc.

9. (b)

Clone refers to the population of genetically identical individuals obtained from asexual reproduction or produced vegetatively from single organism. An individual member of a clone is called ramete.

10. (b)

New banana plants develop through sucker. Sucker is the sub-aerial modification of stem which originates from the basal and underground portion of main stem. It also occurs in mint, Chrysanthemum, etc

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