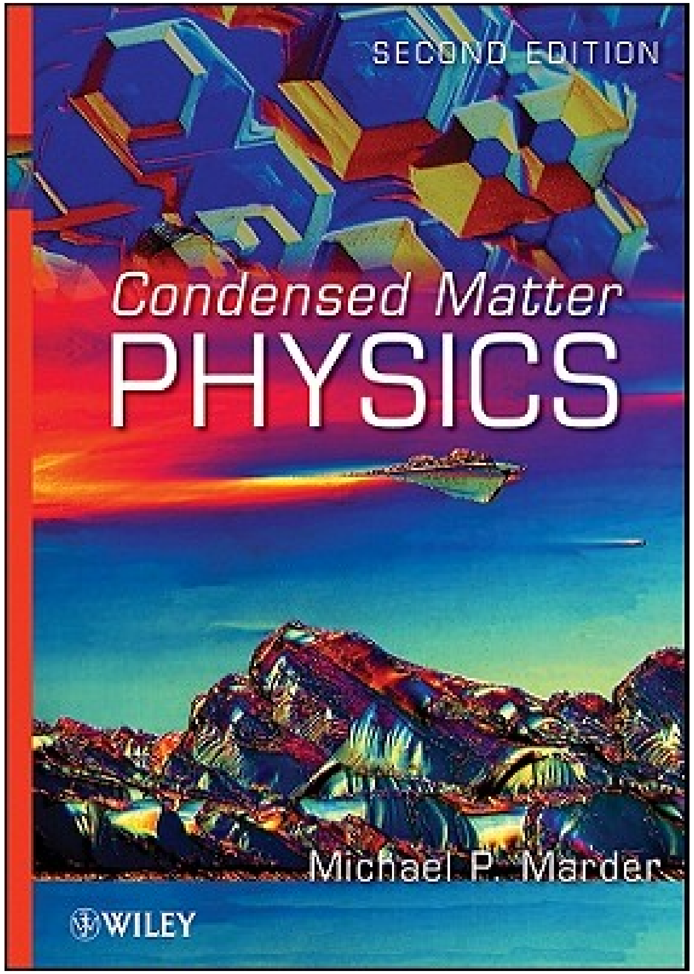


Textbook: *Condensed matter physics*, 2nd ed. By M. Marder
References: *Solid state physics*, by Ashcroft and Mermin
Principles of the theory of solids, by Ziman
TA: 劉雲平
Grading: homework: 60% final exam: 40%
Prerequisites:
Introduction to solid state, Quantum mechanics, Statistical mechanics

Part I: ATOMIC STRUCTURE
- Ch 1: The Idea of Crystals
- Ch 2: Three-Dimensional Lattices
- Ch 3: Scattering and Structures
- Ch 4: Surfaces and Interfaces
- Ch 5: Beyond Crystals

Part II: ELECTRONIC STRUCTURE
- Ch 6: The Free Fermi Gas and Single Electron Model
- Ch 7: Non--Interacting Electrons in a Periodic Potential
- Ch 8: Nearly Free and Tightly Bound Electrons
- Ch 9: Electron--Electron Interactions
- Ch 10: Realistic Calculations in Solids

Part III: MECHANICAL PROPERTIES
- Ch 11: Cohesion of Solids
- Ch 12: Elasticity
- Ch 13: Phonons
- Ch 14: Dislocations and Cracks
- Ch 15: Fluid Mechanics

Lecture files available at
http://phy.ntnu.edu.tw/~changmc/

The scope of solid state physics (< condensed matter physics)

Solid state physics studies physical properties of materials

Material	Structure	Shape	Properties
metal	crystal	bulk	electrical
semiconductor	amorphous	surface	optical
insulator	… etc	interface	thermal
superconductor		nano-cluster	mechanical
magnetic		… etc	… etc
… etc			

Solid state physics = {A} × {B} × {C} × {D}

- Always try to understand a physics phenomenon from the microscopic point of view (atoms plus electrons).

Chap 1 The idea of crystals

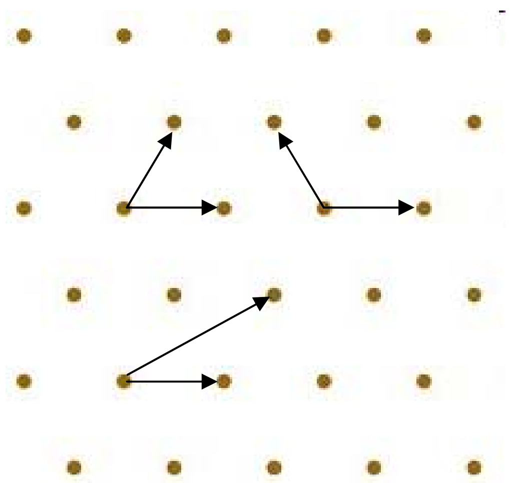
- Introduce 2D crystals in Ch 1; 3D crystals in Ch 2.
- Most of the concepts introduced here for 2D can be easily extended to 3D

Dept of Phys

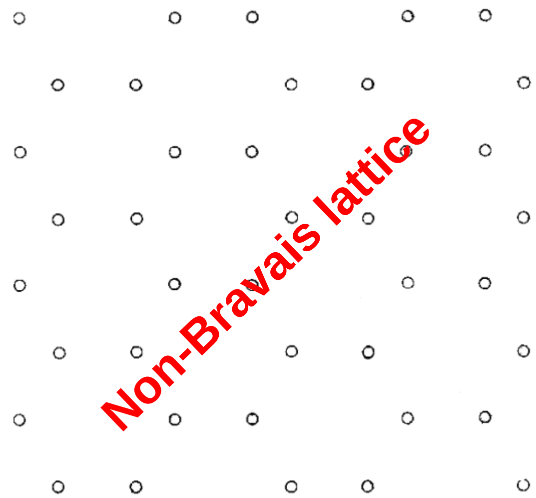
M.C. Chang

• A Bravais lattice = a set of points in which every point has exactly the same environment

Hexagonal (or triangular) lattice



Honeycomb lattice

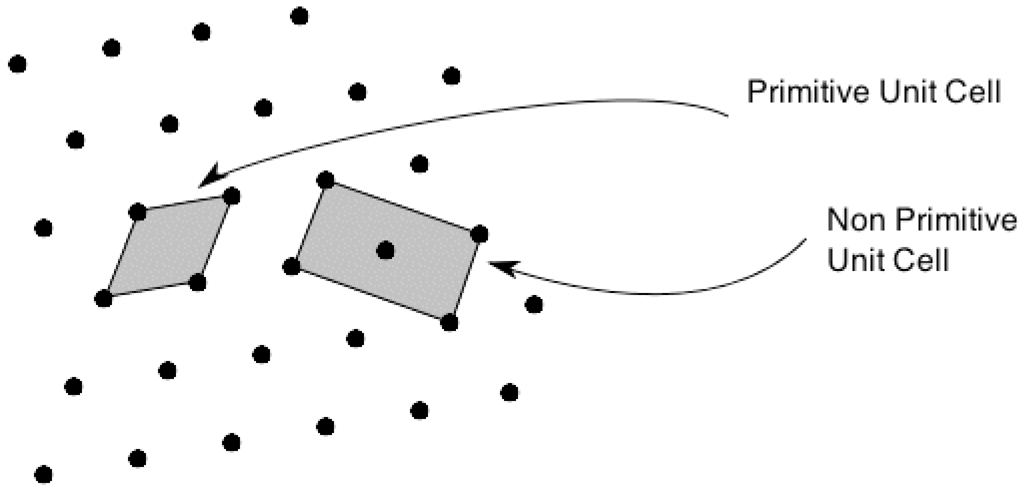


• Bravais lattice point can be expanded as

$\boldsymbol{R} = n_1\boldsymbol{a}_1 + n_2\boldsymbol{a}_2$ (n_1, n_2 are integers)

where $\boldsymbol{a}_1$ *and* $\boldsymbol{a}_2$ are called primitive vectors

An unit cell can be primitive or non-primitive



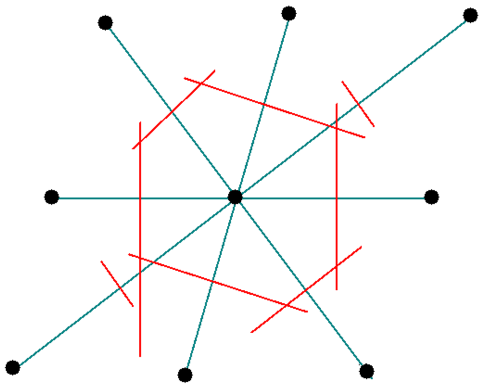
• a primitive cell contains a lattice point

• a non-primitive cell contains 2 or more lattice points
(sometimes it's more convenient to use this one)

A special primitive cell: Wigner-Seitz cell

• The WS cell enclosing a lattice point is the region of space that is closer to that lattice point than to any others.

• Method of construction



• why using a WS cell?

It has the same symmetry as the Bravais lattice

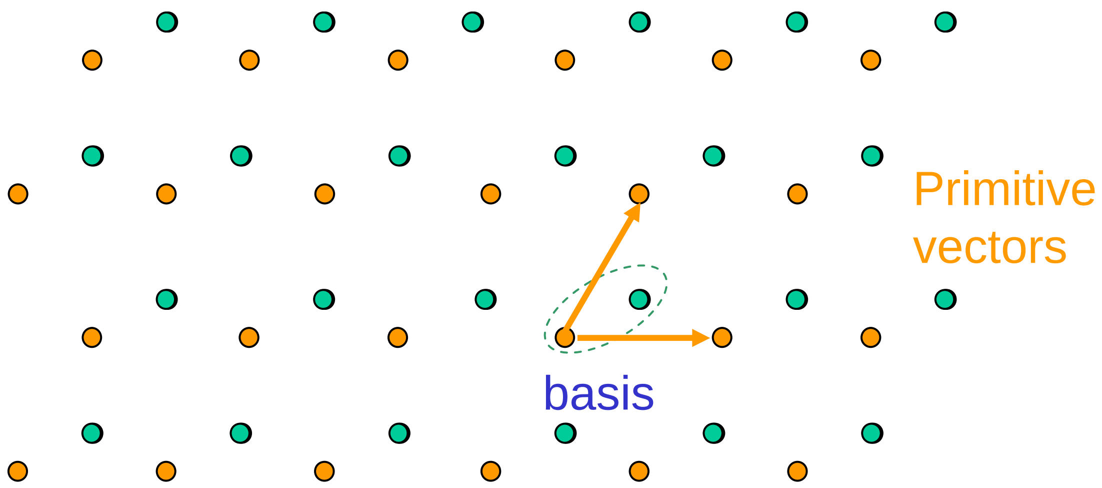
(symmetry here means inversion, translation, and rotation)

Non-Bravais lattices, how do we describe them?

Method 1: $\boldsymbol{R} = n_1\boldsymbol{a_1}+n_2\boldsymbol{a_2}$ (with some n_1, n_2 missing)

Method 2: Bravais lattice + basis ✓

Ex: honeycomb lattice



honeycomb lattice = hexagonal lattice + 2-point basis

(i.e. superposition of 2 hexagonal lattices)

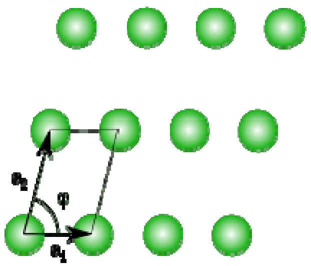
Lattices can be classified by their symmetries

- Symmetry operation: a rigid operation that takes the lattice into itself
- For a Bravais lattice, the symmetry operation can only be
    - an inversion (every BL has it)
    - a translation
    - a rotation
    - combination of above

For non-Bravais lattices, it's possible to have extra symmetries involving glide plane and screw axis. (later)

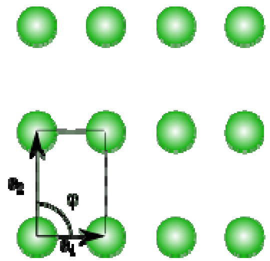
- The collection of symmetry operations form a space group
- A subset of symmetry operations (inversion, rotation) that leave a lattice point fixed form a point group

For 2D Bravais lattices, there are 5 space groups



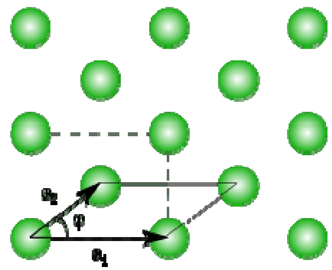
$|a_1| \neq |a_2|$, $\varphi \neq 90°$

Oblique (C_2)



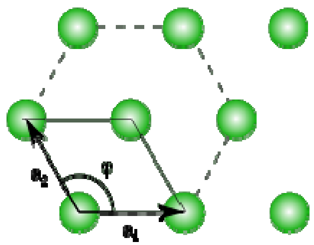
$|a_1| \neq |a_2|$, $\varphi = 90°$

Rectangular (C_{2v})



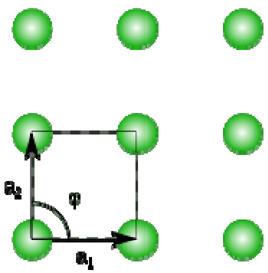
$|a_1| \neq |a_2|$, $\varphi \neq 90°$

Centered rectangular (C_{2v})



$|a_1| = |a_2|$, $\varphi = 120°$

Hexagonal (C_{6v})



$|a_1| = |a_2|$, $\varphi = 90°$

Square (C_{4v})

From wiki

Q: How many different point groups? 4

C_n : *n*-fold rotation axis.

C_{nv} (C_{nh}) : C_n with a mirror plane

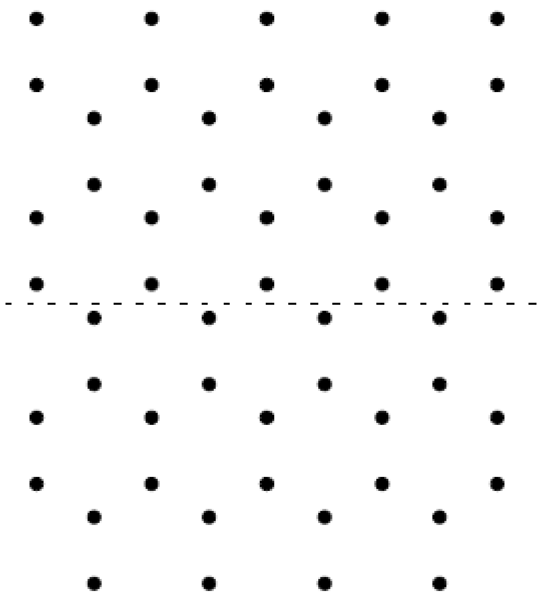
// ($\perp$) to the axis of rotation.

Glide line in 2D and glide plane (滑移對稱面) in 3D

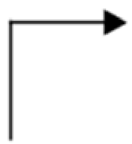
Not a Bravais-lattice vector

A glide plane consists of a translation parallel to a given plane, followed by a reflection in that plane

Glide line

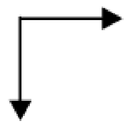


Glide plane



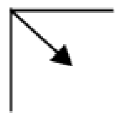
Axial glide plane

Glide a/2 along arrow



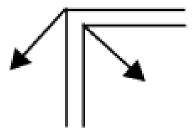
Double glide plane

2 glide directions



Diagonal glide plane

Glide along (a+b)/2, (a+b+c)/2 … etc



Diamond glide plane

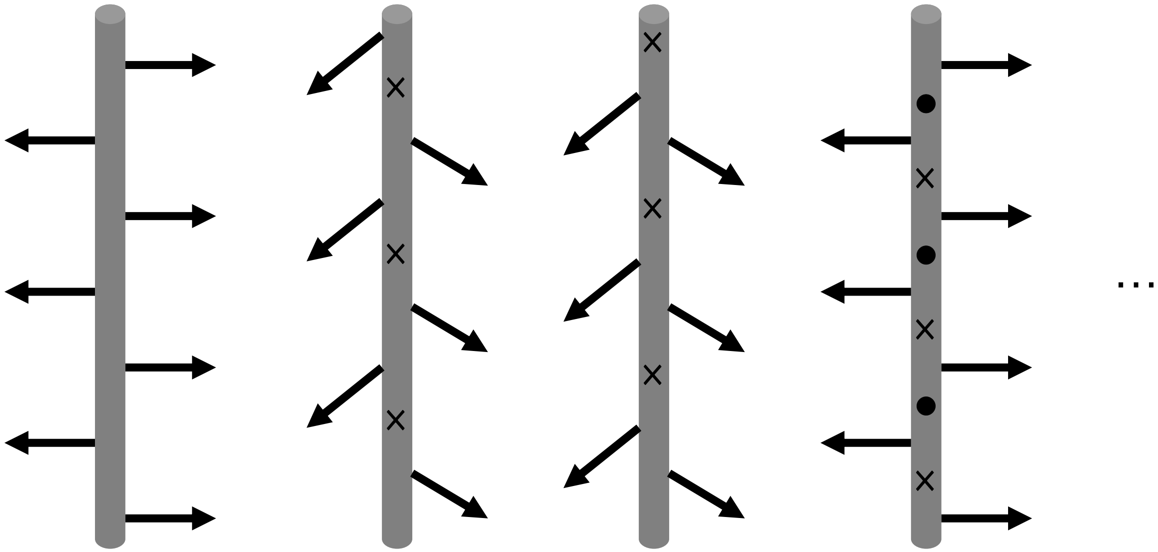
Glide along (a+b)/4, (a+b+c)/4 … etc

Screw axes (螺旋對稱軸), only in 3D

Not a Bravais lattice vector

A screw axis is a translation along an axis about which a rotation is simultaneously occurring

2-fold, 3-fold, 4-fold, and 6-fold



2_1 3_1 Right-handed 3_2 Left-handed 4_1

n_m: shift by (m/n)a