SOLID STATE PHYSICS- I

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Types of Solids

- Solids can be divided into two group
  based on the arrangement of the at
  These are

  –Crystalline

  –Amorphous

AMORPHOUS AND CRYSTALLINE SOLID

Amorphous solids:

Amorphous means shapeless. There are certain substances like pitch, silicate glass, plastics, Naphthalene, in which the molecules do not form regular pattern. It has irregular arrangement of solid particles. The intermolecular forces are not equal. Also, the distance between particles varies. They have undefined geometric shape.

Crystalline solids:

A solid of definite shape with its atoms, ions or molecules arranged in some regular repetitious 3-D pattern is termed as a crystal. In crystalline solids the particles are arranged in a 3 dimensional order. The particles have equal intermolecular forces. They have sharp melting point and are anisotropic. They are called true solids. Example: Benzoic acid, Diamond.

Difference between Crystalline and Amorphous	
CRYSTALLINE SOLIDS	**AMORPHOUS SOLIDS**
Atoms are arranged in regular 3D	Do not have regular arrangement
Sharp melting point	No particular melting point
Anisotropic	Isotropic
True solid	Pseudo solid
Symmetrical	Unsymmetrical
More rigid	Less rigid
Long range order	Short range order
Ex: Potassium nitrate, copper	Ex: Glass, polyvinyl chloride

Some Definitions:

Lattice: In a crystalline structure, the atoms are regularly arranged. The periodic arrangement of atoms in a crystal is called the lattice.

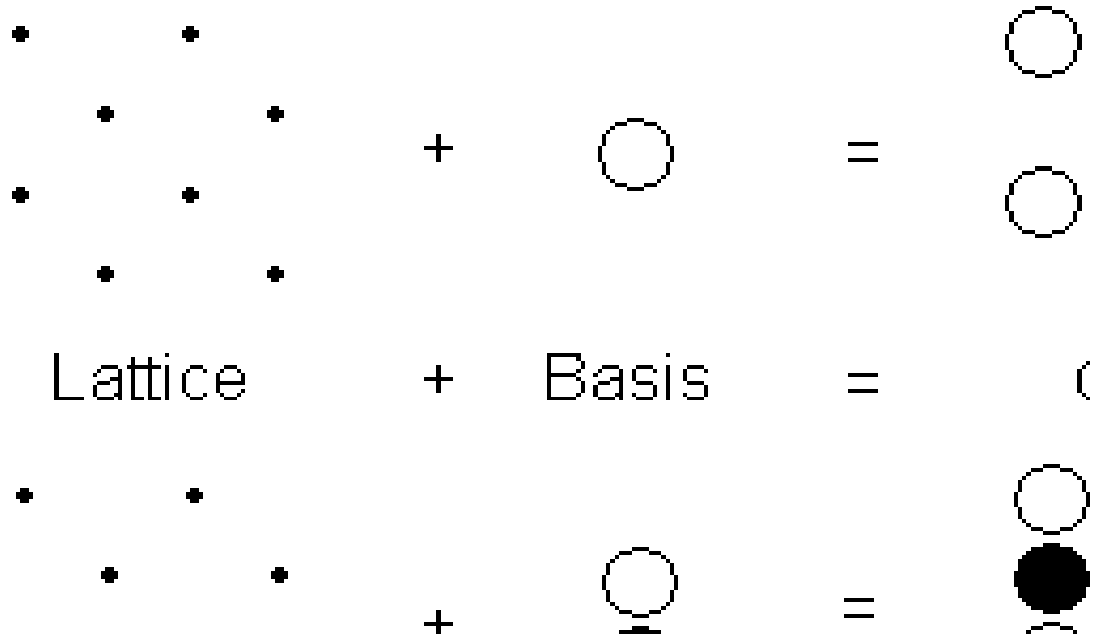
a. Plane Lattice: If the arrangement of atoms is represented in a plane, any atom has got the same environment as any other atom in 2-D. Such an array of atoms is called a plane lattice.

b. Space Lattice: A space lattice is defined as an infinite array of points (atom or molecule) in 3-D in which every point has identical surroundings.

Basis: A basis is defined as an assembly of atoms, ions or molecules identical in composition, arrangement and orientation, which when repeated in 3-D generates a crystal structure.

Crystal Structure:

The structure of a crystal is defined in terms of a lattice with the structural unit or **'basis'** attached to each '**lattice point**'. The lattice points form a set such that the structure is the same as seen from each point.

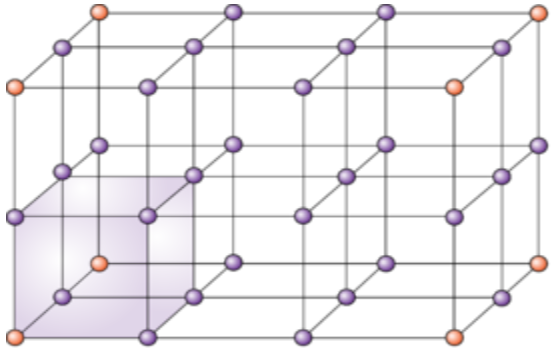


Unit Cell:

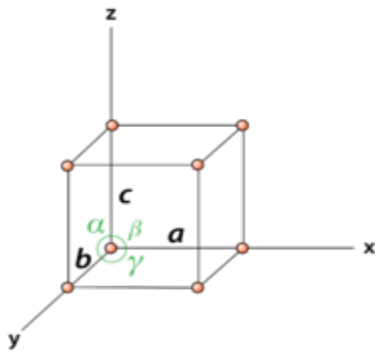
A **unit cell** is the most basic and least volume consuming repeating structure of any **solid**. It is used to visually simplify the crystalline patterns **solids** arrange themselves in. When the **unit cell** repeats itself, the network is called a lattice. A unit cell may or may not be primitive.

Translation Vectors:

The **translation vector** is the distance through which an atom must be moved (**translated**) in order to be in the next unit cell. `



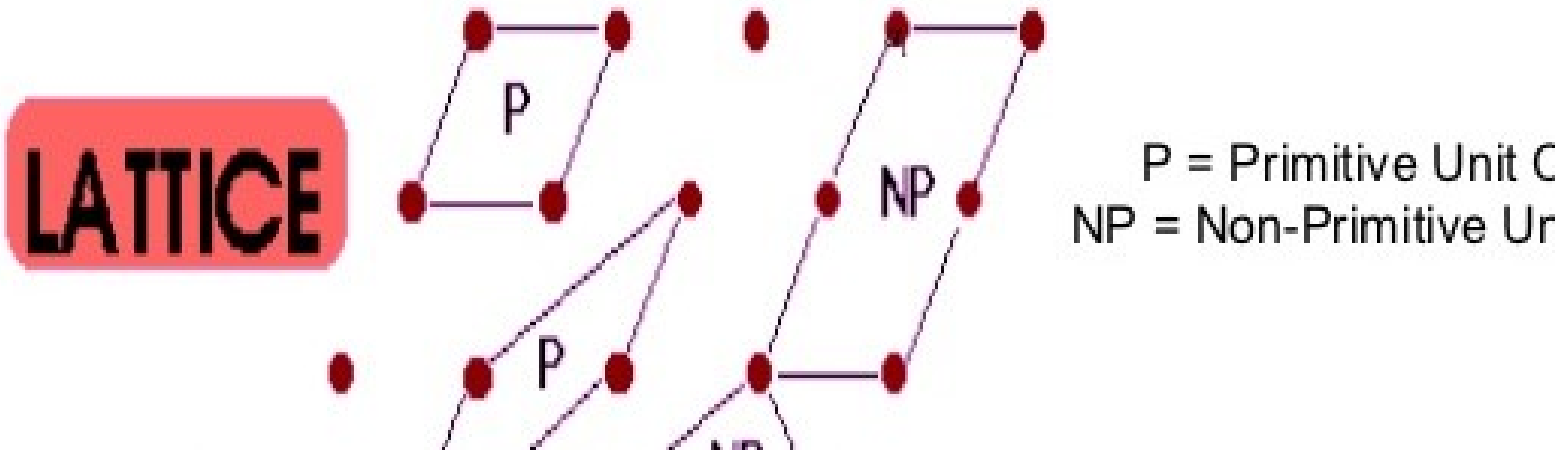
Crystal Lattice



Unit Cell

Primitive Unit Cell

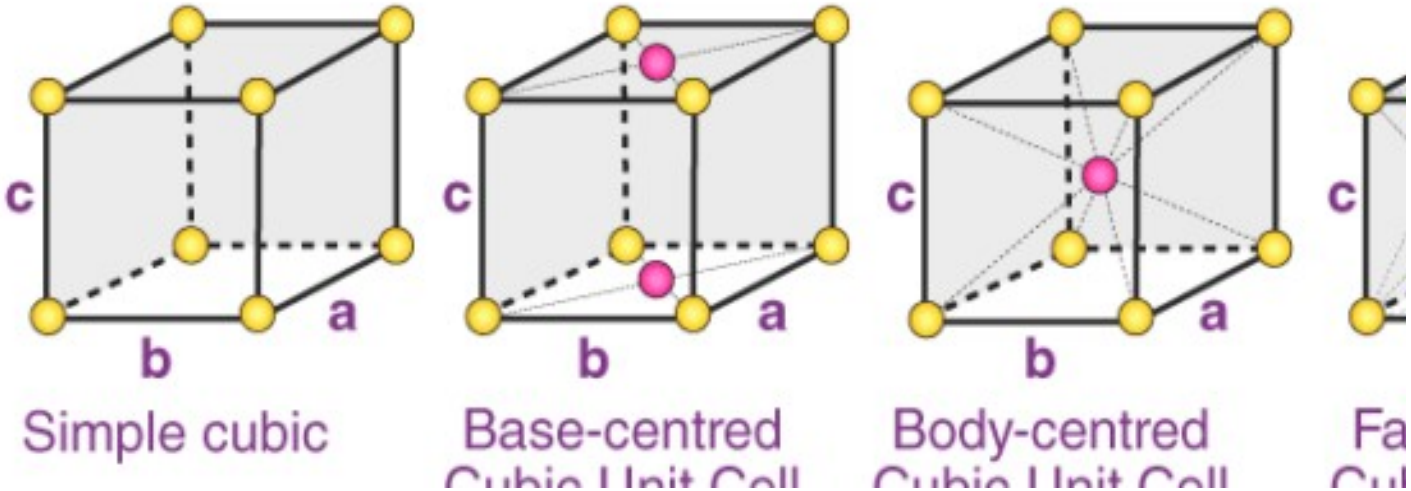
- The primitive unit cell must have only one lattice
- There can be different choices for lattice vectors volumes of these primitive cells are all the same



CRYSTAL SYSTEMS AND BRAVAIS LATTICES

There are Seven different crystal systems specifying different translation vectors (a, b, c) and lattice parameters (α,β,γ).

Bravais lattices -- Fourteen simple and complex lattices within the seven crystal systems. The complex lattices have atoms centered either in the center of a "primitive" unit cell or in the center of two/or more of the unit cell faces.

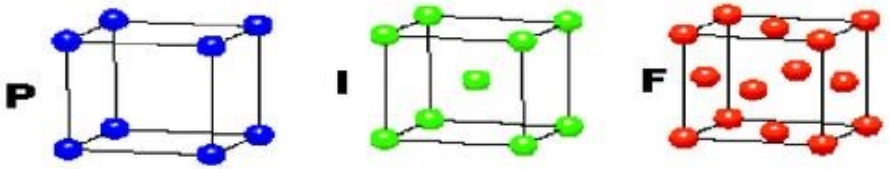


Lattices classified into **crystal systems**

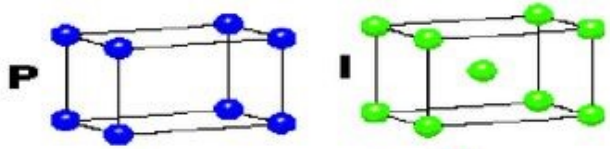
System	Interaxial Angles	Axes
1. Triclinic	$\alpha \neq \beta \neq \gamma \neq 90°$	$a \neq b \neq c$
2. Monoclinic	$\alpha = \gamma = 90° \neq \beta$	$a \neq b \neq c$
3. Orthorhombic	$\alpha = \beta = \gamma = 90°$	$a \neq b \neq c$
4. Tetragonal	$\alpha = \beta = \gamma = 90°$	$a = b \neq c$
5. Cubic	$\alpha = \beta = \gamma = 90°$	$a = b = c$
6. Hexagonal	$\alpha = \beta = 90°, \gamma = 120°$	$a = b \neq c$
7. Trigonal	$\alpha = \beta = 90°, \gamma \neq 120°$	$a = b \neq c$

Bravais Lattice

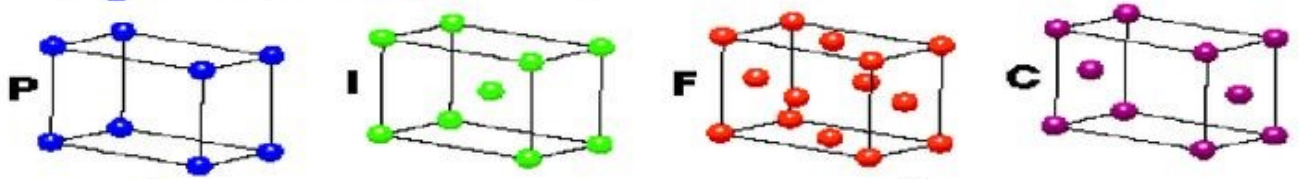
CUBIC
$a = b = c$
$\alpha = \beta = \gamma = 90°$



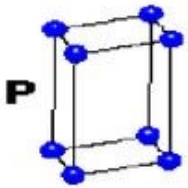
TETRAGONAL
$a = b \neq c$
$\alpha = \beta = \gamma = 90°$



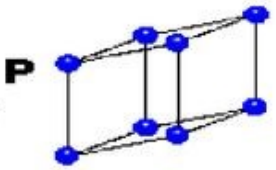
ORTHORHOMBIC
$a \neq b \neq c$
$\alpha = \beta = \gamma = 90°$



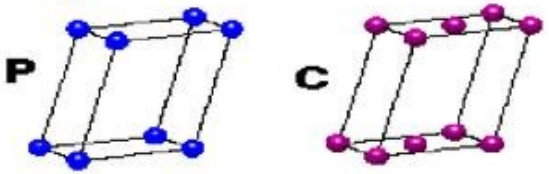
HEXAGONAL
$a = b \neq c$
$\alpha = \beta = 90°$
$\gamma = 120°$



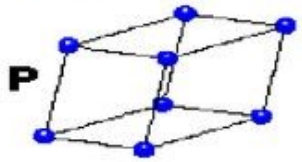
TRIGONAL
$a = b = c$
$\alpha = \beta = \gamma \neq 90°$



MONOCLINIC
$a \neq b \neq c$
$\alpha = \gamma = 90°$
$\beta \neq 120°$



TRICLINIC
$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma \neq 90°$



4 Types of Unit Cell
P = Primitive
I = Body-Centred
F = Face-Centred
C = Side-Centred
+
7 Crystal Classes
→ **14 Bravais Lattices**

7 Crystal Classes with 4 possible unit cell types
Symmetry indicates that only 14 3-D lattice types occur

MILLER INDICES

Definition:- Miller Indices are the reciprocals of the fractional intercepts (with fractions cleared) which the plane makes with the crystallographic x, y, z axes of the three nonparallel edges of the cubic unit cell.

$$Miller\ \ Indices = \left(\frac{1}{a}, \frac{1}{b}, \frac{1}{c}\right)\ \ with\ fractions\ cleared\ !$$

Miller indices

The group of three numbers that indicates the orientation of a plane or set of parallel planes of atoms in a crystal. The reciprocals of these intercepts are computed, and fractions are cleared to give the three **Miller indices** (h,k,l).

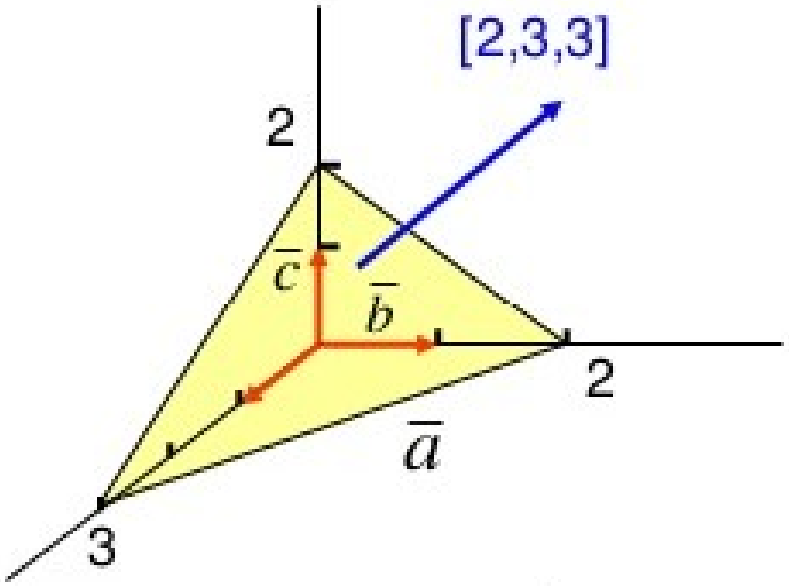
To calculate **Miller indices** (h, k, l) :

- Determine the intercepts of the face along the crystallographic axes, in terms of unit cell dimensions.
- Take the reciprocals.
- Clear fractions.
- Reduce to lowest terms.

For example, if the x-, y-, and z- intercepts are 2,1, and 3, the **Miller indices** are **calculated** as:

1. Take reciprocals: ½, 1/1, 1/3.
2. Smallest integers: 3, 6, 2
3. **Miller Indices** are (3, 6, 2)

Miller Indices

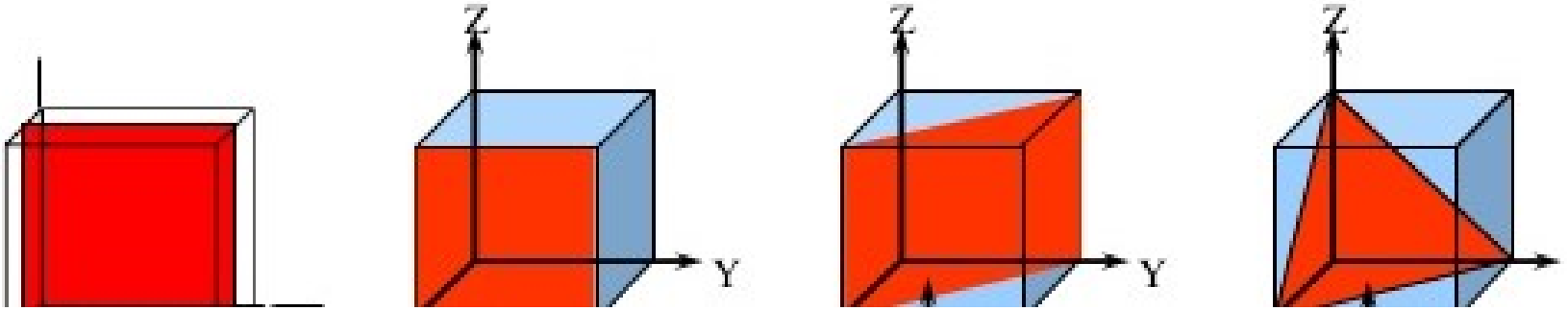


Plane intercepts axes at $3\bar{a}, 1$

Reciprocal numbers are: $\frac{1}{3},$

Indices of the plane (Miller): (2

Indices of the direction: [2,3,3



Spacing between planes

$$d_{hkl} = \frac{1}{\sqrt{(h/a)^2 + (k/b)^2 + (l/c)^2}}$$

where,

d_{hkl} = inter-planar spacing between planes with Miller indices h, k, and l.

a, b, c = lattice constants

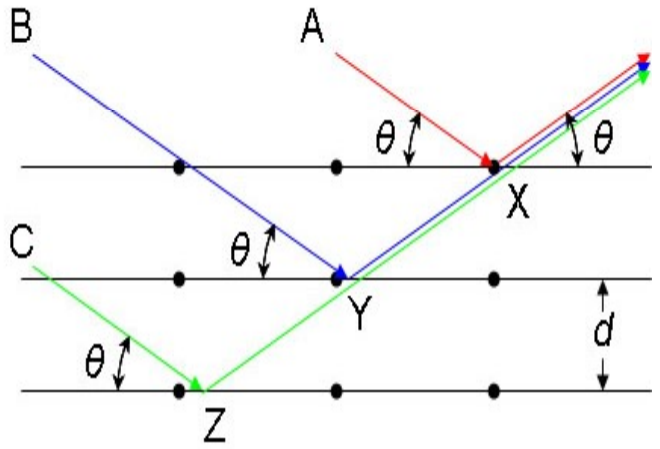
h, k, l = Miller indices

For a cubic crystal a = b= c

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

X- Ray Diffraction and Braggs Law

The **law** states that when the **x-ray** is incident onto a crystal surface, its angle of incidence, θ, will reflect back with a same angle of scattering, θ. Then the scattered radiation will undergo constructive interference and thus the crystal will appear to have reflected the **X**-radiation.



The **Bragg law** is useful for measuring wavelengths and for determining the lattice spacing of crystals.

X-ray Diffraction and Braggs Law

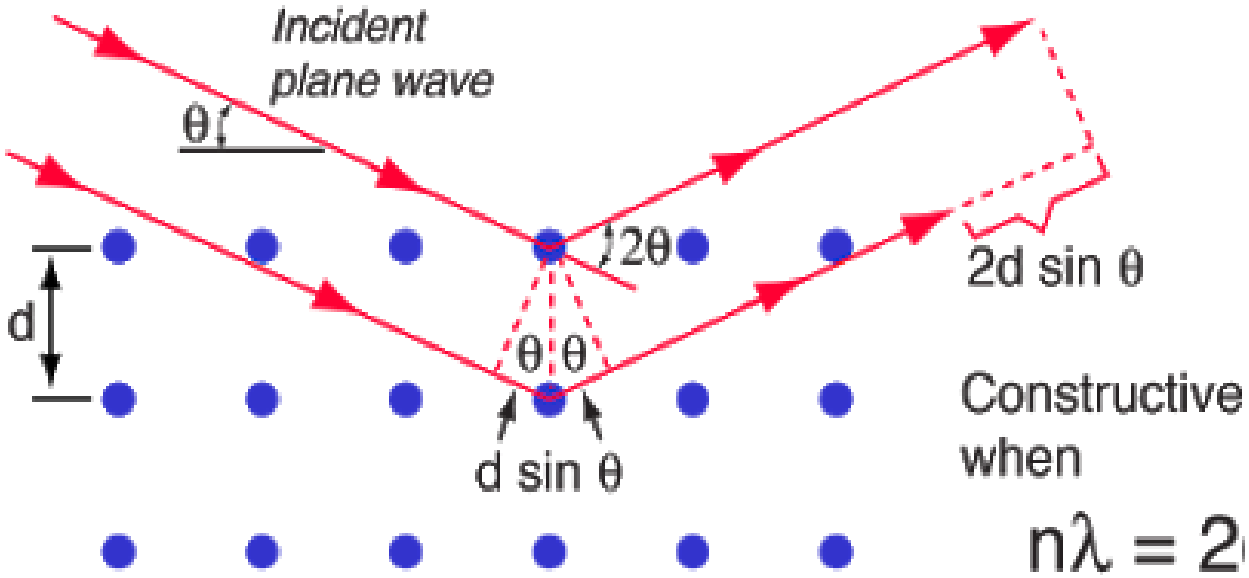
$$n\,\lambda = 2\,d_{hkl}\,\sin\theta$$

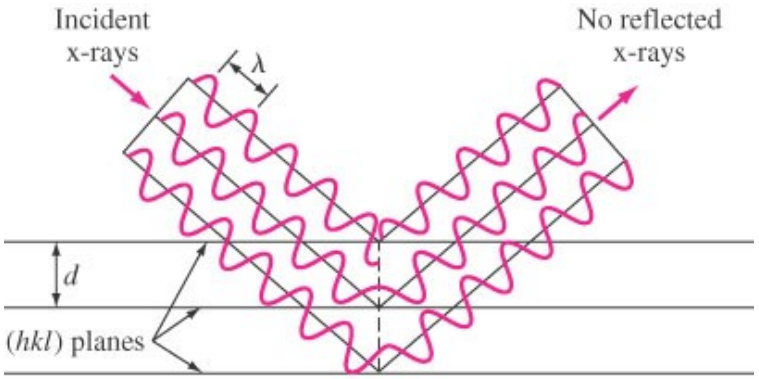
n = order of reflection

λ = x-ray wavelength

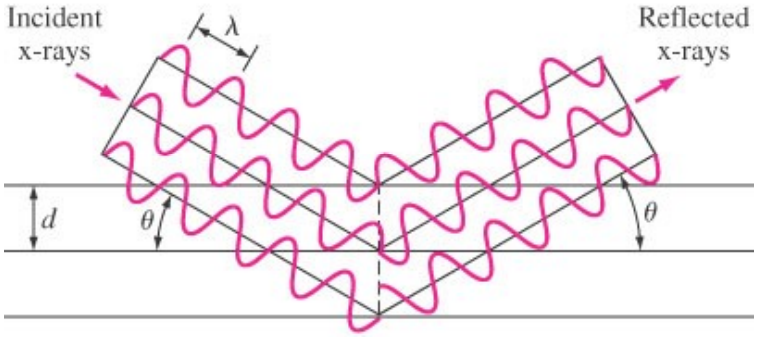
d_{hkl} = spacing between planes with indices (hkl)

θ = angle between incident x-ray beam and crystal planes (hkl)

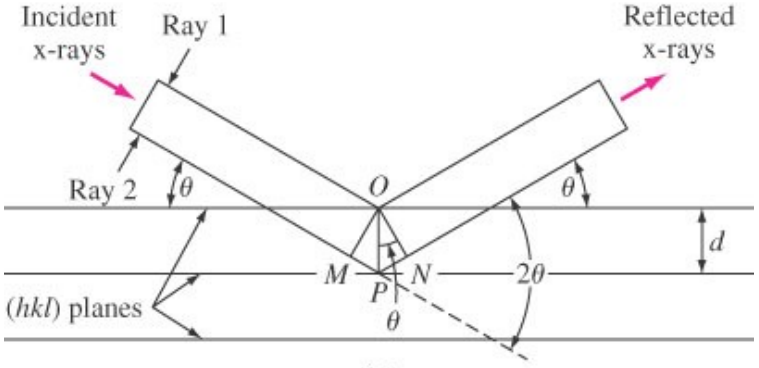



Incident
x-rays
No reflected
x-rays
λ
d
(hkl) planes

(a)


Incident
x-rays
λ
Reflected
x-rays
d
θ
θ

(b)


Incident
x-rays
Ray 1
Reflected
x-rays
Ray 2
θ
O
θ
d
M
N
2θ
P
θ
(hkl) planes

(c)


Thanks