Semiconductor Fundamentals

Presented to
EE2187 class in
Semester 1 (Segment 12) 2019/20

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Lecture 2

Course information

- Semiconductors Materials - Types of Solids, Space lattice, Atomic Bonding,
- Introduction to quantum theory, Schrodinger wave equation, Electron in free space, Infinite well, and step potentials, Allowed and forbidden bands
- Electrical conduction in solids, Density of states functions, Fermi-Dirac distribution in Equilibrium,
- Valence band and Energy band models of intrinsic and extrinsic Semiconductors. Degenerate and non degenerate doping
- Thermal equilibrium carrier concentration, charge neutrality
- Carrier transport – Mobility, drift, diffusion, Continuity equation.

Reference

Text Book:

1. Physics of Semiconductor Devices, *S. M. Sze*, John Wiley & Sons (1981).
2. Solid State Electronics by *Ben G. Streetman and Sanjay Banerjee*, Prentice Hall International , Inc.
3. Semiconductor Physics and Devices, Donald A. Neamen, Tata Mcgraw-Hill Publishing company Limited.
4. Advanced Semiconductor Fundamentals by Pirret

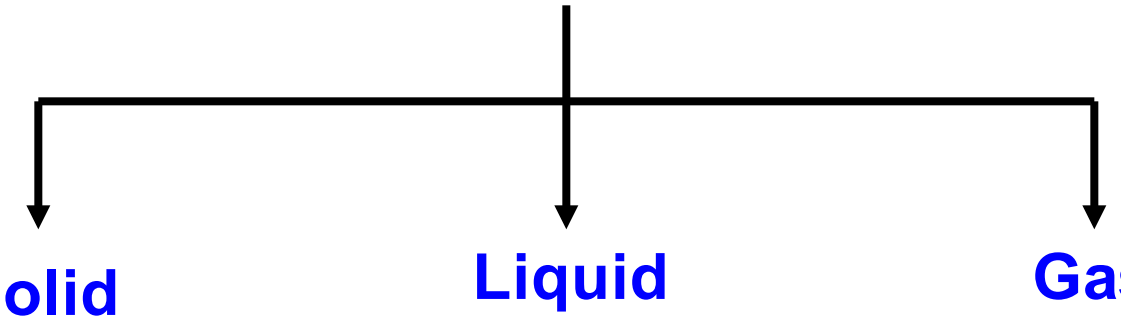
Reference Book:

1. Fundamentals of Solid-State Electronic Devices, *C. T. Sah*, Allied Publisher and World Scientific, 1991.
2. Complete Guide to Semiconductor Devices, *K. K. Ng*, McGraw Hill, 1995.
3. Solid state physics, Ashcroft & Mermins.
4. Introduction to Solid State Electronics, *E. F. Y. Waug*, North Holland, 1980.

Outline

- Material classification
- Crystal
- Bravais lattice
- Miller Indices
- Conclusion

Material Classification



Classical Criteria: Viscosity (Density, Atomic Diffusivity, Mechanical Strength).

Advance Criteria: Aperiodicity or randomness of the location of the constituent atom or molecule

Measured by correlation length (Distance within which atomic position show regularity).

Solid: Long/short range order (spatial) but fixed with time

Long range order (Crystalline, Orientation and position), Short range order (Plastic, positional orders but orientation disorder) and very short range order (Amorphous, both orientation as well locational)

Liquid: Short range ordering both Space and Time

Gas: Completely Random both Space and Time

Classification Scheme of Solids

Geometrical (Crystallinity vs Imperfection)

Electrical (Electrical Conductivity)

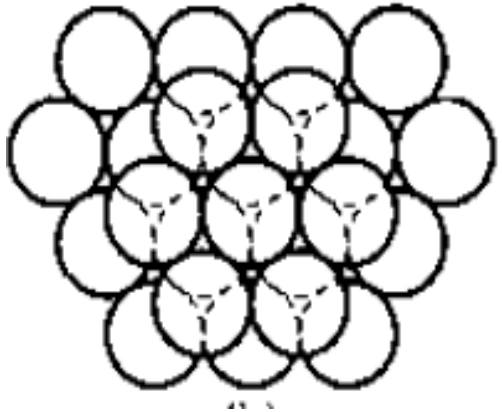
Mechanical (Binding Force)

Symmetry

Which object shows highest level of Symmetry?

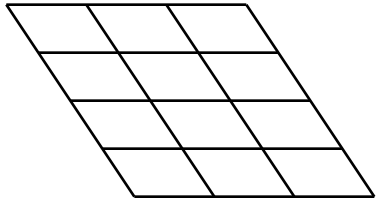
- Johannes Kepler (1611) speculated on the question as to why snowflakes always have six corners, never five or seven.

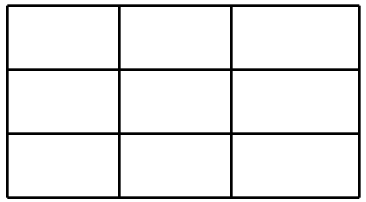
Snowjake crystal,

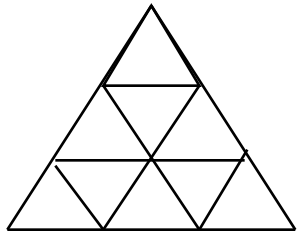


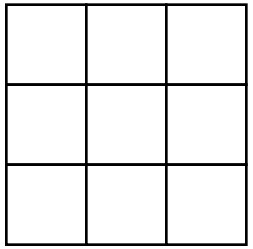
close-packing of spheres

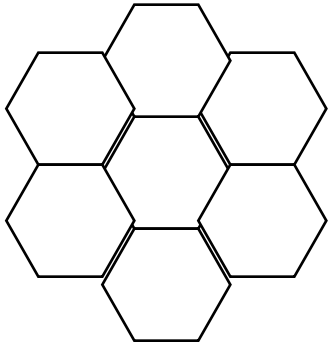
Cont.

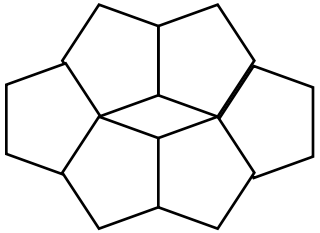


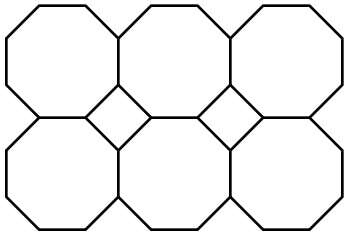








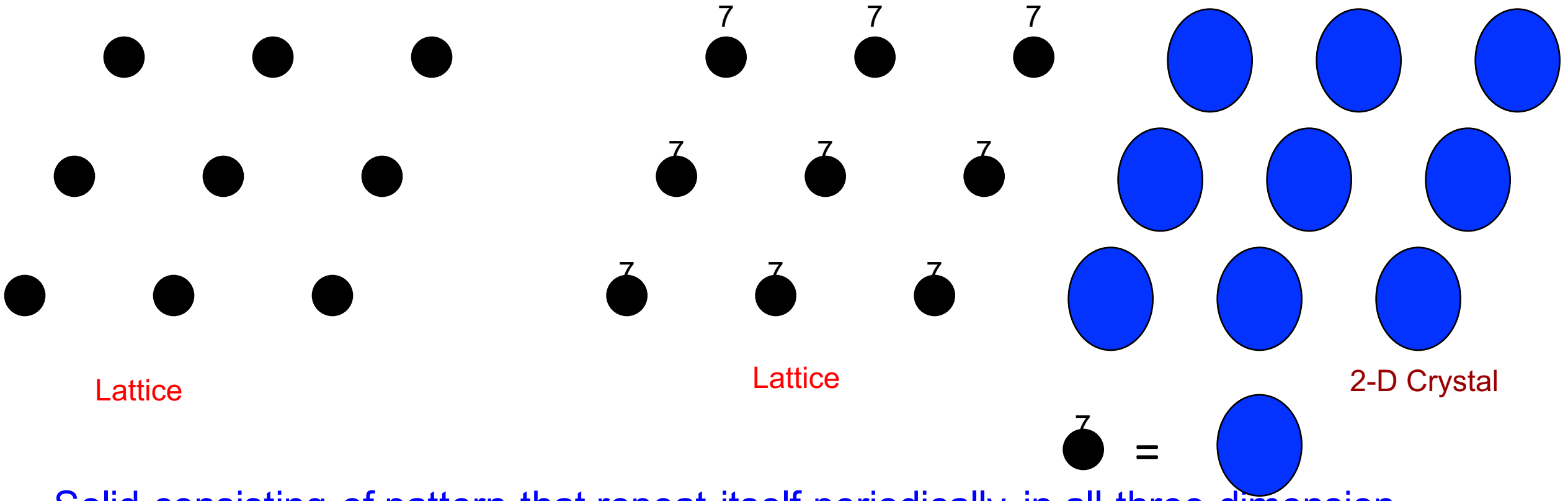




What is crystal and their structure?

Crystal = Lattice + Pattern

Lattice: Mathematical object which consist of periodic arrangement of point in all direction of space.

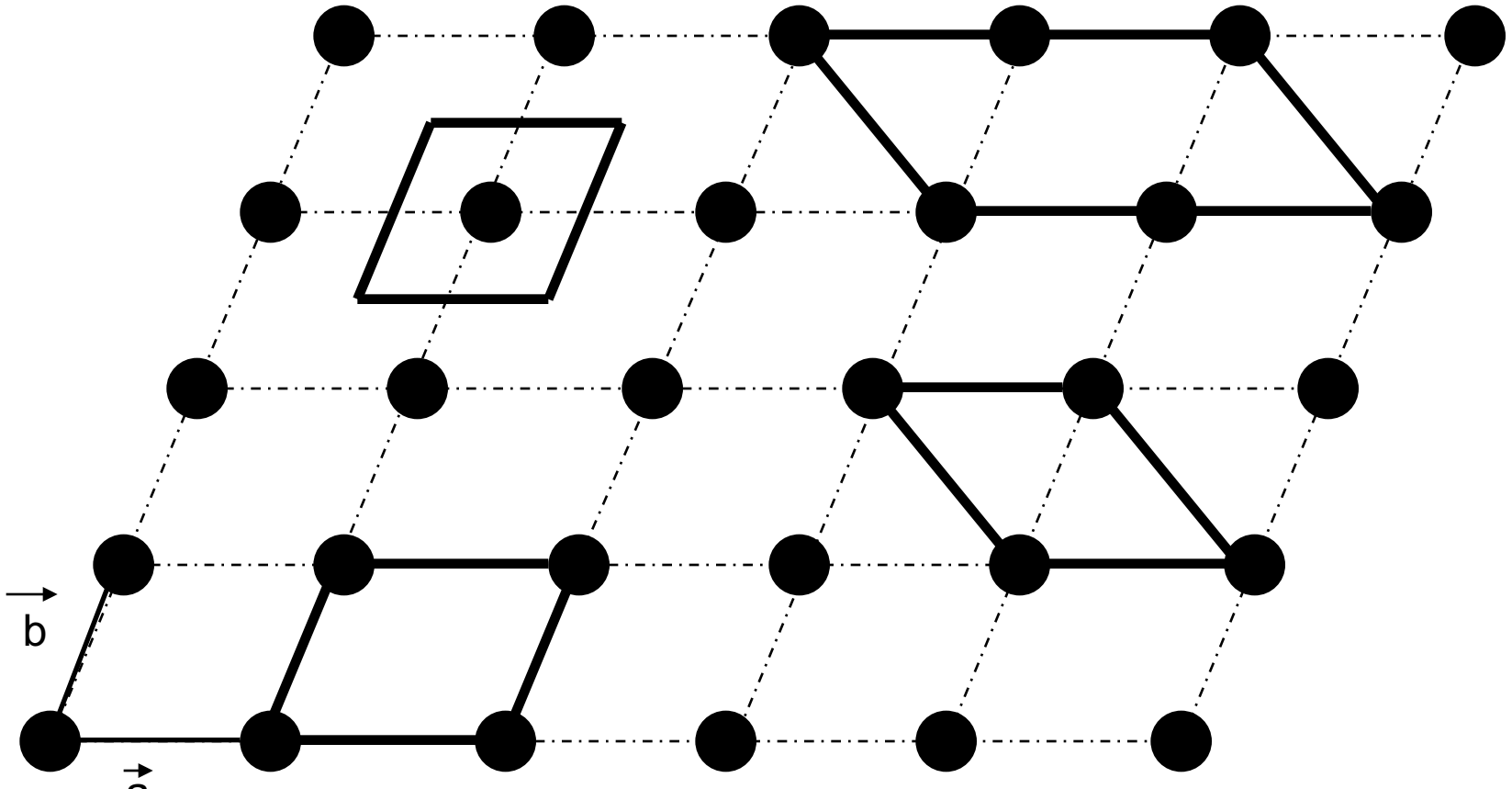


Solid consisting of pattern that repeat itself periodically in all three dimension.

Crystal Structure

Unit Cell: Small portion of any crystal that can be used to reproduced the entire crystal

Primitive Unit Cell: Unit Cell with smallest volume



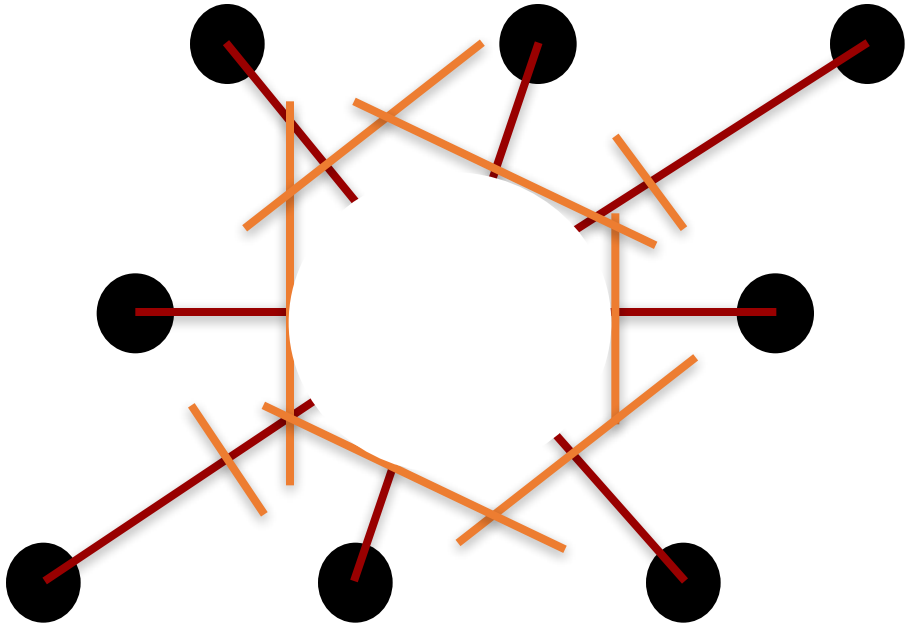
Wigner-Seitz Primitive Cell

Choose a reference atom

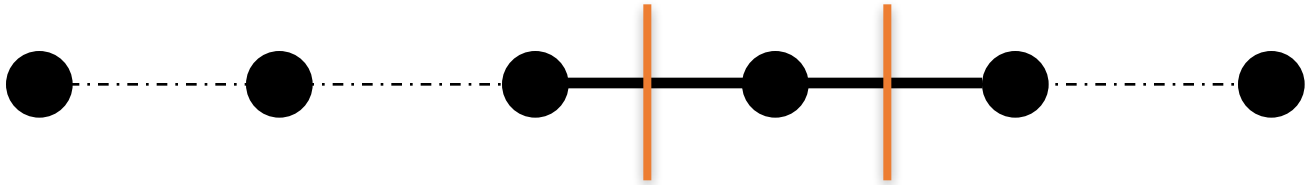
Connect to all its neighbors by straight lines

Draw lines (in 2D) or planes (in 3D) normal to and at the midpoints of lines drawn in step 2

Smallest volume enclosed is the Wigner-Seitz primitive cell

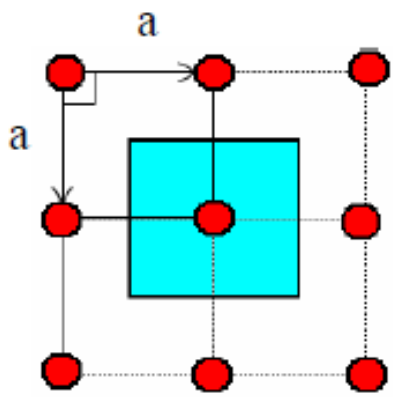


Unit Cells in 1-D Crystals

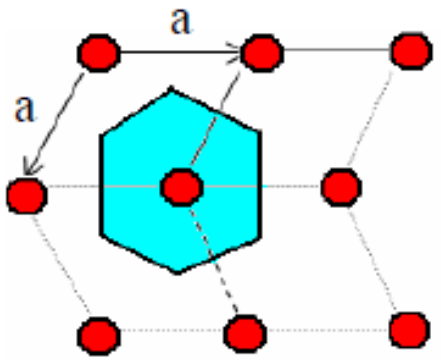


System truly 1-D?

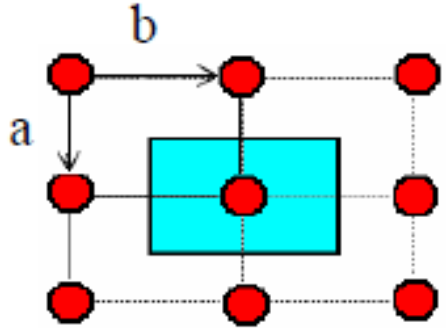
Unit Cells in 2-D Crystals



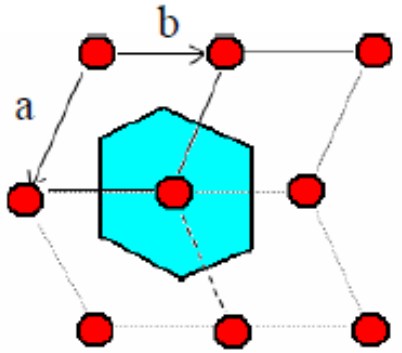
a=b, ϕ=90



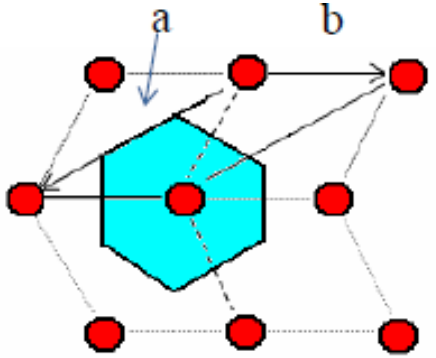
a=b, ϕ>90



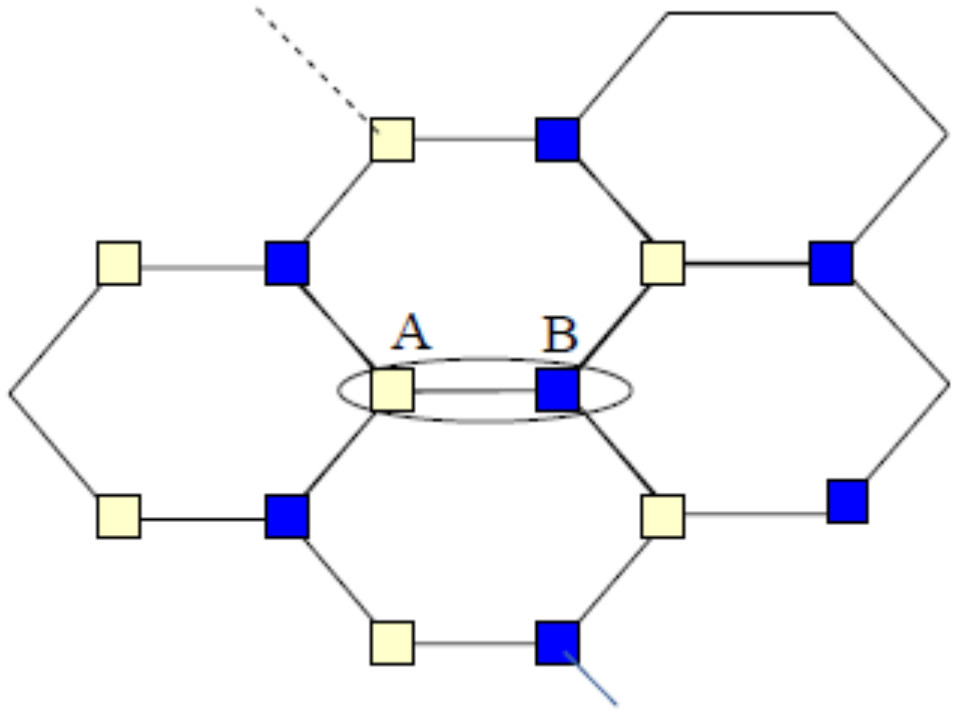
a<b, ϕ=90



a>b, ϕ>90

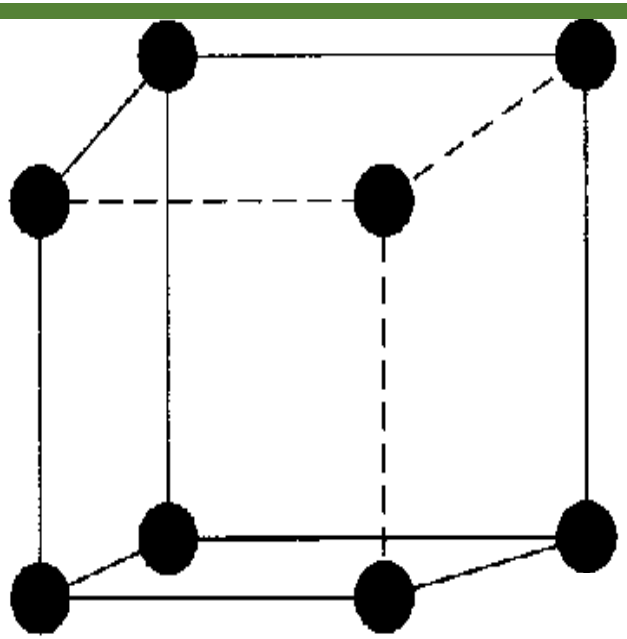


Example

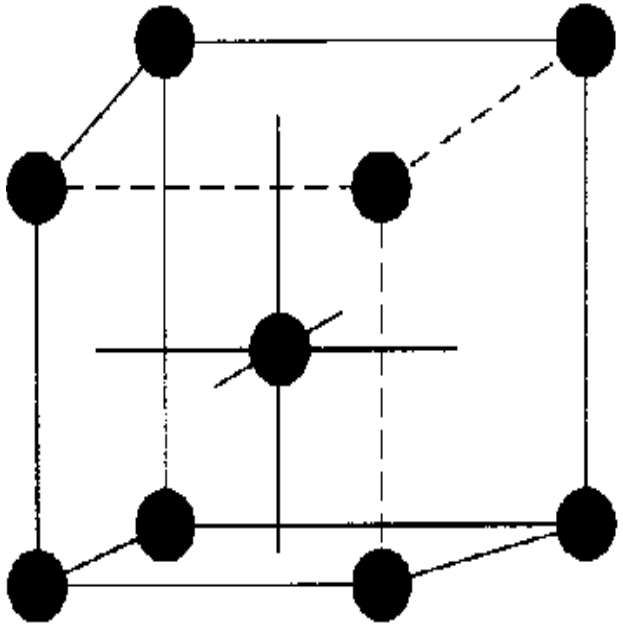


Graphene

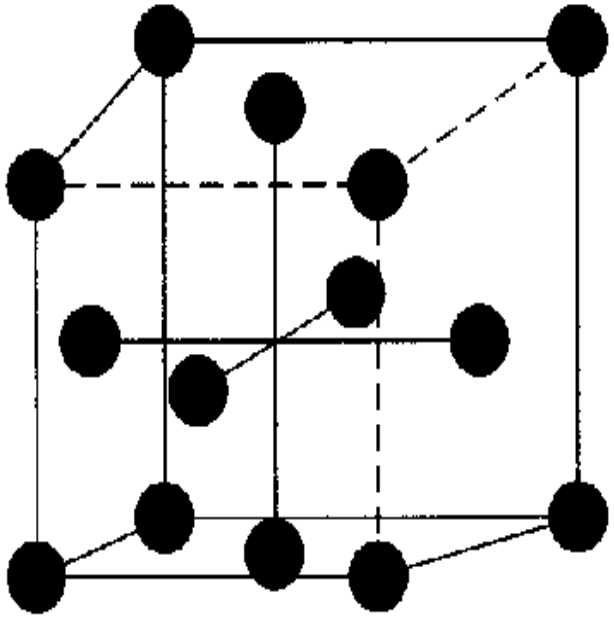
3-D Unit Cell



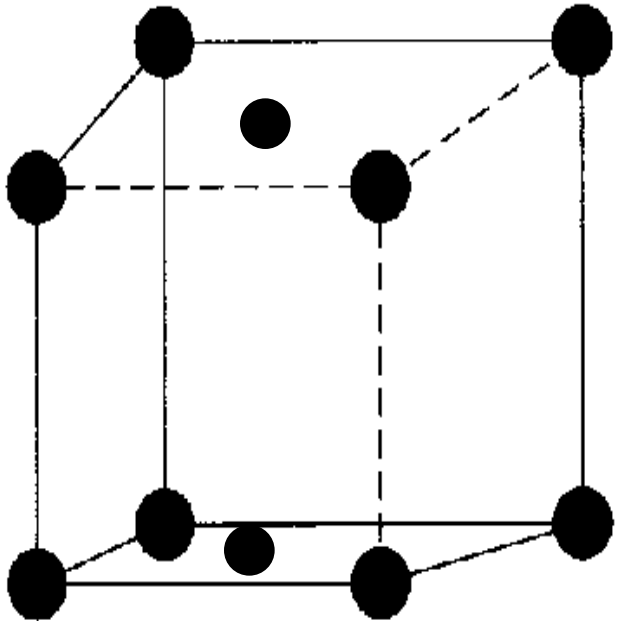
Simple



Body center



Face center



C-center

Symmetry properties used for classification of Crystal system

1)n-fold rotational Symmetry

2)Plane of symmetry (mirror image)

3)Inversion center symmetry

4)Rotational –inversion symmetry

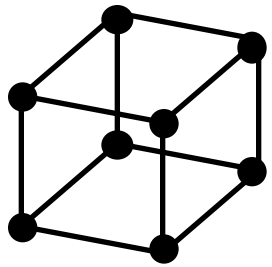
Crystal System

All possible lattices can be grouped in the seven crystal systems

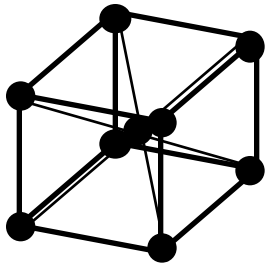
Cubic	$a=b=c,\ a=b=g=90^o$
Tetragonal	$a=b\neq c,\ a=b=g=90^o$
Orthorhombic	$a\neq b\neq c,\ a=b=g=90^o$
Trigonal	$a=b=c, a=b=g\neq 90^o$
Hexagonal	$a=b=c,\ a=b=90^o,\ g=120^o$
Monoclinic	$a\neq b\neq c,\ a=g=90^o=b$
Triclinic	$a\neq b\neq c,\ a\neq b\neq g\neq 90^o$

Note: No crystal have a structure other than one of those in the seven classes

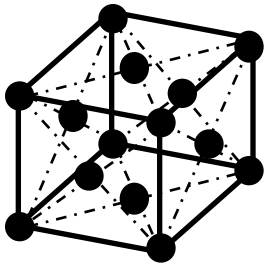
Bravais Lattice



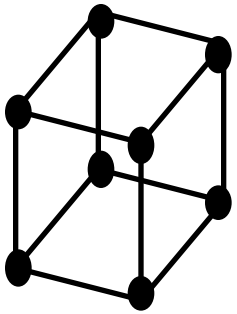
Simple cubic



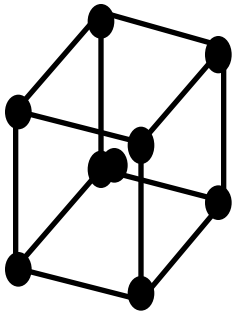
Body centered cubic



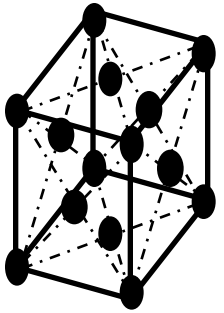
Face centered cubic



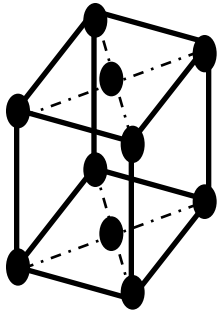
Simple orthorhombic



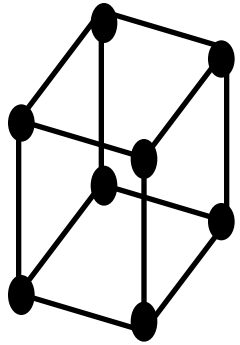
Body centered orthorhombic



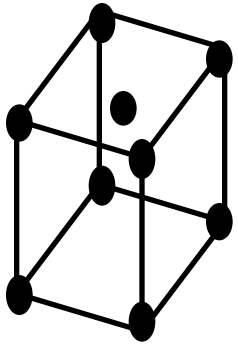
Face centered orthorhombic



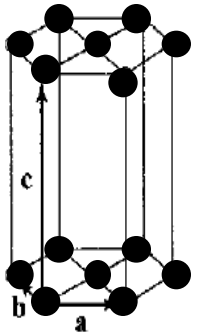
Base-centered orthorhombic



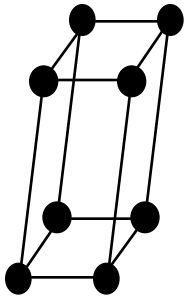
Simple tetragonal



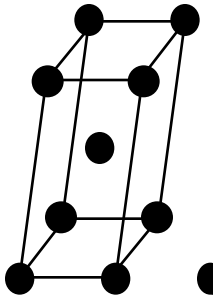
Body centered tetragonal



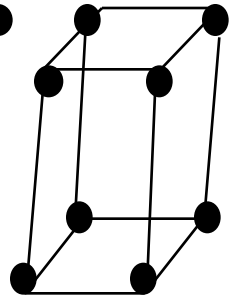
Hexagonal



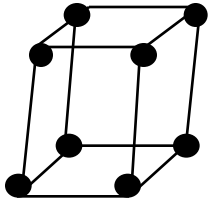
Simple monoclinic



Base centered monoclinic



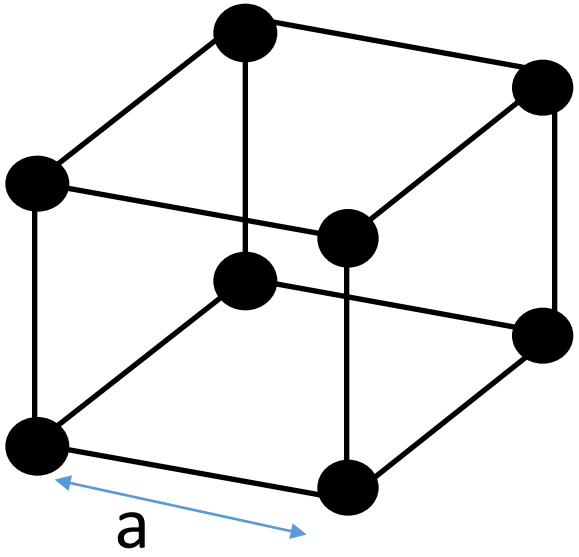
Triclinic



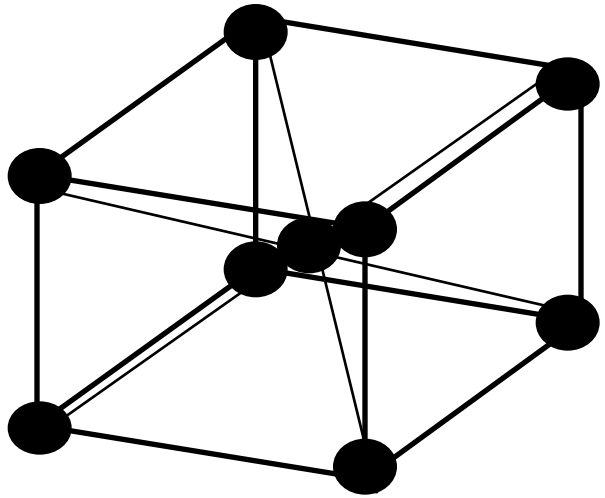
Trigonal

No crystal have a lattice other than one of those 14 Bravais lattices

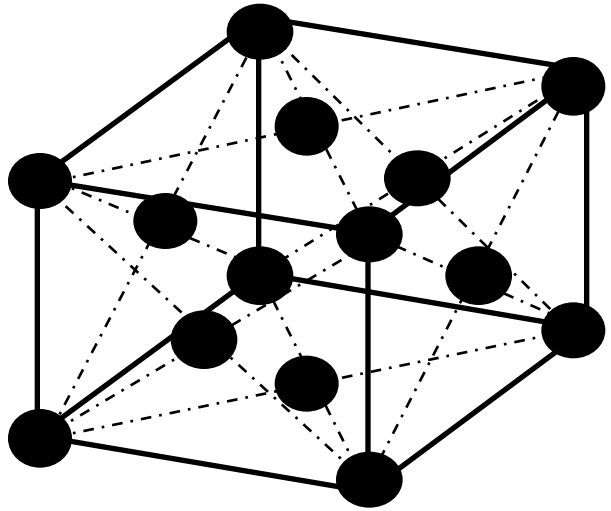
Cubic Lattice



Simple cubic



Body centered cubic



Face centered cubic

Determine Lattice Point per cell

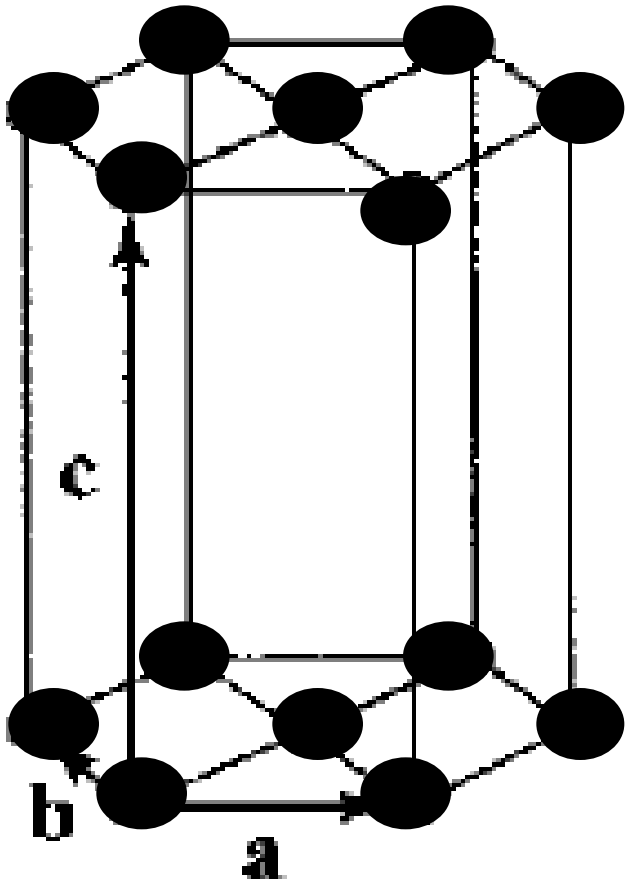
Determine Number density

Packing density=Volume filled/ total volume

Determine Arial density

Hexagonal Lattice

Determine Point per cell



Hexagonal