Jan-9-2013

PHYS 342/555
Introduction to solid state physics

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(Room 407A, Nielsen, 974-1509)
(Office hours: TR 1:10PM-2:00 PM)
Lecture 2, room 306 Nielsen
Chapter 2: Crystal Structures

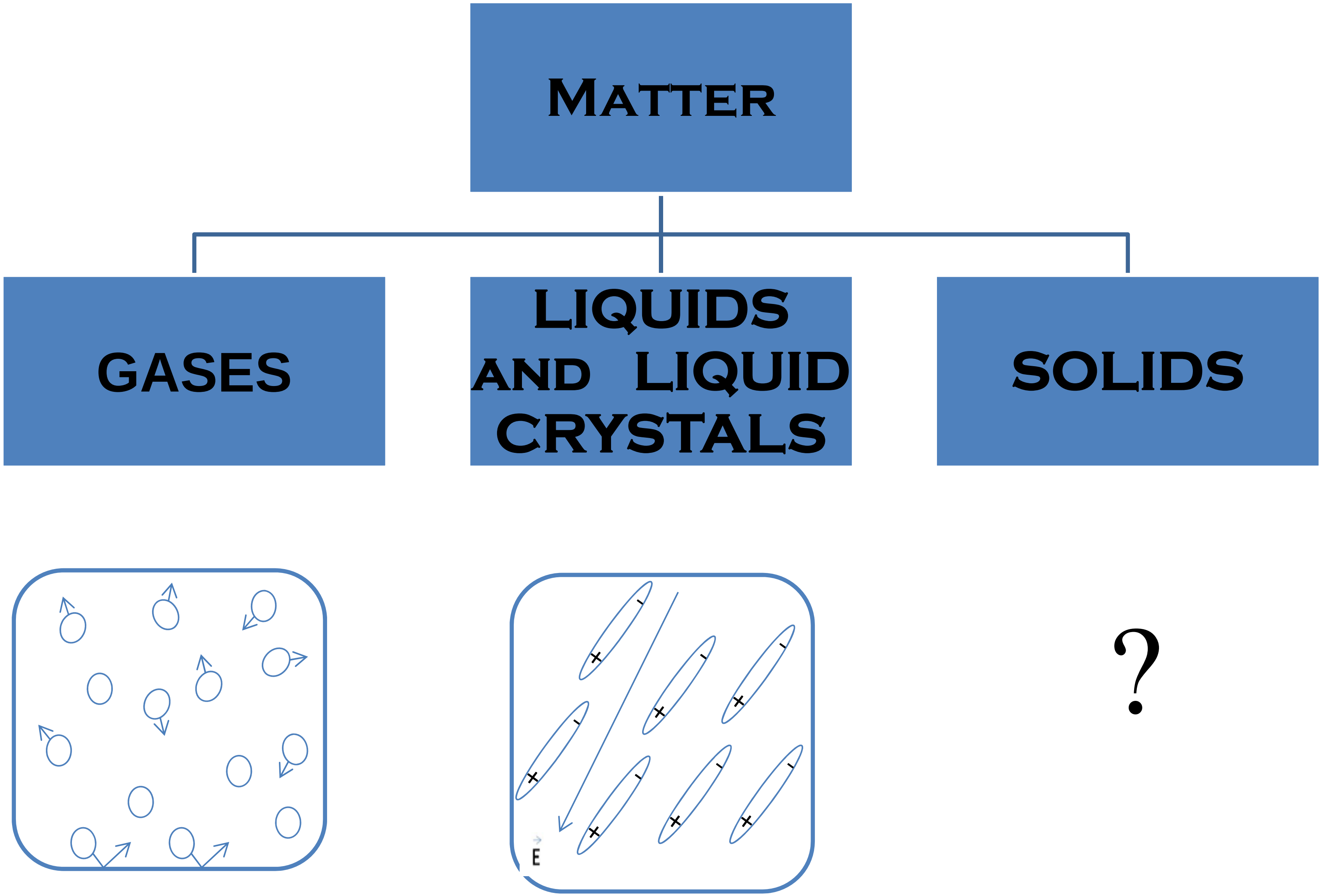
Lecture in pdf format will be available at:
http://www.phys.utk.edu

Solid or Condensed

- Solid state physics
- condensed matter physics
- SSP is the applied physics associated with <u>technology rather than interesting fundamentals</u>

Acknowledge

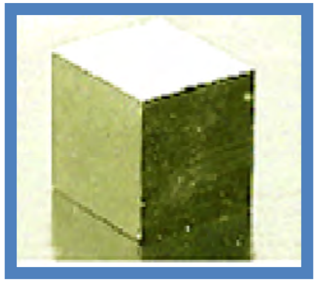
- Pengcheng’s slides
- Prof.Dr.Besire Gonul
- Wikipedia
- others

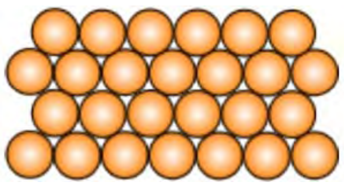

MATTER
GASES
LIQUIDS AND LIQUID CRYSTALS
SOLIDS
E
?

SOLID MATERIALS

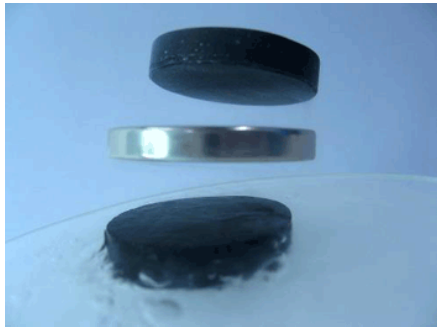
CRYSTALLINE

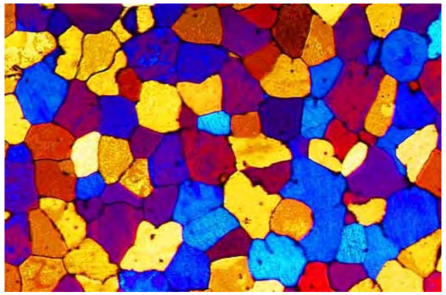
Single Crystal

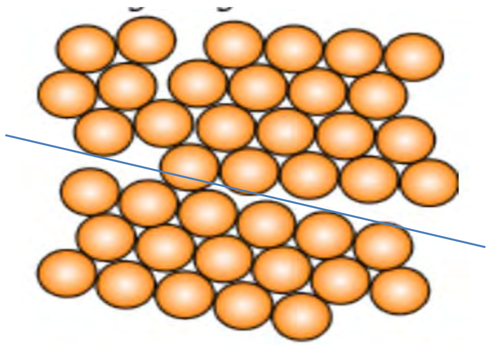




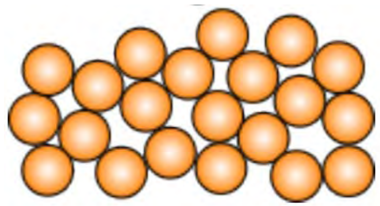
POLYCRYSTALLINE





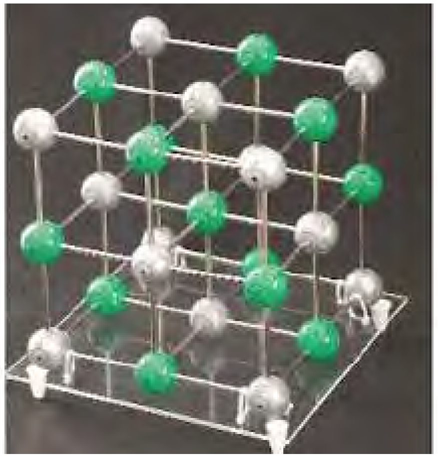
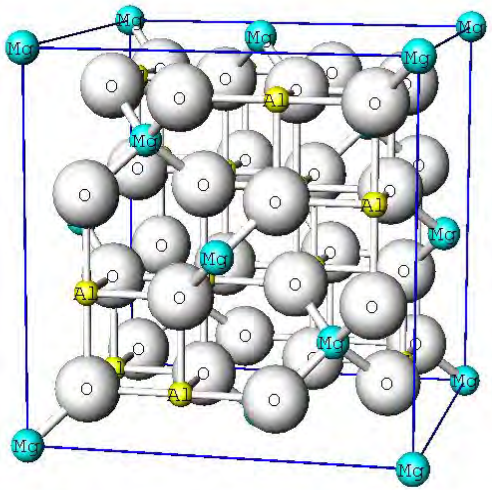


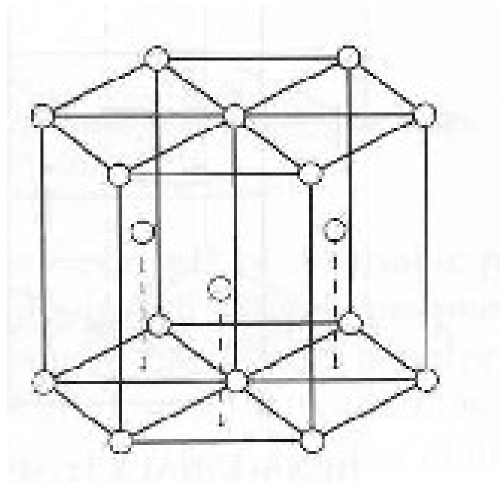
AMORPHOUS (Non-crystalline)



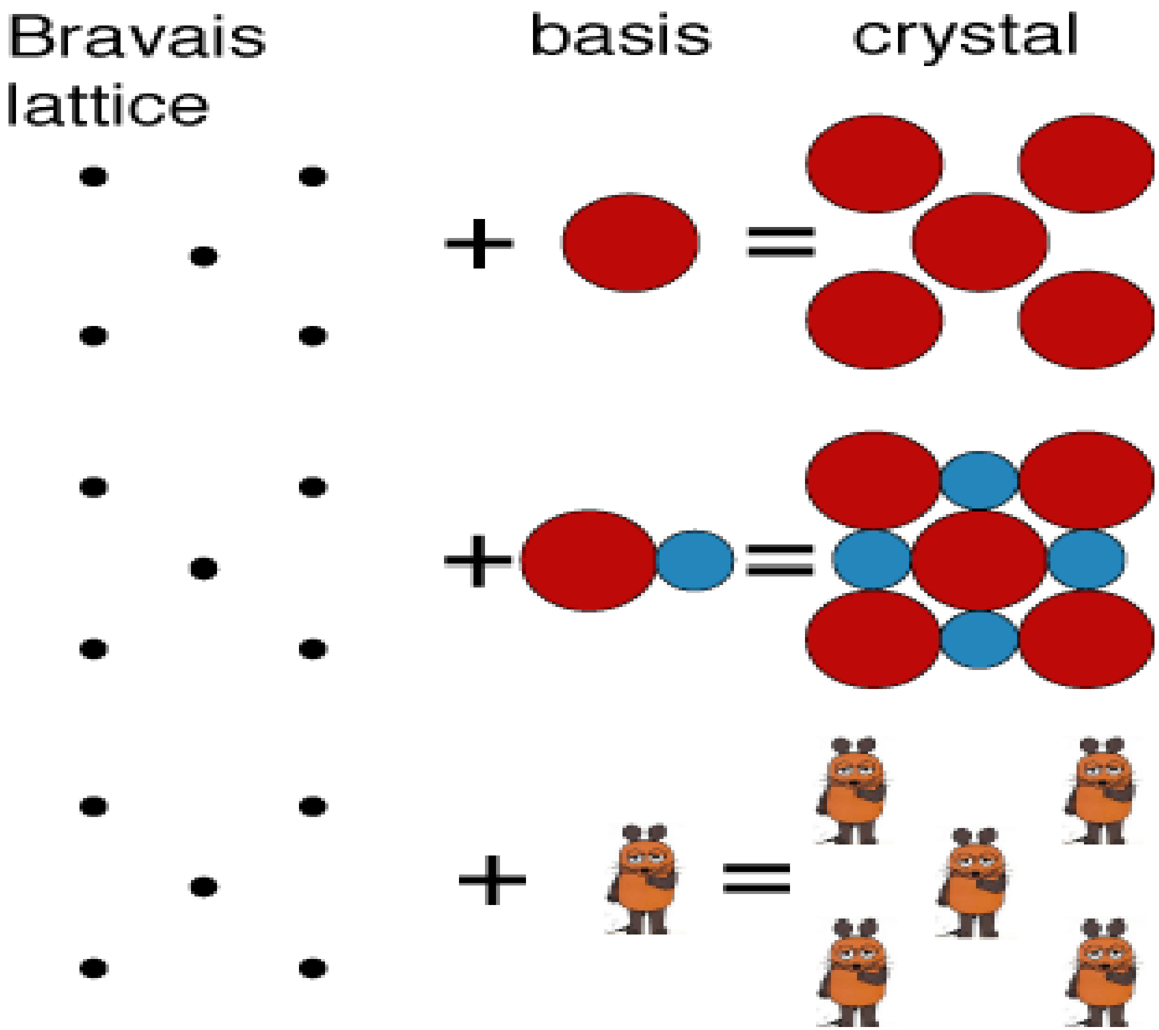
Crystal Shape?





Bravais Lattice



Bravais Lattice

1, An array of points such that every point has ***identical surroundings***

2, primitive lattice: (a mimimum-volume unit cell)

3, position vector:

$$\vec{R} = n_1\vec{a}_1 \quad \text{(1D)}$$

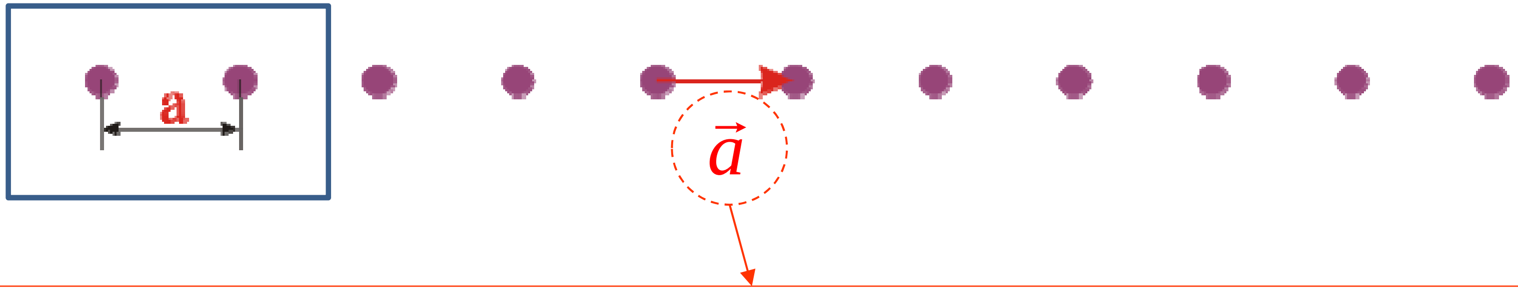
$$\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 \quad \text{(2D)}$$

$$\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 + n_3\vec{a}_3 \quad \text{(3D)}$$

n_1, n_2, n_3 integer (+, -, or 0)

a_1, a_2, and a_3 not all in same plane (Primitive vector)

1D Lattices



Starting with a point the lattice translation vector (basis vector) can generate the lattice

- In 1D there is only one kind of lattice
- This lattice can be described by a single lattice parameter (a)
- The unit cell for this lattice is a line segment of length a

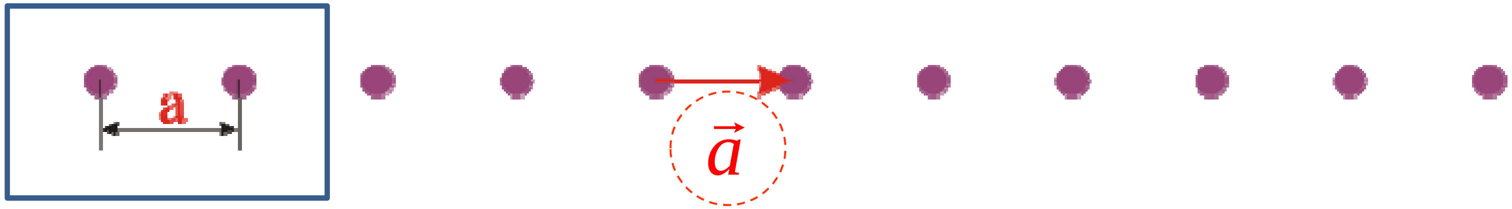
Position vector: $\vec{R} = n_1 \vec{a}_1$

Premitive vector: a_1

premitive cell:?

Size: a_1

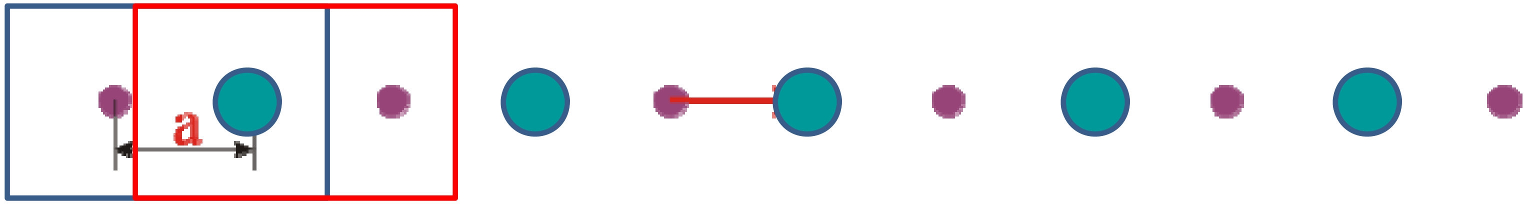
1D Lattices



Position vector: $\vec{R} = n_1\vec{a}_1$

Premitive vector: a_1

Unit cell:?

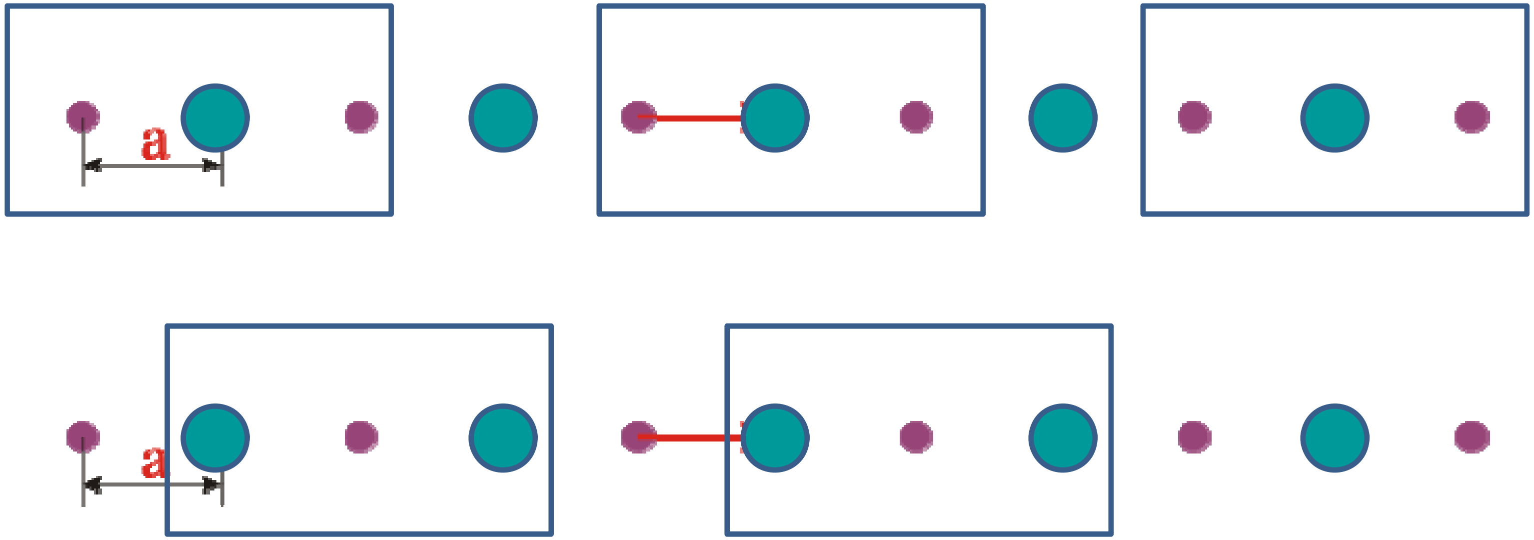


Position vector: ?

Premitive vector: ?

Unit cell:?

1D Lattices



Position vector: $R=n_1*(2a)$
Premitive vector: 2a
premitive cell:?

2D Lattices

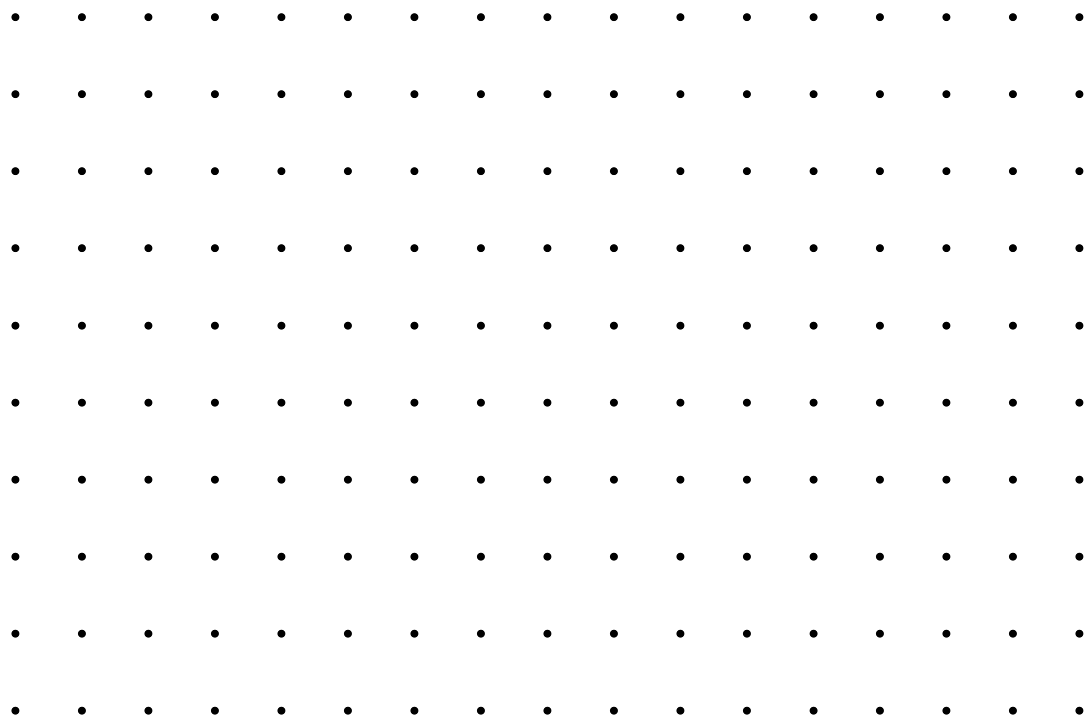
Position vector: $\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2$.

Premitive vector: $a_{1,}$ a_2

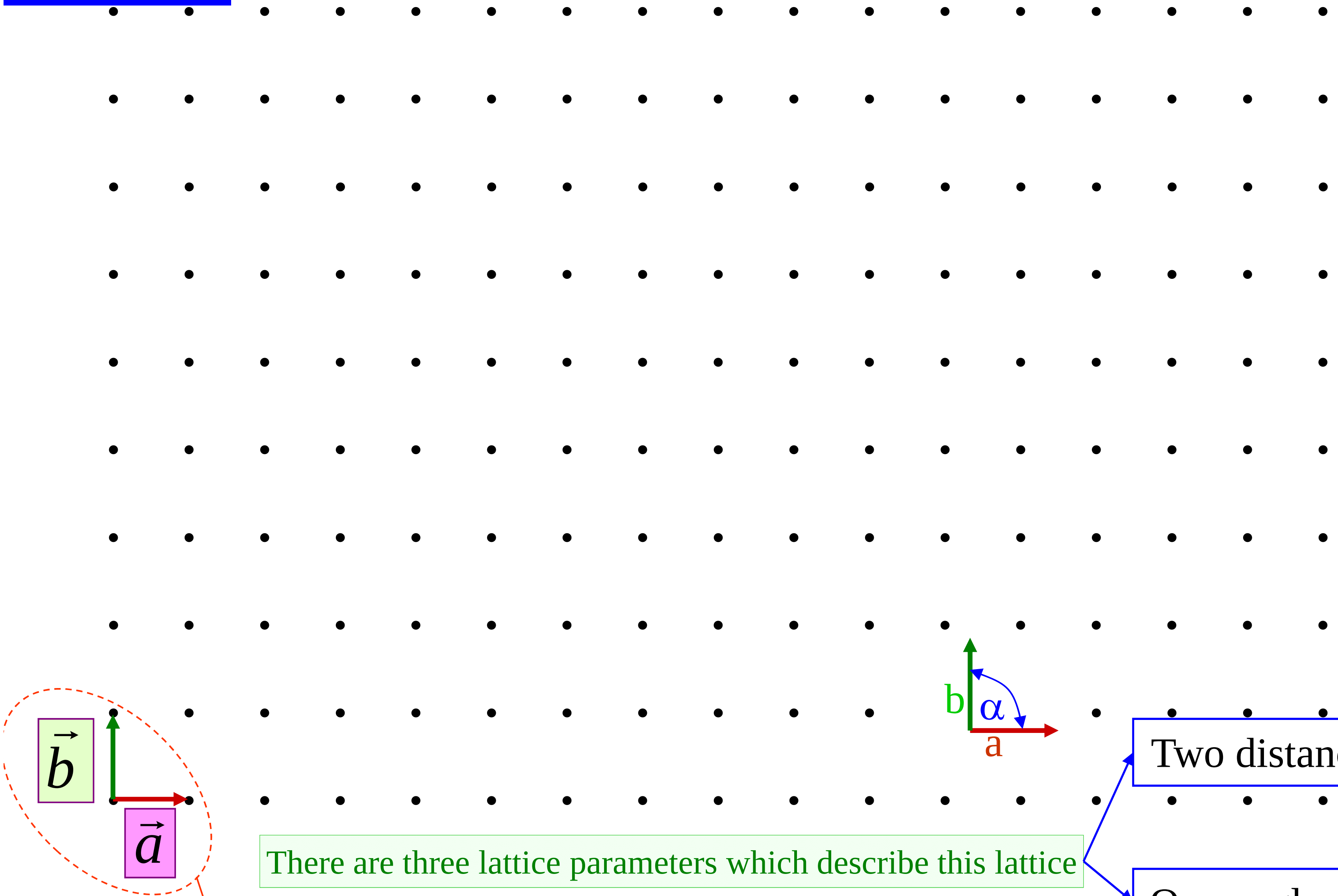
Unit cell:?

Primitive cell:?

Size: $a_1 \times a_2$



2D Lattices



There are three lattice parameters which describe this lattice

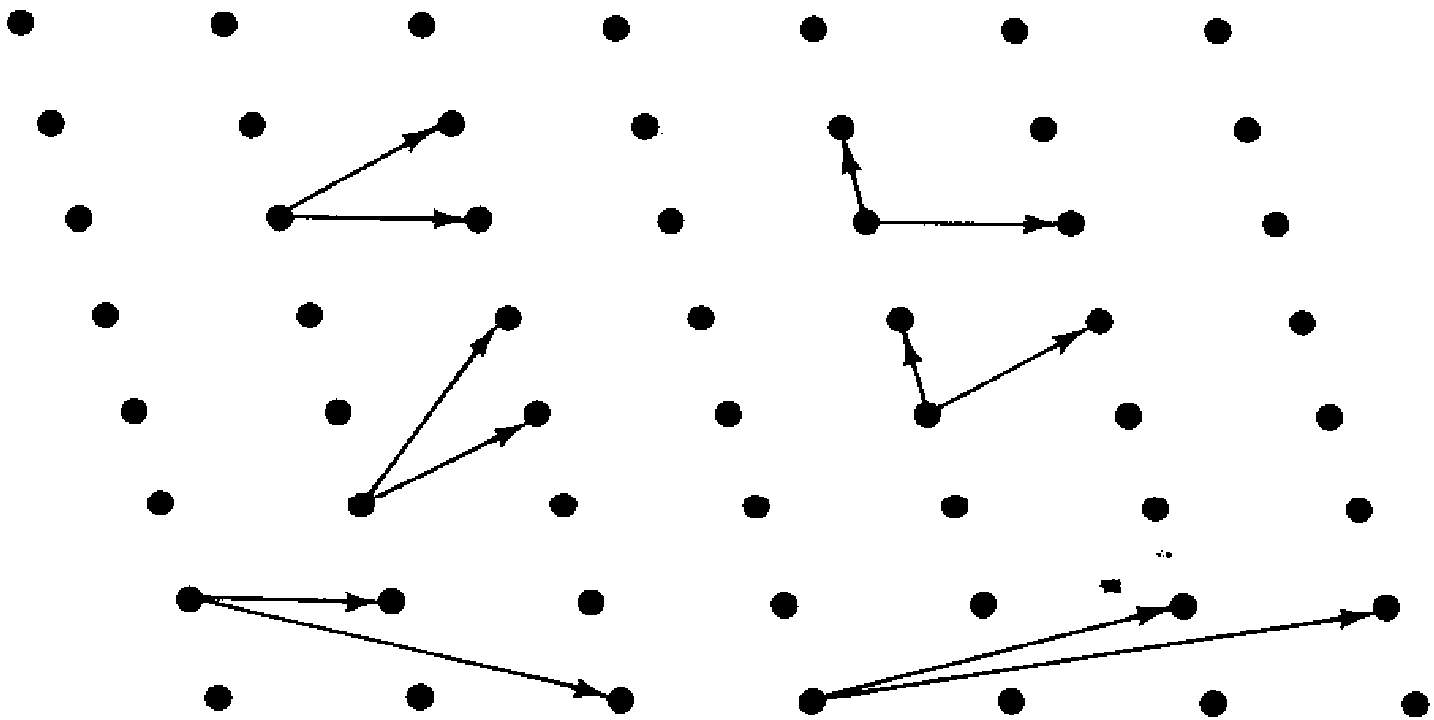
Two distances: a, b

One angle: α

$= 90^\circ$ *in the current exam*

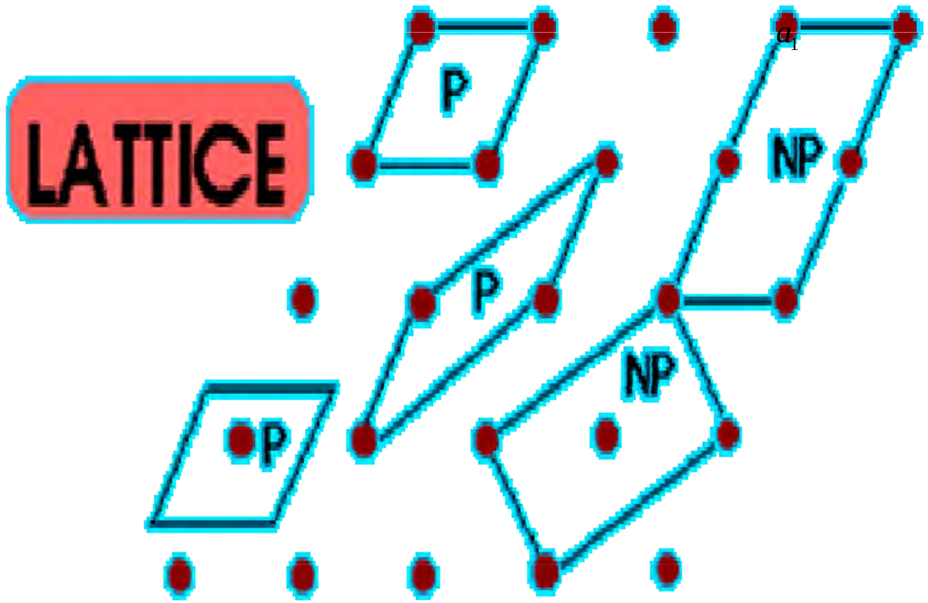
Two basis vectors generate the lattice

For any given Bravais lattice, the set of primitive vectors is not unique. There are many nonequivalent choices.



Primitive Unit Cell

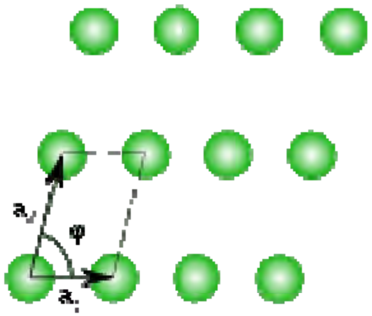
- The primitive unit cell must have only one lattice point.
- There can be different choices for lattice vectors , but the volumes of these primitive cells are all the same.



P = Primitive Unit Cell
NP = Non-Primitive Unit Cell

2D Lattices (Five lattices)

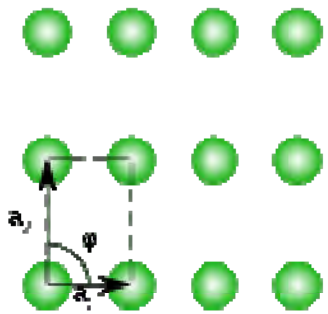
Parallelogram Lattice



$|a_1| \neq |a_2|, \varphi \neq 90°$

1

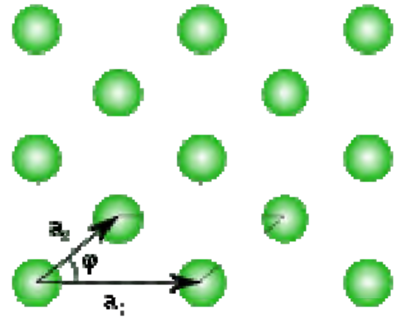
Rectangle Lattice



$|a_1| \neq |a_2|, \varphi = 90°$

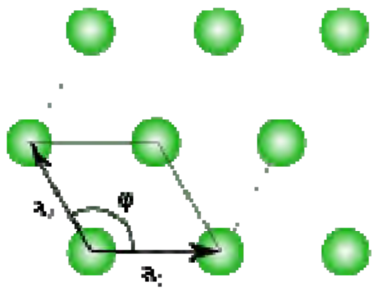
2

Centred Rectangle Lattice



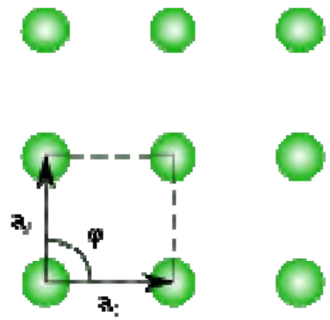
$|a_1| \neq |a_2|, \varphi \neq 90°$

3



$|a_1| = |a_2|, \varphi = 120°$

120° Rhombus Lattice

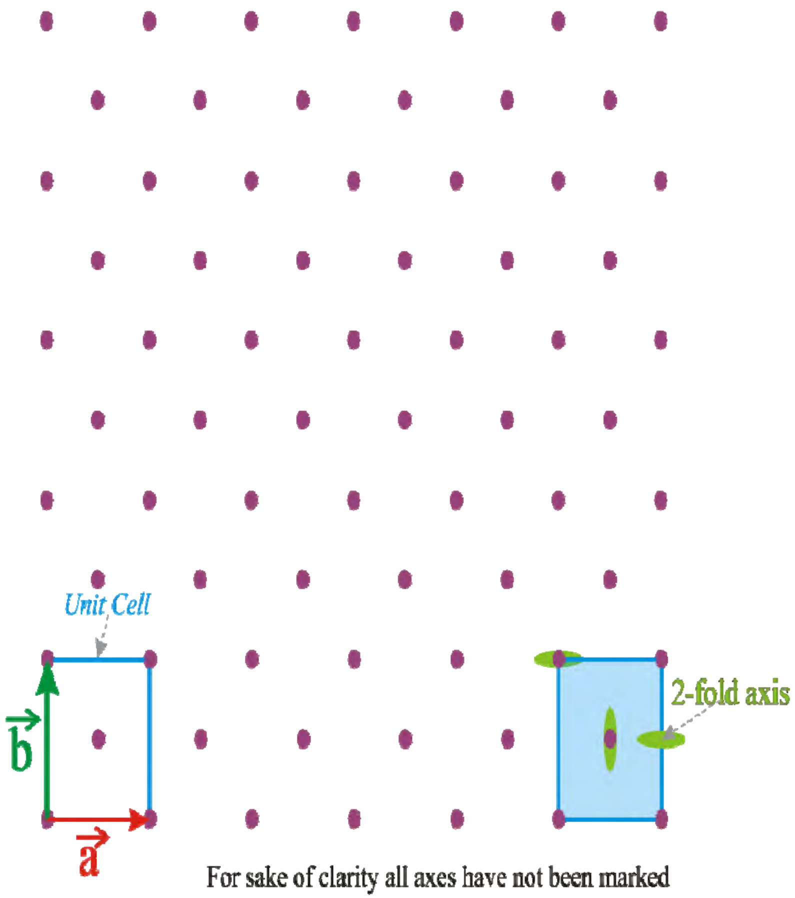


$|a_1| = |a_2|, \varphi = 90°$

5

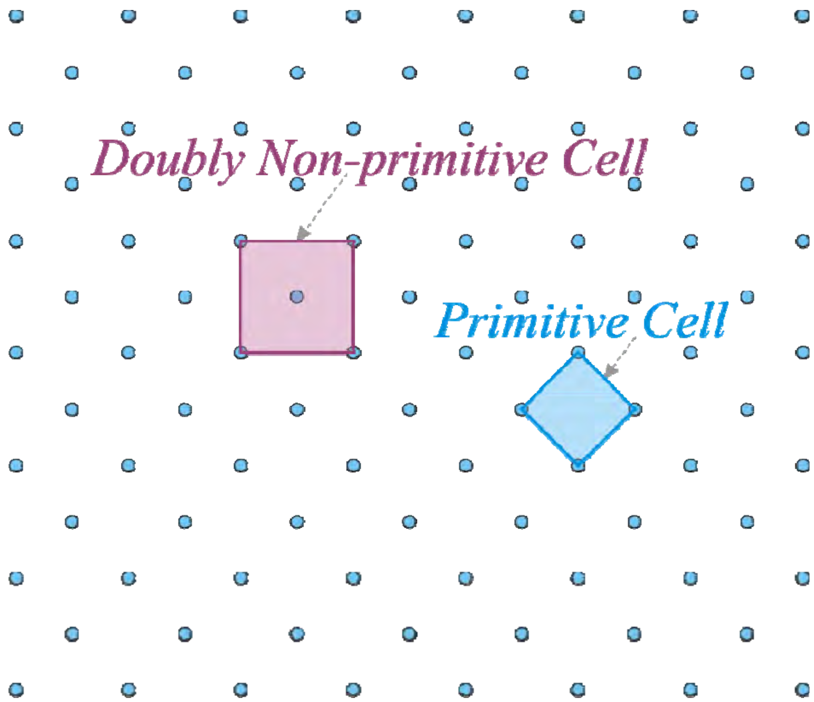
Square Lattice

Centred Rectangle Lattice



Lattice parameters: a, b, α = 90°

Centred cubic Lattice?



Summary of 2D lattices

Lattice	Symmetry	Shape of UC	Lattice Parameters
1. Square	4mm	1. Square	(a = b , α = 90°)
2. Rectangle	2mm	2. Rectangle	(a ≠ b, α = 90°)
3. Centred Rectangle	2mm	"	(a ≠ b, α = 90°)
4. 120° Rhombus	6mm	3. 120° Rhombus	(a = b, α = 120°)
5. Parallelogram	2	4. Parallelogram	(a ≠ b, α general value)

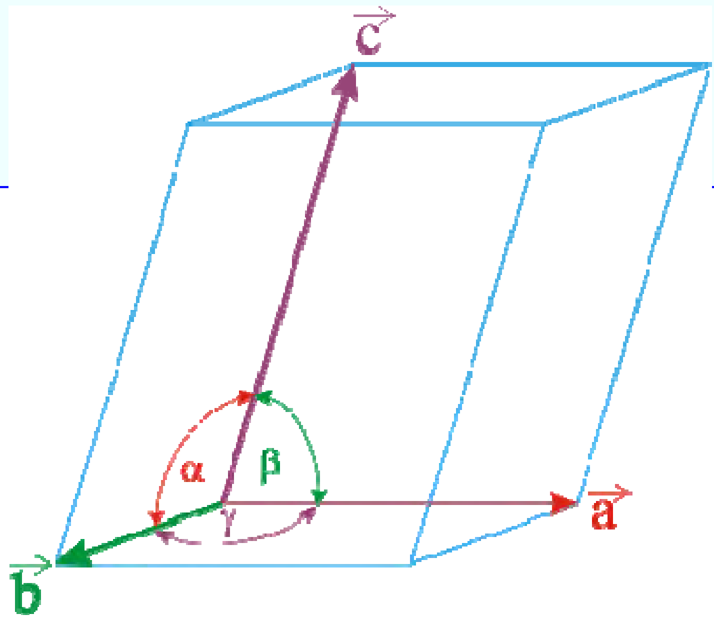
Lattice	Simple	Centred
Square	✓	✗
Rectangle	✓	✓
120° Rhombus	✓	✗
Parallelogram	✓	✗

Every lattice that you can construct is present somewhere in the list
→ the issue is where to put them!

Shows the equivalence

3D Lattices

- 3D lattices can be generated with three basis vectors
- They are infinite in three dimensions
- 3 basis vectors generate a 3D lattice
- The unit cell of a general 3D lattice is described by 6 numbers (in special cases all these numbers need not be independent) → 6 lattice parameters



3D Lattices (14)

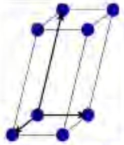
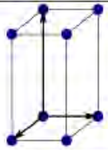
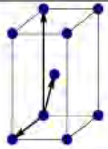
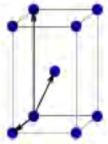
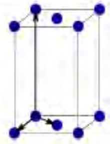
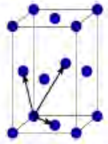
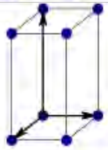
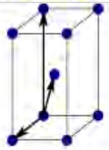
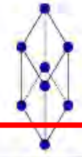
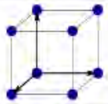
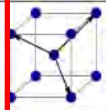
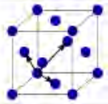
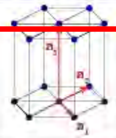
Bravais lattice	Parameters	Simple (P)	Volume centered (I)	Base centered (C)	Face centered (F)
Triclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} \neq \alpha_{23} \neq \alpha_{31}$				
Monoclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{23} = \alpha_{31} = 90^\circ$ $\alpha_{12} \neq 90^\circ$				
Orthorhombic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Tetragonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Trigonal	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} < 120$				
Cubic	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Hexagonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = 120^\circ$ $\alpha_{23} = \alpha_{31} = 90^\circ$				

Table 1.1: Bravais lattices in three-dimensions.

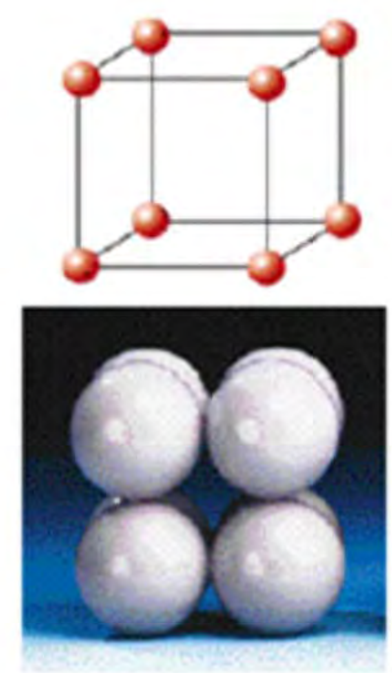
Cubic(P)

Position vector: $\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 + n_3\vec{a}_3$

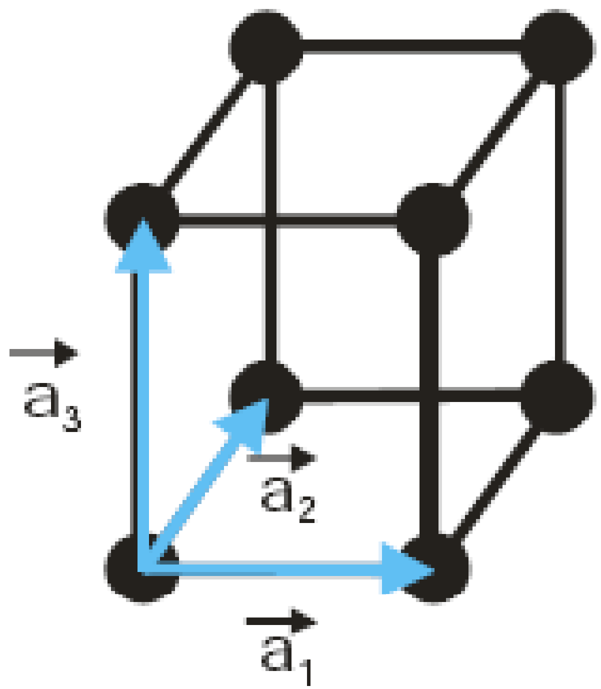
Premitive vector: a_1, a_2, a_3

Primitive cell:?

Size: $a_1 \cdot (a_2 \times a_3)$

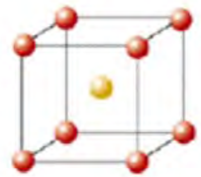


simple cubic

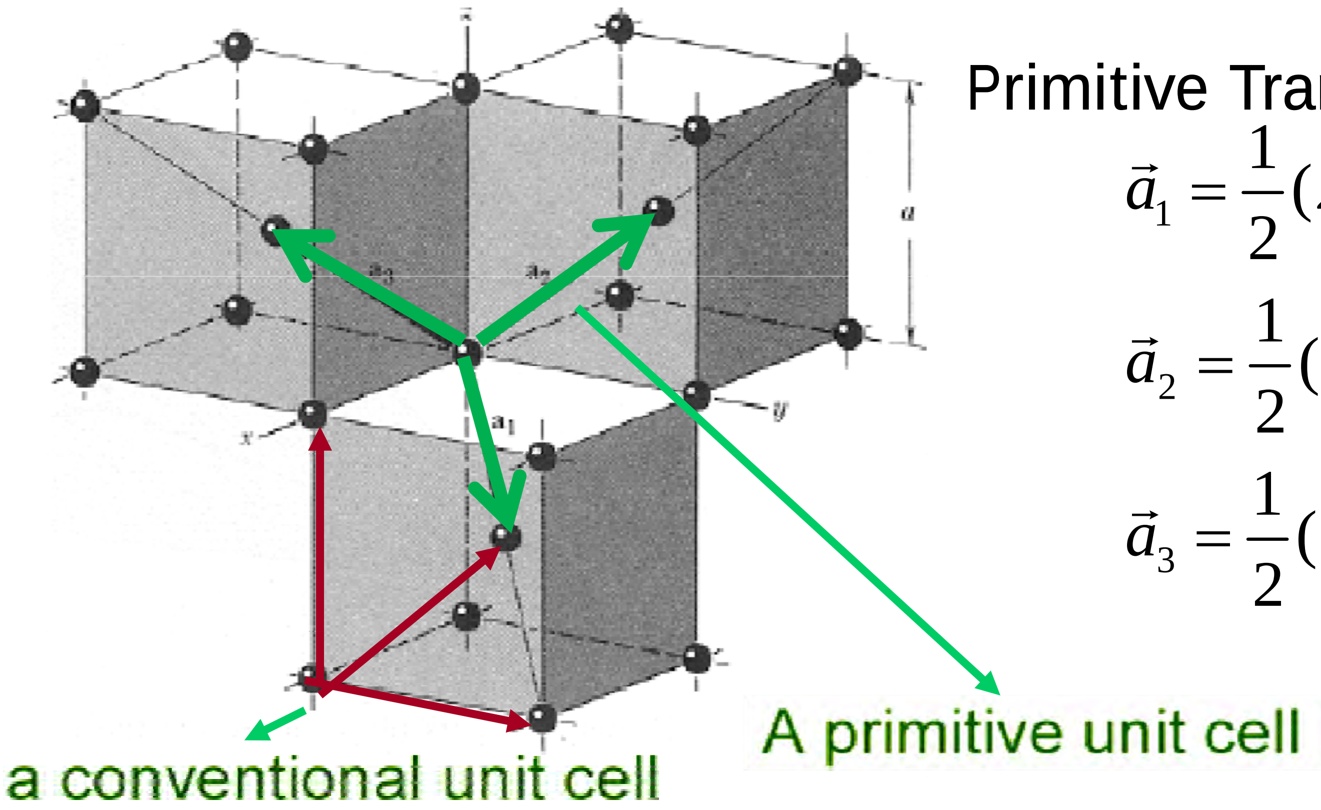


$V = a^3$

Cubic(I)



Primitive and conventional cells



Primitive Translation Vectors:

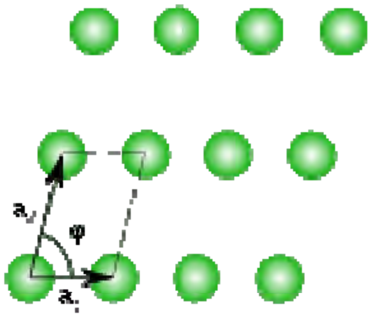
$$\vec{a}_1 = \frac{1}{2}(\hat{x} + \hat{y} - \hat{z})$$

$$\vec{a}_2 = \frac{1}{2}(-\hat{x} + \hat{y} + \hat{z})$$

$$\vec{a}_3 = \frac{1}{2}(\hat{x} - \hat{y} + \hat{z})$$

2D (5 lattice)

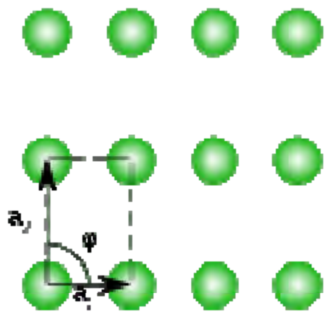
Parallelogram Lattice



$|a_1| \neq |a_2|,\ \varphi \neq 90°$

1

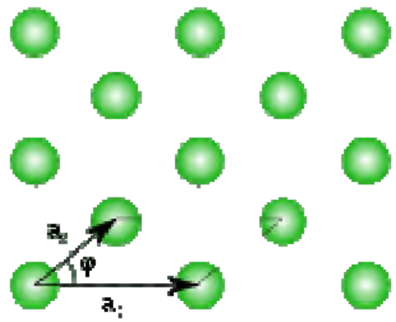
Rectangle Lattice



$|a_1| \neq |a_2|,\ \varphi = 90°$

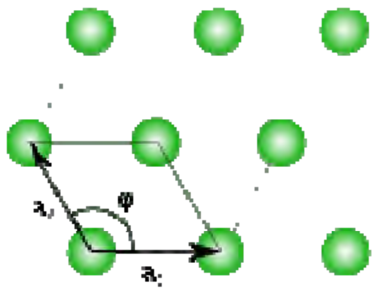
2

Centred Rectangle Lattice



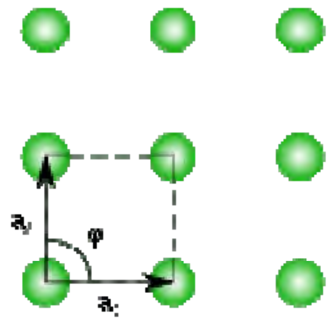
$|a_1| = |a_2|,\ \varphi \neq 90°$

3



$|a_1| = |a_2|,\ \varphi = 120°$

120° Rhombus Lattice



$|a_1| = |a_2|,\ \varphi = 90°$

5

Square Lattice

Review of lecture one

3D Lattices (14)

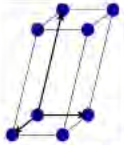
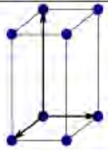
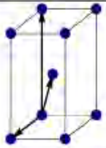
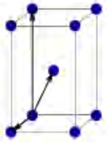
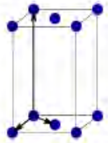
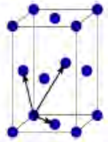
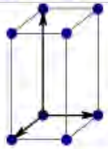
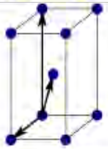
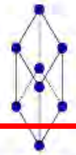
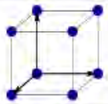
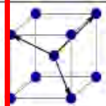
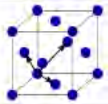
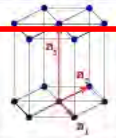
Bravais lattice	Parameters	Simple (P)	Volume centered (I)	Base centered (C)	Face centered (F)
Triclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} \neq \alpha_{23} \neq \alpha_{31}$				
Monoclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{23} = \alpha_{31} = 90^\circ$ $\alpha_{12} \neq 90^\circ$				
Orthorhombic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Tetragonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Trigonal	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} < 120^\circ$				
Cubic	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90^\circ$				
Hexagonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = 120^\circ$ $\alpha_{23} = \alpha_{31} = 90^\circ$				

Table 1.1: Bravais lattices in three-dimensions.

Review of lecture one

Bravais Lattice

1, An array of points such that every point has ***identical surroundings***

2, primitive lattice: (a mimimum-volume unit cell)

3, position vector:

$$\vec{R} = n_1\vec{a}_1 \quad \text{(1D)}$$

$$\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 \quad \text{(2D)}$$

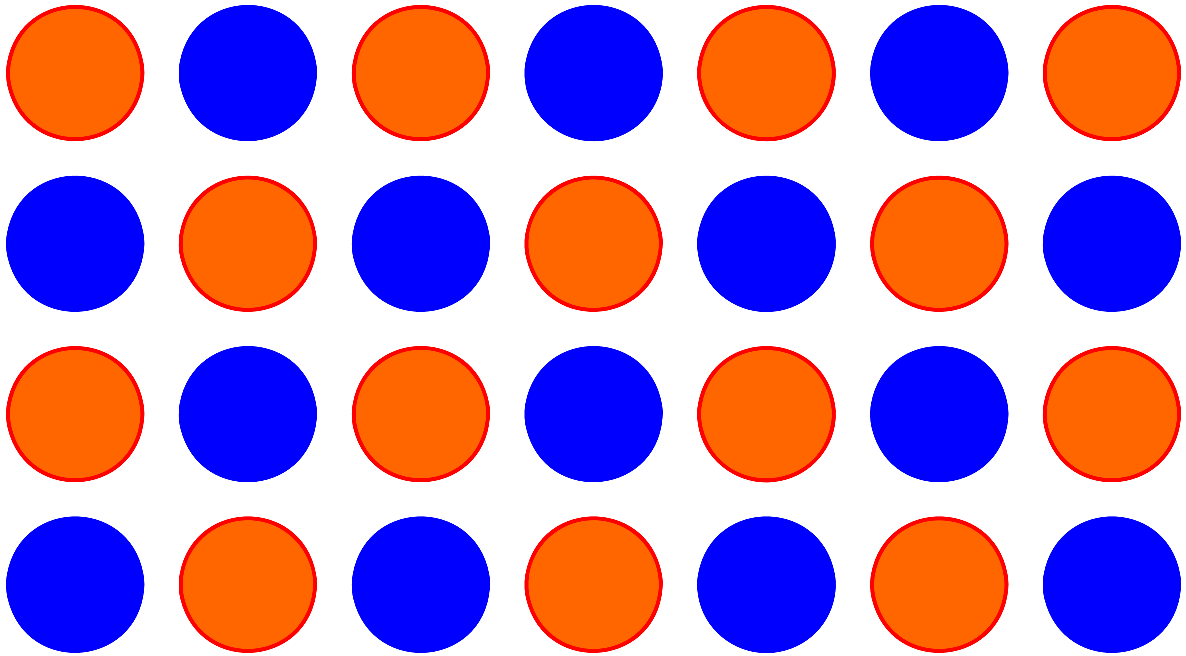
$$\vec{R} = n_1\vec{a}_1 + n_2\vec{a}_2 + n_3\vec{a}_3 \quad \text{(3D)}$$

n_1, n_2, n_3 integer (+, -, or 0)

a_1, a_2, and a_3 not all in same plane (Primitive vector)

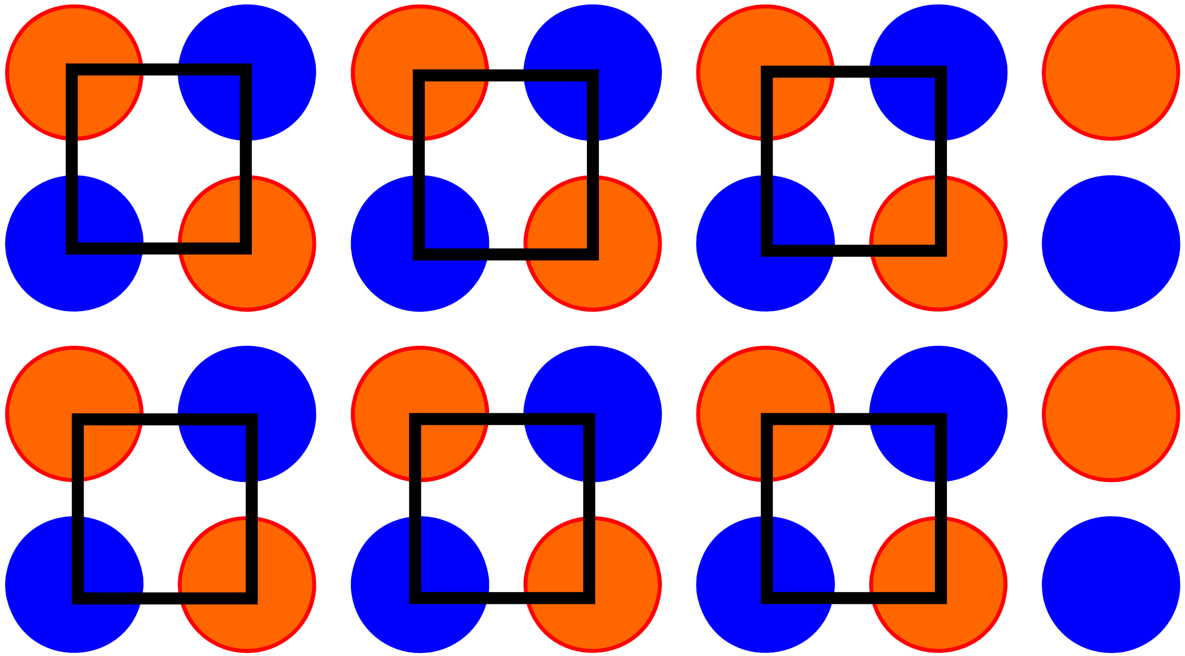
Review of lecture one

2D Unit Cell example -(NaCl)



We define lattice points ; these are points with *identical environments*

This is NOT a unit cell even though they are all the same - empty space is not allowed!



In 2D, this IS a unit cell