ENGINEERING PHYSICS

QUESTION BANK

UNIT-01

Q1) Deduce Interplanar spacing of cubic crystal system? What are Miller Indices? How are they obtained? (Co1:

Q2) illustrate the working and construction of powder-diffraction by debye scherrer method.

Q3) Elucidate points defect in crystals?

Q4) what are matter waves? Develop Debroglie wavelength of matter waves?

Q5) Obtain Schrodinger Time Dependent & Independent Equation?

Q6) Derive Eigen Values & Eigen Vectors in the Case of Particle in “Potential Box”?

SAQ’S

Q1) Define space lattice and unit cell?

Q2) State and prove Bragg’s Law?

Q3) write down few applications of point defect?

Q4) what are matter waves? Inscribe few properties of matter waves?

Q5) Write the properties & physical significance of wave function?

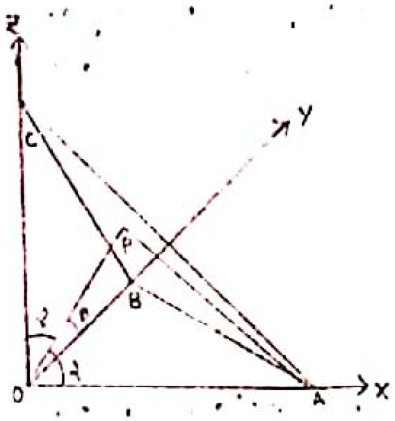
Q6) What is meant by wave function?

Q7) Differentiate between Electromagnetic wave and Matter Waves?

Interplanar Spacing (Cubic Crystal)

LAQ's

1)



* Let us consider three Co-ordinate axises OX, OY, OZ
* Let plane (h, K, L) is parallel to the plane passing through the origin. If a/h, b/K, c/L are the intercepts made at A, B, C along three Crystallographic axes.
* Let $OP = d$ and α, β, γ are the orthogonal along three axes.

$$\cos\alpha = \frac{OP}{OA} = \frac{d}{a/h} = \frac{dh}{a}$$

$$\cos\beta = \frac{OP}{OB} = \frac{d}{b/K} = \frac{dK}{b}$$

$$\cos\gamma = \frac{OP}{OC} = \frac{d}{c/L} = \frac{dL}{c}$$

By using Law of directional Cosines

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

$$\left(\frac{dh}{a}\right)^2 + \left(\frac{dK}{b}\right)^2 + \left(\frac{dL}{c}\right)^2 = 1$$

$$d^2\left[\frac{h^2}{a^2} + \frac{K^2}{b^2} + \frac{L^2}{c^2}\right] = 1$$

For cubic System

$a = b = c$; $\alpha = \beta = \gamma = 90^\circ$

$a^2 = b^2 = c^2$

$$d^2\left[\frac{h^2}{a^2} + \frac{K^2}{a^2} + \frac{L^2}{a^2}\right] = 1$$

$$d^2\left[\frac{h^2 + K^2 + L^2}{a^2}\right] = 1$$

$$d^2(h^2 + K^2 + L^2) = a^2$$

$$d^2 = \frac{a^2}{h^2 + K^2 + L^2} \Rightarrow d = \frac{(a^2)^{1/2}}{(h^2 + K^2 + L^2)^{1/2}}$$

$$\therefore \boxed{d_{hKL} = \frac{a}{\sqrt{h^2 + K^2 + L^2}}}$$

Miller Indices

* Miller suggested the concept of miller indices to locate the crystal planes mathematical
* Miller indices is the three smallest possible integers which has the same ratio as their reciprocals of the concern plane along the crystallographic axes.

Procedure to evaluate Miller Indices

1. Take the intercepts of the concerned plane.
2. Take the reciprocals of the intercepts
3. Reduce it to a whole number

Important features of Miller Indices

1. If a plane is parallel ~~is~~ to any axis, then the intercept is taken as infinity and the Miller Indices is equal to zero.
2. If the intercept of the concerned plane is negative, then we put a bar on the Miller Indices.
3. All equally spaced parallel planes have same Miller Indices.
4. The ~~plane~~ M.I h,k,l does not defined a particular plane but a set of planes.

Calculate the Miller Indices of the plane having the intercepts $-2a, 3b, \frac{1}{4}c$ along Crystallographic axes.

Sol: ① $-2, 3, \frac{1}{4}$

② $\frac{-1}{2}, \frac{1}{3}, 4$

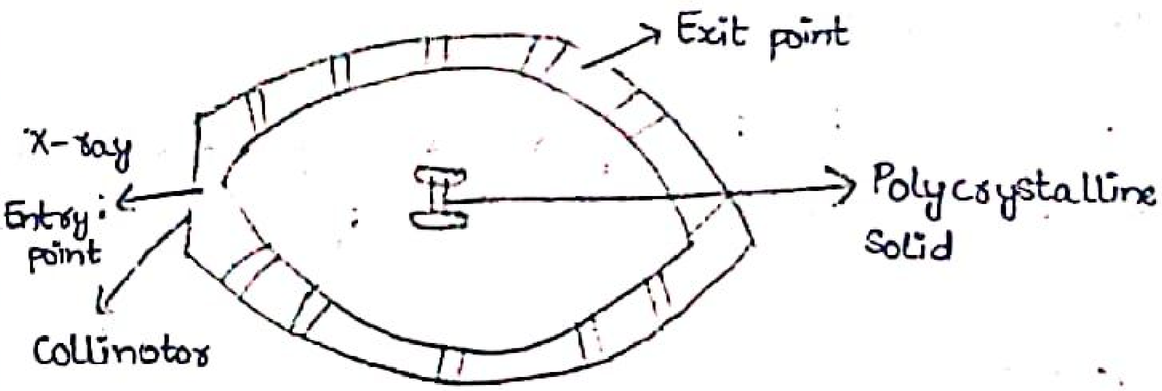
L.C.M of $2, 3 \rightarrow 6$

③ $\frac{-1}{2} \times 6, \frac{1}{3} \times 6, 4 \times 6$

④ $-3, 2, 24$

$(\bar{3}\ 2\ 24)$

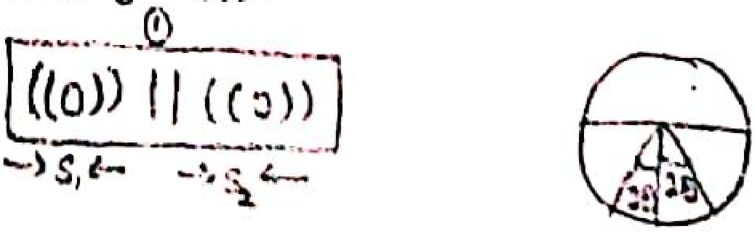
2) Powder-Method (Debye-Scherer method crystallites)



Construction

* Let us consider a poly crystaline solid which is made into crystalite with a adacive capillary tube walls and the crystalites are mixed.
* A thin film is attached in a ~~cry~~ cylindrical casette
* A thin film is take in the dark room after the diffraction pattern is obtained.
* A thin film is made in such a way the entry and exit point are mid way as shown in the figure (1)

Working rule:-



1. When a monochromatic x-ray beam is made to incident on the capillary tube, the beam get scattered in all the possible direction w.r.t the crystalite.

The diffraction pattern obtained satisfy the bragg's law.

2. The set of lattice plane obtained on the x-ray flim is as shown in figure (2).

3. If the bragg's angle. $\theta = 45°$ the corresponding cone open's out into a circle.

4. If the bragg's angle is greater than $45°$ then back reflections are obtain as the varies from $0°$ to $90°$ different diffraction pattern is absorbs on a cylindrical film.

5. Mathematically various diffraction angle θ with a known camera radius (R) can be calculated as $4\theta = \frac{S}{R}$

distance of the consecutive arc $\theta = \frac{S}{4R}$

$$\theta = \frac{S}{4R} \times \frac{180}{\pi}$$

Applications of Powder Diffraction Method

1. **Identification of Crystalline Phases**
2. **Determination of Crystal Structure**
3. **Phase Purity Analysis**
4. **Strain and Stress Analysis**
5. **Crystallite Size Determination**
6. **Quantitative Phase Analysis**
7. **Thermal Stability Studies**
8. **Characterization of Thin Films and Coatings**

3) Point Defect

Any duration is Localized arrangement of Latice points and on the lattice site is said to be point defect

1. Substitution defect

When a Foreign atom replaces a parent atom in the Lattice Site it is said to be Substitution defect.

Ex:- Exterinsic Semi Conductor

2. Interstitial defect.

When a Small sized atom occupies the empty space in between the Lattice Sites is said to be Interstitial defect.

Ex:- Carbon Iron

3. Vacancy

When an unoccupide atom position exist in the Lattice site of the Crystal it is said to be vacancy.

Ex:- Hole in a Semiconductor

4. Schottky defect

When an atom (or) ion is missing from its normal in the Crystal Lattice it is said to be Schottky defect.

Ex:- NaCl, AgBr, etc....

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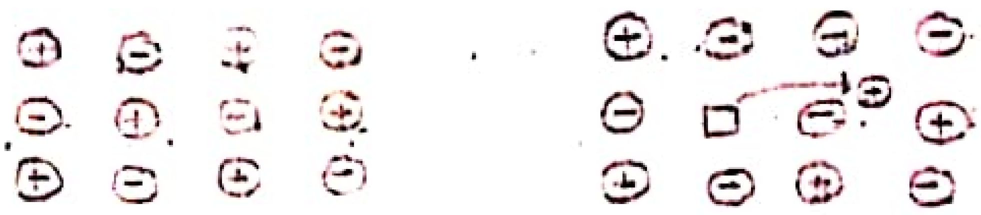
5. Frenkel defect



When an atom (or) ion is displaced from its normal site to interstitial site it is said to be Frenkel defect.

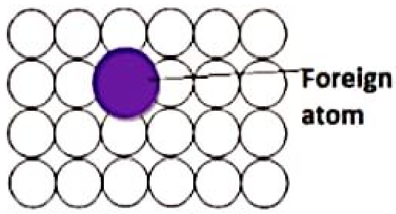
Ex:- AgCl, ZnS, etc....

2. Write a short note on classification of point defects (5M) (BTL 2)

1.**Point Defects**: It is localized disruption in regularity of the lattice on and between lattice sites. Point defects are of three types:

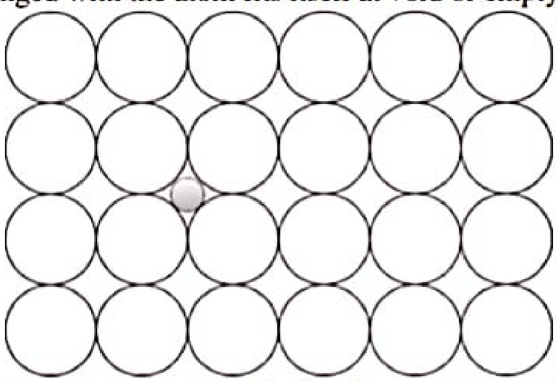
3) from sir's pdf

(i) Substitutional impurity: when a foreign atom replaces a parent atom in the lattice, substitutional defect is generated inside the crystal.
If the impurity atom has roughly same size and valency as the parent atoms, then substitutional impurity is created. Ex: phosphorous in silicon

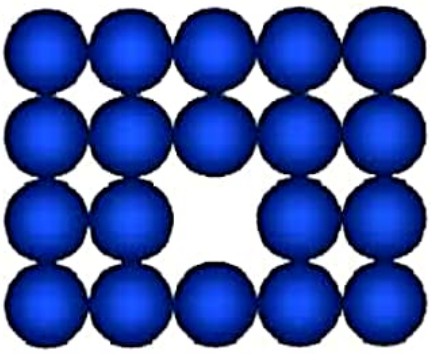


Substitutional defects

(ii)Interstitial impurity: when a small sized atom occupies the empty space in between the parent atom. Ex: Alloying element carbon in Iron.
It occupies position between lattice sites and the impurity is generated, if the volume of the crystal remains unchanged with the atom fits itself at void or empty space between lattice sites.

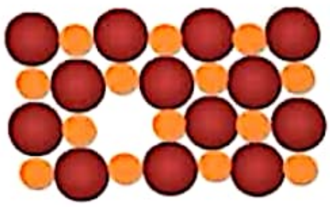


(iii)Vacancy: A vacancy or vacant site implies on occupied atom position within the crystal sites. They are also known as unoccupied lattice sites. Ex: Hole in semiconductor.
It occurs as a result of imperfect packing during crystallization and if atom leaves its site and dissolves interstitially into the structure.



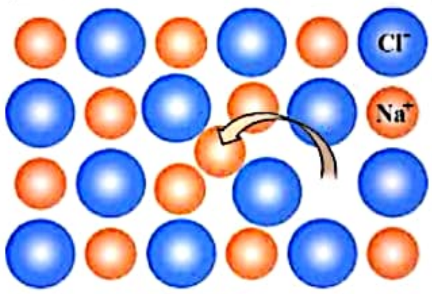
Schottky Defect: It is the combination of one cation vacancy and one anion vacancy.

Ex: Nacl, Kcl.



Schottky's Defects

Frenkel Defect: Vacancy created if an atom leaves its site and dissolve interstitially into the structure is known as Frenkel defect. Ex: silver halides etc.,



Frenkel defect

2.Write any three application of point defects.(BTL 3)

Applications of point defects:

1. Mechanical and electrical properties of crystals are improved by point defects.
2. Addition of trivalent and pentavalent impurities in Silicon and Germanium semiconductors increases their electrical conductivity.

3. Addition of carbon atoms in gold increases the ductility of gold, so that it can be drawn into wires for making ornaments.
4. Impurity defects produces the diffusion and phase transformation processes.

Q: What are matter waves?

4)

Ans:

Matter waves, also known as **de Broglie waves**, are the wave-like properties associated with particles of matter. According to **de Broglie's hypothesis**, every moving particle has a wavelength given by:

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

Derivation of de Broglie Wavelength

Step 1: Photon energy and momentum

From Planck's relation:

$$E = h\nu = \frac{hc}{\lambda}$$

$$E = pc \quad \Rightarrow \quad p = \frac{E}{c}$$

Equating both expressions for E:

$$\frac{hc}{\lambda} = pc \Rightarrow \boxed{p = \frac{h}{\lambda}} \Rightarrow \boxed{\lambda = \frac{h}{p}}$$

Step 2: Extension to matter particles

de Broglie assumed the same relation applies to **particles** like electrons, protons, etc.

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For a particle of:

- mass m
- velocity v

Momentum:

$$p = mv$$

Substitute into the wavelength formula:

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

This is the **de Broglie wavelength** for a material particle.

Alternate form (in terms of kinetic energy)

For a non-relativistic particle,
$KE = \frac{1}{2}mv^2$

Solve for velocity:

$$v = \sqrt{\frac{2KE}{m}}$$

Substitute into the de Broglie equation:

$$\lambda = \frac{h}{\sqrt{2mKE}}$$

Key Points

- **Formula:** $\boxed{\lambda = \frac{h}{mv}}$

Key Points

- **Formula:** $\boxed{\lambda = \frac{h}{mv}}$
- Applies to **all moving matter particles.**
- **Verified** by experiments like the **Davisson-Germer experiment.**
- Important in **quantum mechanics, electron microscopy, atomic models,** etc.

Conclusion

The de Broglie hypothesis established that **every moving particle has an associated wave**, with a wavelength given by:

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

5) ~~Sh~~ Schroedinger equation

The eqn which gives the information regarding the wave nature of the particle and the energy of the particle (or) system such equations are said to be schroedinger equation

* There are two types of schroedinger eqn

i) schroedinger time dependent eqn

ii) schroedinger time Independent eqn

Schroedinger time dependent eqn :

Let us consider the particle having mass 'm' moving with the velocity 'v' possess kinetic energy in terms of momentum and potential energy 'v'.

- $K.E = \frac{p^2}{2m}$

$K.E = \frac{1}{2}mv^2$

$K.E = \frac{1}{2}mv^2 \times \frac{m}{m}$

$= \frac{(mv)^2}{2m}$ $\because p = mv$

$K.E = \frac{p^2}{2m}$

$E = K.E + P.E$

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

mul ψ on b.s

$E\psi = \left[\frac{p^2}{2m} + V\right]\psi$ - ①

Quantum operators are measuring devices

Energy operator $\Rightarrow E = i\hbar \frac{d}{dt}$

momentum operator $\Rightarrow p^2 = -\hbar^2 \nabla^2$

substituting the value of energy & momentum operator in eq ①

$$i\hbar \frac{d}{dt}\psi = \left[\frac{-\hbar\nabla^2}{2m} + V\right]\psi$$

Schroedinger Time Independent eqn.

Let us consider the partical having mass 'm' and moving with the velocity with 'v' if ψ be the wavefunction of the partical along x, y, z direction at time 't'.

We know that the debroglie hypothesise $\lambda = h/mv$

the classical differential eqn of a progressive wave is given as

$$\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} = \frac{1}{v^2}\frac{d^2\psi}{dt^2}$$

$$\nabla^2\psi = \frac{1}{v^2}\frac{d^2\psi}{dt^2} \quad - (1)$$

since eq (1) is a second order differential eqn the soln of eqn (1) maybe

$$\psi = \psi_0 e^{-i\omega t}$$

Diff ψ w.r.t 't'

$$\frac{d\psi}{dt} = \psi_0 e^{-i\omega t}(-i\omega)$$

again diff ψ w.r.t t

$$\frac{d^2\psi}{dt^2} = \psi_0 e^{-i\omega t}(-i\omega)^2 \quad \left[\because i^2 = -1,\ \psi_0 e^{-i\omega t} = \psi\right]$$

$$\frac{d^2\psi}{dt^2} = -\psi\omega^2$$

sub $\frac{d^2\psi}{dt^2}$ value in (1)

$$\nabla^2\psi = -\frac{\omega^2}{v^2}\psi$$

$$\nabla^2\psi + \frac{\omega^2}{v^2}\psi = 0 \quad - (2)$$

$$\omega = 2\pi\nu$$

$$\because \nu = \frac{v}{\lambda}$$

$$\omega = 2\pi\left(\frac{v}{\lambda}\right) \Rightarrow \frac{\omega}{v} = \frac{2\pi}{\lambda} \quad \text{S.O.B.S}$$

$$\frac{\omega^2}{v^2} = \frac{4\pi^2}{\lambda^2} \quad \left[\because \lambda = \frac{h}{mv} \Rightarrow \lambda^2 = \frac{h^2}{m^2v^2}\right]$$

$$\frac{\omega^2}{v^2} = \frac{4\pi^2}{h^2}(m^2v^2)$$

Substitude $\frac{\omega^2}{v^2}$ values in eq (2)

$$\nabla^2\psi + \frac{4\pi^2}{h^2}(m^2v^2)\psi = 0 \longrightarrow (3)$$

'E' is the Total Energy

$$E = K.E + P.E$$

$$E = \frac{1}{2}mv^2 + V$$

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$E - V = \frac{1}{2}mv^2$ multiply m on both sides

$(E-V)m = \frac{1}{2}m^2v^2$ $\quad \because m^2v^2 = 2m(E-V)$

Substitude m^2v^2 value in eq ③

$\nabla^2\psi + \frac{4\pi^2}{h^2}(2m(E-V))\psi = 0 \Rightarrow \nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0$ is the Schroedinger time independent equation.

2. Solving the Schrödinger equation

Q6) Derive Eigen Values & Eigen Vectors in the Case of Particle in "Potential Box"?

- The time-independent Schrödinger equation is:

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

where:

  - $\hbar$ is the reduced Planck constant
  - m is the mass of the particle
  - $\psi(x)$ is the wave function
  - V(x) is the potential energy
  - E is the total energy

- Inside the box (where V(x)=0), the equation simplifies to:

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This can be rearranged to:

$$\frac{d^2\psi(x)}{dx^2} + \frac{2mE}{\hbar^2}\psi(x) = 0$$

- Let $k^2 = \frac{2mE}{\hbar^2}$. The equation becomes:

$$\frac{d^2\psi(x)}{dx^2} + k^2\psi(x) = 0$$

- The general solution to this differential equation is:

$$\psi(x) = A\sin(kx) + B\cos(kx)$$

where A and B are constants.

3. Applying boundary conditions

- The wave function must be zero at the boundaries of the box (ψ(0)=0 and

3. Applying boundary conditions

- The wave function must be zero at the boundaries of the box ($\psi(0)=0$ and $\psi(L)=0$).
- Applying $\psi(0) = 0$:

  $$A\sin(0) + B\cos(0) = 0$$

  $$A(0) + B(1) = 0$$

  This implies $B=0$.
- So, the wave function becomes:

  $$\psi(x) = A\sin(kx)$$
- Applying $\psi(L) = 0$:

  $$A\sin(kL) = 0$$

  This means either $A=0$ (which leads to a trivial solution where the particle doesn't exist) or $\sin(kL) = 0$.
- For $\sin(kL) = 0$, we must have:

- For $\sin(kL) = 0$, we must have:

  $$kL = n\pi$$

  where n is a positive integer (n = 1, 2, 3,...). Note that n cannot be 0, as that would result in $\psi(x) = 0$.

4. Determining the eigenvalues (energy)

- From $k = \frac{n\pi}{L}$ and $k^2 = \frac{2mE}{\hbar^2}$, E can be solved:

  $$E = \frac{\hbar^2 k^2}{2m} = \frac{\hbar^2 (n\pi/L)^2}{2m} = \frac{n^2\pi^2\hbar^2}{2mL^2}$$

  Since $\hbar = \frac{h}{2\pi}$ where h is the Planck constant, this can also be written as:

  $$E_n = \frac{n^2h^2}{8mL^2}$$

- These are the allowed energy values (eigenvalues) for the particle in the box, and they are quantized (only discrete

$$E_n = \frac{n^2 h^2}{8mL^2}$$

- These are the allowed energy values (eigenvalues) for the particle in the box, and they are quantized (only discrete values are permitted).

5. Determining the eigenfunctions (wave functions)

- Substituting the value of k back into the wave function, the eigenfunctions are:

$$\psi_n(x) = A \sin\left(\frac{n\pi x}{L}\right)$$

- To determine the constant A, normalize the wave function, meaning the total probability of finding the particle inside the box must be 1:

$$\int_0^L |\psi_n(x)|^2 dx = 1$$

- Substituting the wave function and

- To determine the constant A, normalize the wave function, meaning the total probability of finding the particle inside the box must be 1:

$$\int_0^L |\psi_n(x)|^2 dx = 1$$

- Substituting the wave function and solving the integral gives:

$$A = \sqrt{\frac{2}{L}}$$

- Therefore, the normalized eigenfunctions (eigenvectors) for the particle in a 1-D box are:

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$$

for 0 < x < L, and $\psi_n(x) = 0$ otherwise.

Saq's

1)

Q1) Define Space Lattice and Unit Cell

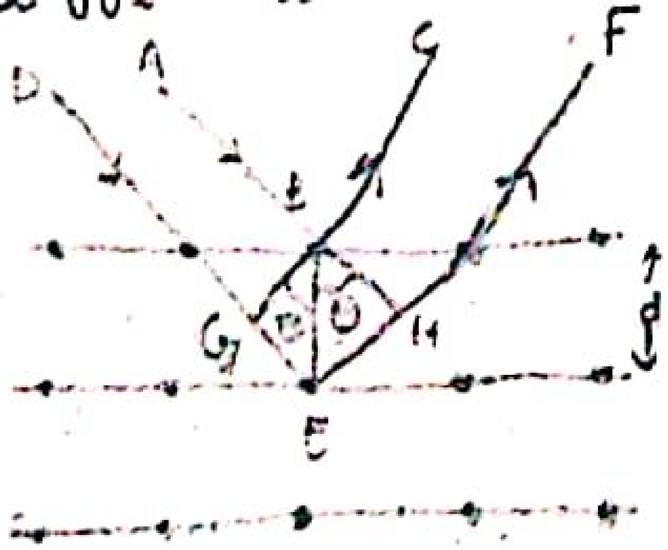
Space Lattice:

A **space lattice** is a **regular three-dimensional arrangement of points** in space where each point represents the position of an atom, ion, or molecule in a crystal.

Unit Cell:

A **unit cell** is the **smallest repeating structural unit** of a crystal lattice which, when repeated in all three dimensions, produces the entire lattice.

2) Bragg's Law



Let us consider a wave front of monochromatic X-ray beam of wavelength λ which is made to incident at an angle θ on the atomic planes.

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I.

Each atom Scatters the x-rays in all the directions, in certain direction the radiations are in phase with each other.

ΔGBE

$\sin\theta = \frac{GE}{BE} \Rightarrow \sin\theta = \frac{GE}{d}$

$GE = d\sin\theta$

ΔEBH

$\sin\theta = \frac{EH}{BE} \Rightarrow \sin\theta = \frac{EH}{d}$

$EH = d\sin\theta$

$\Delta = GE + EH \Rightarrow \Delta = 2d\sin\theta$

If two waves/consecutive planes are in phase with each other

$\Delta = n\lambda$

$\boxed{2d\sin\theta = n\lambda}$

Q3) Write Down Few Applications of Point Defect

Point defects are imperfections in the atomic arrangement at specific lattice points. Applications include:

- **Doping in semiconductors** (e.g., creating n-type or p-type silicon)
- **Controlling electrical conductivity**
- **Enhancing diffusion** in materials
- **Tailoring mechanical strength** (e.g., hardening metals)
- **Color centers in crystals** (e.g., F-centers in NaCl)

Q4) What Are Matter Waves? Inscribe Few Properties of Matter Waves

Matter Waves:

According to de Broglie, **moving particles** (like electrons) are associated with waves called **matter waves** or **de Broglie waves.**

Properties:

- Wavelength: $\lambda = \frac{h}{mv}$
- Show **interference and diffraction**
- **Inversely proportional to momentum**
- Have **no electric or magnetic fields**
- Important in **quantum mechanics** and atomic structure

Q5) Write the Properties & Physical Significance of Wave Function

Wave Function (ψ) Properties:

- Describes the **quantum state of a** particle
- Can be **complex-valued**
- Must be **finite, continuous,** and **single-valued**
- Its square, $|\psi|^2$, gives the **probability density**

Physical Significance:

- $|\psi(x,t)|^2, dx$: probability of finding a particle between x and $x + dx$
- Not directly observable; only $|\psi|^2$ has physical meaning

6) Wave Function:

A wave function (Ψ) in quantum mechanics is a mathematical function that describes the state of a particle. The square of its absolute value, $|\Psi|^2$, gives the probability of finding the particle at a certain position.

Q7) Differentiate Between Electromagnetic Wave and Matter Wave

Feature	Electromagnetic Wave
Nature	Wave (of electric and magnetic fields)
Exists For	Light, radio waves, X-rays, etc.
Has mass?	No (massless photons)
Speed	Speed of light (3×10^8 m/s)
Equation	$c = \lambda\nu$
Fields involved	Electric & Magnetic
Observable as	Light, EM radiation

Q7) Differentiate Between Electromagnetic Wave and Matter Wave

ɡnetic Wave	Matter Wave
lectric and ields)	Wave associated with a particle
waves,	Electrons, protons, neutrons, etc.
ess photons)	Yes (associated with massive particles)
ght $(3 \times 10^8$	Depends on particle's velocity $\lambda = \frac{h}{mv}$
Magnetic	No electric or magnetic field
adiation	Electron diffraction, quantum behavior