Solid State Physics

- Solid state physics is largely concerned with crystals and electrons in crystals.

Crystal : Crystal is a three-dimensional periodic array of atoms. In case of grophene it is two dimensional.

- In condensed matter physics, including crystals we also study amorphous or noncrystalline solids, glasses and liquids. This is the most vigorous area of physics.

Lattice : It is a regular periodic array of points in space.
It is related by lattice translation operator $T = u_1\vec{a}_1 + u_2\vec{a}_2 + u_3\vec{a}_3$, u's are integer → $\vec{a}$'s are crystal axes.

Basis : the Group of atoms is called the basis.

$$\boxed{\text{Lattice} + \text{Basis} = \text{Crystal structure}}$$

- An Ideal crystal is constructed by the infinite repetition of identical structural units in space.

Bravais Lattice :—

Two equivalent definitions

(i) A Bravais lattice is an infinite array of discrete points with an arrangement and orientation that appears exactly the same, from whichever ~~point~~ of the points the array is viewed.

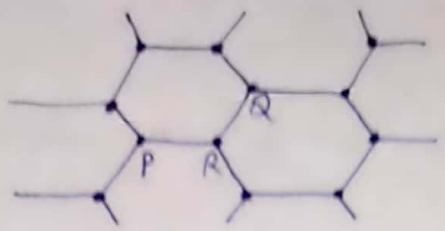
(ii) A (3-D) Bravais lattice consists of all points with position vectors $\vec{R}$ of the form

$$\boxed{\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 + n_3\vec{a}_3}$$

$n_1, n_2, n_3 \longrightarrow$ Integers $(\cdots -1, 0, 1 \cdots)$

$\vec{a}_1, \vec{a}_2, \vec{a}_3$ any three vectors not all in same plane.

Note

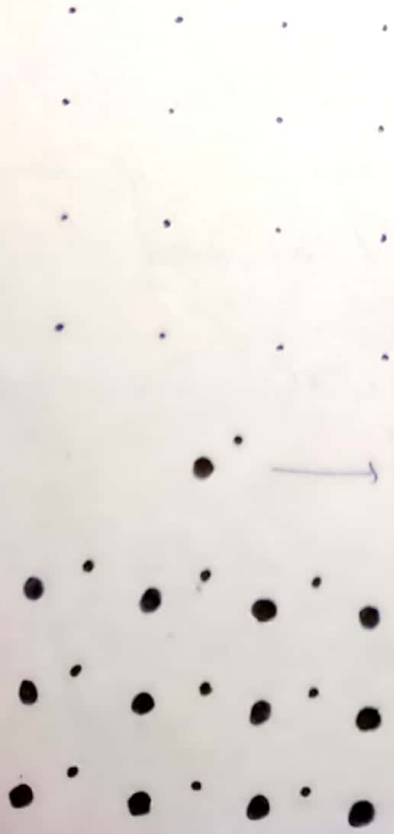


(i) The vertices of a two-dimensional honeycomb do not form a Bravais lattice. The array of points has the same appearance whether viewed from point P or Q. However, the view from point R is rotated through 180°.

(ii) The diamond lattice is not a Bravais lattice, because the environment of any point differs in orientation from the environment of its nearest neighbours.

(iii) A 2-D Bravais lattice is also known as net.

Basis and Crystal Structure :- A basis of atoms is attached to every lattice point, with every basis identical in ~~structure~~ composition, arrangement, and orientation.



ⓐ Space lattice

ⓑ Basis containing two different ions

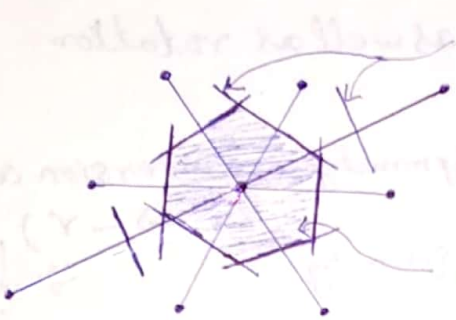
ⓒ Crystal Structure

Here → The crystal structure is formed by addition of the basis ⓑ to every lattice point of lattice ⓐ. In fig. ⓒ we can recognize the basis and then we can abstract the space lattice. It does not matter where the basis is put in relation to a lattice point. (as in graphene)

Primitive Lattice cell :

- Primitive cell is a minimum volume cell.
- There are many ways of choosing the primitive axes and primitive cell for a given lattice. $(\bar{a}_1, \bar{a}_2, \bar{a}_3)$
- # of atoms in a primitive cell is always same for a given crystal structure. or basis
- There is always one lattice point per primitive cell.

Choosing ~~Choosing~~ a primitive cell – A well known method –



Oblique lattice → It is invariant under rotation of π & 2π about one lattice point. (In case of general lattice of the type above)

Note More than one lattice is always possible for a given structure, and more than one set of axes is always possible for a given lattice.

In simple Cubic (SC) system three lattice are SC, bcc, fcc.

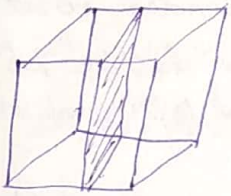
Crystal Symmetry :—

Crystal possess different symmetries or symmetry elements. They are described by the certain operations. A symmetry operation is one that leaves the crystal and its environment invariant.

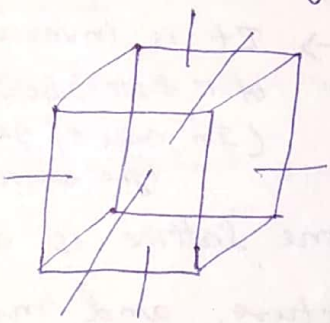
Point group symmetry operation :→ symmetry operations performed about a point (lattice point) or a line.

Space group symmetry operations → symmetry operation performed by translation as well as rotation

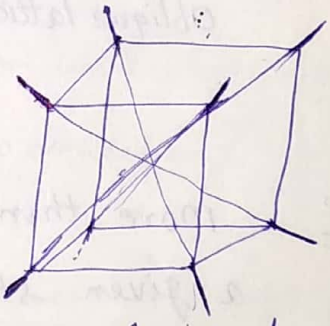
3 ~~possibility~~ three types →
- Centre of symmetry or inversion centre ($r \to -r$) e.g.
- Reflection symmetry
- Rotation symmetry



Plane of symmetry or reflection symmetry



3 tetrad axes of Cube
(axis of symmetry or rotation symmetry)



4 triad axis

{ similarly at the 12 edges we have 6 diad axes

Total # of crystallographic symmetry elements of the cubic systems are →

– Centre of symmetry	1	
– Straigh Planes	3	9 plane
– diagonal Planes	6	
→ tetrad axes	3	13 axes
– triad axes	4	
– diad axes	6	

Total = 23.