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1) (a) $\vec{A} = \hat{i} + \hat{j} + 2\hat{k}$

$$\hat{A} = \frac{\hat{i} + \hat{j} + 2\hat{k}}{\sqrt{1+1+4}}$$

$$= \frac{\hat{i} + \hat{j} + 2\hat{k}}{\sqrt{6}}$$

$\therefore$ the unit vector along $\vec{A}$ is $\frac{1}{\sqrt{6}}(\hat{i}+\hat{j}+2\hat{k})$

(b) $\vec{F} = 3\hat{i} - 2\hat{j} + 4\hat{k}$

$\vec{r} = 2\hat{i} + 3\hat{j} + 5\hat{k}$

$$\therefore \vec{T} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -2 & 4 \\ 2 & 3 & 5 \end{vmatrix}$$

$$= \hat{i}(-10-12) - \hat{j}(15-8) + \hat{k}(9+4)$$

$$= -22\hat{i} - 7\hat{j} + 13\hat{k}$$

$\therefore \vec{T}$ of the system $\rightarrow -22\hat{i} - 7\hat{j} + 13\hat{k}$

c) LHS

$\vec{a} \times (\vec{b} \times \vec{c}) + \vec{b} \times (\vec{c} \times \vec{a}) + \vec{c} \times (\vec{a} \times \vec{b})$

$= \vec{b}(\cancel{\vec{a} \cdot \vec{c}}) - \vec{c}(\cancel{\vec{a} \cdot \vec{b}}) + \vec{c}(\cancel{\vec{b} \cdot \vec{a}}) - \vec{a}(\cancel{\vec{b} \cdot \vec{c}})$
$+ \vec{a}(\cancel{\vec{c} \cdot \vec{b}}) - \cancel{\vec{b}}(\vec{c} \cdot \vec{a})$

[From, $\vec{A} \times (\vec{B} \times \vec{C}) = \vec{B}(\vec{A} \cdot \vec{C}) - \vec{C}(\vec{A} \cdot \vec{B})$]

$= 0$ RHS (Proved)

d) coefficient of viscosity -

$f \propto \frac{dv}{dx}$

$\Rightarrow f = \eta \frac{dv}{dx}$

where,
[η (eta) = ~~Constant~~ coefficient of viscosity
f = force per unit area
dv = Small change of velocity
dx = Small change of distance]

dimension - $[ML^{-1}T^{-1}]$ $\left[\because \eta = \frac{F/A}{V/S} = \frac{[MLT^{-2}]/[L^2]}{[LT^{-1}]/[L]}\right]$

The coefficient of viscosity is defined as a force of friction that is required to maintain the difference of velocity of 1cm/s between the layers of liquid / ~~fut~~ fluid.

e) Hooke's law - the ratio of stress to strain is constant.

Stress $\propto$ Strain

$\Rightarrow \frac{\text{Stress}}{\text{Strain}} = \text{Constant}$

2)(a) central force - In classical mechanics the central force on an object is a force direct ~~a~~ towards or away from a point.

(b) curl $\vec{F} = 0$

$\Rightarrow$ curl $f(\vec{r}) = 0$

$\Rightarrow \vec{\nabla} \times f(\vec{r}) = 0$

$\Rightarrow \vec{\nabla} \times f(\vec{r})\, \hat{r} = 0$

$\Rightarrow \vec{\nabla} \times \frac{f(\vec{r})\, \vec{r}}{r} = 0$

$\Rightarrow \vec{\nabla} \times \frac{f(\vec{r})}{r} (x\hat{i} + y\hat{j} + z\hat{k})$

Now,

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \frac{x}{r}f(\vec{r}) & \frac{y}{r}f(\vec{r}) & \frac{z}{r}f(\vec{r}) \end{vmatrix}$$

$$= \hat{i}\left(\frac{z}{r}\frac{\partial f}{\partial y} - \frac{y}{r}\frac{\partial f}{\partial z}\right) - \hat{j}\left(\frac{z}{r}\frac{\partial f}{\partial x} - \frac{x}{r}\frac{\partial f}{\partial z}\right) + \hat{k}\left(\frac{y}{r}\frac{\partial f}{\partial x} - \frac{x}{r}\frac{\partial f}{\partial y}\right)$$

Now, $\frac{\partial f}{\partial y} = \frac{y}{r} \cdot \frac{\partial f}{\partial r}$, $\frac{\partial f}{\partial z} = \frac{z}{r} \cdot \frac{\partial f}{\partial r}$, $\frac{\partial f}{\partial x} = \frac{x}{r} \cdot \frac{\partial f}{\partial r}$

$\therefore i\left(\frac{z}{r} \cdot \frac{y}{r}\frac{\partial f}{\partial r} - \frac{y}{r} \cdot \frac{z}{r} \cdot \frac{\partial f}{\partial r}\right)$

$= i \times 0$

$= 0$

Similarly, $\hat{j} \times 0 = 0$, $\cancel{k \times 0}$ $\hat{k} \times 0 = 0$

$\therefore \vec{\nabla} \times \frac{f(\vec{r})}{r}(x\hat{i} + y\hat{j} + z\hat{k}) = 0$ (Proved)

$\therefore$ central force is conservative.

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c) $\vec{F} = -\frac{\hat{r}}{r^n}$

$= -\frac{\vec{r}}{r^{n+1}}$

Now, $\vec{\nabla} \times \vec{F} = \vec{\nabla} \times \left(-\frac{\vec{r}}{r^{n+1}}\right)$

$= \vec{\nabla}\left(-\frac{1}{r^{n+1}}\right) \times \vec{r} - \frac{1}{r^{n+1}}(\vec{\nabla} \times \vec{r})$

Now, $\vec{\nabla} \times \vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ x & y & z \end{vmatrix} = 0$

$\therefore \vec{\nabla} \times \left(-\frac{\vec{r}}{r^{n+1}}\right) = \vec{\nabla}\left(-\frac{1}{r^{n+1}}\right) \times \vec{r}$

$= \frac{(n+1)}{r^{n+2}} \vec{r} \times \vec{r}$ $[\because \vec{r} \times \vec{r} = 0]$

$= 0$

$\therefore \vec{\nabla} \times \vec{F} = \vec{\nabla} \times \left(-\frac{\vec{r}}{r^{n+1}}\right) = 0$

$\therefore$ the force $\vec{F} = -\frac{\hat{r}}{r^n}$ is Conservative.

3)(a) Center of mass (cm) of a system of N-particles- The center of mass of a system is defined as a point G whose position vector $\vec{R}$ is given by,

$$\vec{R} = \frac{\sum m_i \vec{r_i}}{\sum m_i}$$

4)(a) Nuclear fission- Nuclear fission is the subdivision of a heavy atomic nucleus. 1.86 mev energy is released here.
E.g-

$$_{92}U^{285} + {}_0n^1 \longrightarrow {}_{57}La^{148} + {}_{35}Ba^{85} + 3\,{}_0n^1$$

Nuclear fusion- Nuclear fusion is a relation in which two or more atomic neuclei are combined to form one or more different atomic nuclei or subatomic particles. 3.7 mev energy is released here.

Eg – $^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}H + ^{1}_{0}n$ [$^{2}_{1}H$ = Doiterium, $^{3}_{1}H$ = Tritium]

$^{3}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$

b)

Isotopes	Isotones	Isobars
(i) the molecules with same Proton number.	(i) The molecules with same neutron number.	(i) The molecules with same atomic mass.
(ii) Numbers of Protons and electrons are same. Neutrons only differ.	(ii) Numbers of neutrons are same. Number of electrons and Protons differ.	(ii) All neutrons Protons and electron differ.
(iii) Iso means same, P stands for 'Protons'	(iii) Iso means same, N means 'Neutrons'	(iii) Iso means same, 'Baros' means 'weight'.
E.g – K^{39}_{19}, Ca^{40}_{20}	E.g – Ge^{76}_{32}, Ge^{77}_{32}	E.g – C^{14}_{6}, N^{14}_{7}

(C) Isobars - ${}_{6}C^{14}$, ${}_{7}N^{14}$

Isotopes - ${}_{19}K^{39}$, ${}_{20}Ca^{40}$

(d) $${}_{6}C^{14} \longrightarrow {}_{7}N^{14} + \bar{\nu}_e + X$$

$\cancel{X = {}_{1}^{0}n}$ $\cancel{X = \beta = A^{z}}$

Here 'X' is 'β'. It means an electron $[{}_{-1}^{0}e]$.

5)(a) De-Broglie's hypothesis - De-Broglie proposed that the relation $p = \frac{h}{\lambda}$ [where, p = momentum, h = Planck's constant, λ = wavelength] applies for the material particles as well as photones.

$m = 10\ gm$, $v = 0.5\ m/s$
$= 10 \times 10^{-3}\ kg$

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\therefore \lambda = \frac{6.626 \times 10^{-34}}{10 \times 0.5 \times 10^{-3}} = 1.3252 \times 10^{-31}\ m$$

$\therefore$ The wavelength is - $1.3252 \times 10^{-31}\ m$

(b) photoelectric effect - photoelectric effect is a phenomenon in which electrically charged particles are released from a material when it absorbs electromagnetic radiation.

Einstein's photo electric ~~eqn~~ equation -

$$E_{max} = h\nu - w$$

[where,
E_{max} = maximum energy
h = Plank's constant
ν = frequency
W = workfunction]

the another form,

$$E_{max} = h\nu - h\nu_0$$
$$E_{max} = h(\nu - \nu_0)$$
$$E_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

[λ_0 = Threshold wavelength, ν_0 = threshold frequency]

(c) Time independent schrodinger equation -

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)\psi = 0$$

[where,
m = mass of a body
V = Potential energy]

In Classical mechanics, the total energy of a particle is -

$$E = \text{kinetic energy} + \text{potential energy}$$
$$= \frac{P^2}{2m} + V$$

[Here, P = momentum]

multiplying 'ψ' in both side,

$$E\psi = \frac{p^2\psi}{2m} + V\psi$$

$$\Rightarrow E\psi = -\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi$$

$$\Rightarrow \frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + (E-V)\psi = 0$$

$$\Rightarrow \frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}(E-V)\psi = 0$$

$$p\psi = -i\hbar\frac{\partial\psi}{\partial x}$$

$$\Rightarrow \frac{\partial\psi}{\partial x} = \frac{-p\psi}{i\hbar}$$

$$\Rightarrow \frac{\partial^2\psi}{\partial x^2} = \frac{-p}{i\hbar}\frac{d\psi}{dx}$$

$$= \frac{-p}{i\hbar}\cdot\frac{(-p)}{i\hbar}\psi$$

$$\Rightarrow \frac{d^2\psi}{dx^2} = \frac{-p^2}{\hbar^2}\psi$$

$$\therefore p^2\psi = -\hbar^2\frac{d^2\psi}{dx^2}$$

6)(a) Coulomb's law = The magnitude of electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitude of the chargeds and inversely proportionaly to the square of the distance between them.

$$\vec{F_{21}} \propto \frac{q_1 q_2}{r_{21}^2}$$

$$\Rightarrow \vec{F_{21}} = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r_{21}^2}\hat{r_{21}}$$

[where, ϵ_0 = permitivity in ~~vac~~ space
q_1, q_2 = magnitude of two point charges

r_{21} = distance between two point charges]

(C) $C = 4 \times 10^{-6}$ F
$V = 12$ V

we know that, $q = CV$ [q = charge stored in capacitor]

~~$\therefore q = \frac{C}{V}$~~ [C = capacitance
V = voltage]

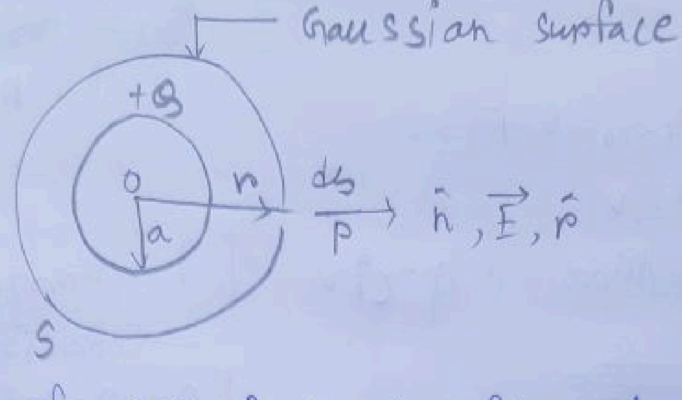
$= 4 \times 10^{-6} \times 12$

~~$= 3.33 \times 10^{-7}$ C~~ $= 4.8 \times 10^{-5}$ C

$\therefore$ the charge stored in capacitor is = ~~3.33×10^{-7}~~ 4.8×10^{-5} C

(b) consider a uniformly changed sphere of radius a carrying a total charge Q. we are to find the electric field at an external point P at a distance r from the centre of the sphere. we construct the Gaussian surface which in this case is a concentric sphere of radius r passing through the point P. For this surface (S) Gauss's law states that

$$\int_S \vec{E} \cdot \vec{ds} = \frac{1}{\epsilon_0} Q$$



Because of spherical ~~Sn~~ symmetry $\vec{E}$-field lines will be normal to the Gaussian surface at every point and $\vec{E}$ will also be of constant magnitude all over the surface, therefore,

$$\int_S \vec{E}\cdot\vec{ds} = E\int_S ds = E\cdot 4\pi r^2$$

Now, $E\cdot 4\pi r^2 = \frac{1}{\epsilon_0} Q$

$$\Rightarrow E = \frac{1}{4\pi\epsilon_0}\cdot\frac{Q}{r^2}$$

In vector form, $\vec{E} = \frac{1}{4\pi\epsilon_0}\cdot\frac{Q}{r^2}\vec{r}$

This is the same field as produced by a point charge Q placed at the centre O. Thus for an outside point the whole charge on the sphere may be assumed to be concentrated at the centre of the sphere. This is the electric field outside a sphere having uniform volume distribution of charge.

7) (a) Electric dipole - Two equal and opposite charges sperated by a very small distance are constitute to electric dipole.

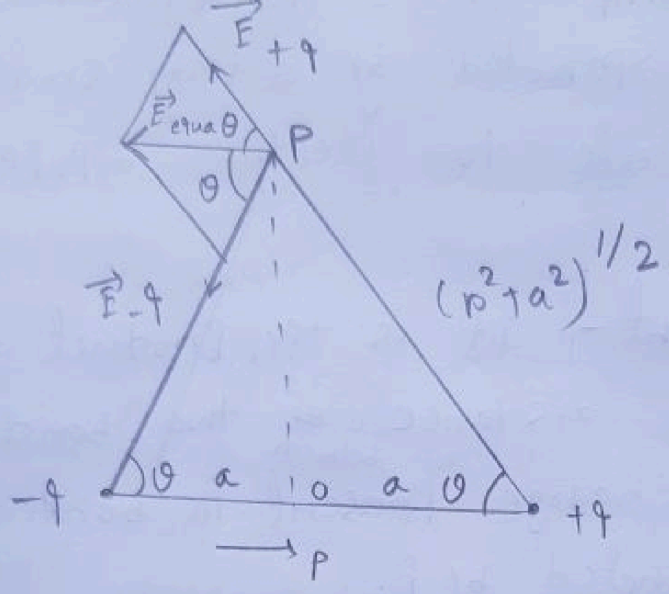
(b) Dipole moment - It is the product of inter-nuclear distance between two bonded atomes and the charge present in bonded atomes. It is denoted by P.

P = 2ql [where, 2l = internuclear distance between two bonded atomes
q = charge present in atomes]

SI unit - Cm. [coulomb·meter]

(c) Ideal or point dipole - we can think of an ideal dipole in which size $2a \to 0$ and charge $q \to \infty$ in such a way that the dipole moment, $P = q \times 2a$ a has a finite value, such a dipole of negligibly small size is called an ideal or point dipole.

(d)



Electric field at an equatorial point of a dipole. As show in fig. consinder on electric dipole consisting of changes q and +q, seperated by distance 2a and placed in vacuum. let P be a point on the equatorial line of the dipole at ~~at a~~ distunce p from it.

Electric field at point P due to +q charge is

$$\vec{E}_{+q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{p^2+a^2}, \text{ along } \vec{BP}$$

Electric field at point P due to -q charge is

$$\vec{E}_{-q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{p^2+a^2}, \text{ along } \vec{PA}$$

Thus, the magnitudes of $\vec{E}_{+q}$ and $\vec{E}_{-q}$ are equal, i.e.

$$\vec{E}_{+q} = \vec{E}_{-q} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{p^2+a^2}$$

Clearly, the components of $\vec{E}_{-q}$ and $\vec{E}_{+q}$ normal to the dipole axis will cancle out. The components parallel to the dipole axis add up. The total electric field $\vec{E}_{equa}$ is opposite to $\vec{p}$.

$$\therefore \vec{E}_{equa} = -(E_{-q}\cos\theta + E_{+q}\cos\theta)\hat{p}$$

$$= -2E_{-q}\cos\theta\,\hat{p} \quad [\because E_{-q} = E_{+q}]$$

$$= -2 \cdot \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{p^2+a^2} \cdot \frac{a}{\sqrt{p^2+a^2}}\hat{p}$$

$$= \frac{-1}{4\pi\epsilon_0} \cdot \frac{p}{(p^2+a^2)^{3/2}}\hat{p} \quad \left[\because \cos\theta = \frac{a}{\sqrt{p^2+a^2}}\right]$$

$$\therefore \vec{E}_{equa} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{p}{(p^2+a^2)^{3/2}}\hat{p}$$

where $p = 2qa$ is the electric dipole moment. If, $p \gg a$, then

$$\vec{E}_{equa} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{p}{p^3}\hat{p}$$

8)(a) ~~Expl.~~ Fundamental Postulates of kinetic theory of gass –

(i) A gas consists a numbers of identical molecules, which are like minute hard elastic spehers, constantly moving in all possible directions with different velocities in ~~an~~ a random fashion.

(ii) During the motion, the molecules colide with one another and also with the walls of the container, this collision being perfectly elastic. on the other words, there is no loss of kinetic energy during the collisions. As the chance of collisions in all directions is same, it ~~dos~~ doesn't effect the molecular density.

(iii) The collisions are esentialy instantinious, that is, the duration of a collision is insignificant compared to the time between collisions.

(iv) The molecules exert no forces (attraction or repulsion) on one another except when they actualy colide, that is, between two successive collisions they move in straight lines with uniform.

(v) Since, the molecules are like geometrical mass points, the volume occupied by them is negligible compared to the total volume of the gas in container.

(c) the numbers of degrees of freedom of a diatomic gas molecule-

we know that, $f = 3N - m$

$= 3 \times 2 - 1$ [for diatomic gas molecule $N = 2$ and $m = 1$]

$= 6 - 1$

$= 5$

(d) The principle of equipartition of energy of gasses - If the energy of the system associated with any degree of freedom is a quadratic ~~equation~~ of function, specifying of variable the degree of freedom, then in a state of thermal equilibrium of the system at the temperature T, the mean value of corresponding energy is $\frac{1}{2}kT$.

b) The r.m.s velocity of hydrozen gas (H_2) at NTP —

$$v_{rms} = \sqrt{\frac{3P}{\rho}}$$

[where, P = Pressure of gas
ρ = density of gas]

$$= \sqrt{\frac{3 \times 1.013 \times 10^5}{0.09}}$$

$$= \sqrt{\frac{3.039 \times 10^5}{0.09}}$$

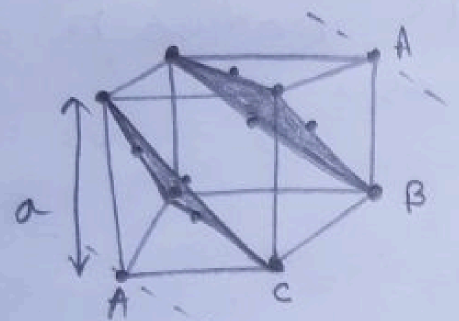
$$= 1837.5 \ m/s$$

9) (i) latice - The periodic arrangements of atomes in crystal is termed as latice.

Basis - The space lattice has been defined as array of imaginary points which are so arranged in space that each point has identical surroundings. the crystal structure is ~~very~~ always described in terms of atomes rather than points. thus in order to obtain a crystal structure, an atom or a group of atoms must be placed on each lattice point in a regular fashion. such an atoms or a group of atomes is called the basis.

(b) The relationship between the latice parameter and the atomic radius r for the monoatomic sc, bcc and fcc structures.

fcc



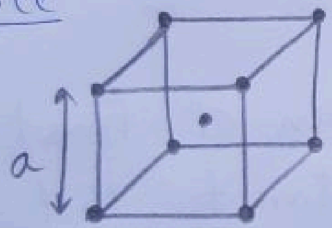
← conventional unit cell of fcc structure

In this structure, the stack of first two layers A and B is similar to that of hcp structure. The difference arises in the third layer which, in the present case, doesn't overlap the first layer. The atoms of the third layer occupy the positions of those valleys of the A layer which are not occupied by the B-layer atoms. The third layer is designated by the letter C. The fourth layer exactly overlaps the first layer and the sequence is repeated. Thus fcc structure is represented by the following stacking sequence: _ ABC ABC _ _

The conventional unit cell of fcc and is shown in the figure. It is a non-primitive cell having effective number of atoms equal to $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$. The atoms touch one another along the face diagonals. The length of the cube edge a, and the atomic radius r, are related to each other as →

$$4r = \sqrt{2}a.$$

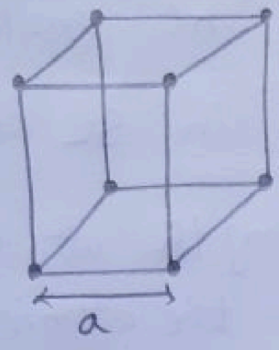
bcc



← conventional unit cell of bcc structure.

The conventional unit cell of bcc structure is non-primitive and shown in this fig. It has cubical shape with atoms located at the corners and the body centre. Thus the effective number of atoms per unit cell is $8 \times \frac{1}{8} + 1 = 2$. & the configuration number of each atom is 8. The atoms touch one another along the body diagonal. Thus a is related to r as → $4r = \sqrt{3}a$ [a = the length of the cube edge
r = the atomic radius]

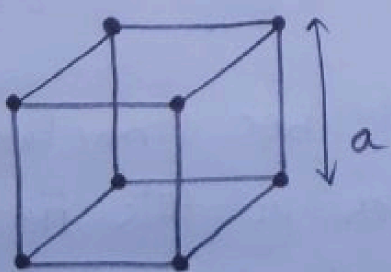
SC-



← Conventional unit cell of sc Structure.

The conventional unit cell of sc structure is the same as its Primitive cell and is shown in this fig. The atoms are located at the corners only and touch one another along the cube edges. thus in sc structures, we have → $a = 2r$ [a = the length of the cube edge
r = the atomic radius]

The Packing ~~fa~~
(C) ~~funct~~ fraction of a sc latice-



← Conventional unit cell of sc Structure.

The conventional unit cell of sc structure is the same as its Primitive cell ~~a~~ and is shown in this fig. The atoms are located at the corners only and touch one another along the cube edges. Thus in SC structures, we have → $a = 2r$ [a = the length of the cube edge, r = the atomic radius]

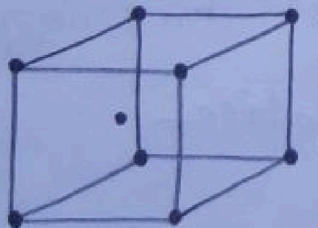
The coordination number of each atom is 6.

The Packing fraction is given by -

$$f = \frac{1 (4/3) \pi r^3}{a^3} = 0.52$$

only Polonium exhibits this type of structure at room temperature.

the Packing fraction of a bcc latice-



a

← conventional unit cell of bcc structure.

The conventional unit cell of bcc structure is non-Primitive and show in this fig. It has cubical shape with atoms located at the corners and the body centre. the the effective number ~~is~~ of atoms per unit cell is $8 \times \frac{1}{8} + 1 = 2$.

The configuration number of each atom is 8. The atoms touch one another along the body diagonal. Thus a is related to r as →

$4r = \sqrt{3}a$ [a = the length of the cube edge, r = the atomic radius]

The packing fraction is given by,

$$f = \frac{2(4/3)\pi r^3}{a^3} = 0.68$$

the examples of materials exhibiting bcc are Na, K etc.

3) a) Centre of mass (cm) of a system of N-particles-

The centre of mass of a system is defined as a point G and its position vector $\vec{R}$ is given by,

$$\vec{R} = \frac{\sum m_i \vec{r_i}}{\sum m_i}$$

b) we know that, $\vec{P} = \sum_i \vec{P_i} = \sum_i m_i \vec{v_i}$

$= \sum_i m_i (\vec{R} + \vec{r_i})$ $[\because \sum m_i \vec{r_i} = 0]$

$= m\vec{v} + \frac{d}{dt} \sum_i m_i \vec{r_i} = m\vec{v}$

$\therefore \vec{P} = m\vec{v}$

we know that, if the resultant force acting on a particle is '0', the linear momentum ($\vec{P}$) remains constant, both in direction and magnitude

$$\frac{d\vec{P}}{dt} = 0 \Rightarrow \vec{P} = \text{constant}$$

Therefore, $\vec{P}$ remain conserved.

we know that, $\frac{d\vec{L}}{dt} = \vec{N} = \Sigma \vec{r_i} \times \vec{F_i} = \Sigma \vec{N_i}$

we also know that, if the resultant moment acting on a particle is '0', the angular momentum ($\vec{L}$) remains constant, both in magnitude and direction.

$$\therefore \frac{d\vec{L}}{dt} = 0 \Rightarrow \vec{L} = \text{constant}$$

Therefore, $\vec{L}$ remain conserved

we know that total energy of a system is—

$$T + V + \frac{1}{2}\sum_{ij}{}' V_{ij} = \text{constant}$$ [T = total energy of the system
V = Potential energy]

The total mechanical energy of the system is constant in time, that is, it is conserved.

Therefore, total energy ($\vec{E}$) remain conserved.