

PAPER-A: CONDENSED MATTER PHYSICS
(B.Sc. Semester-V)

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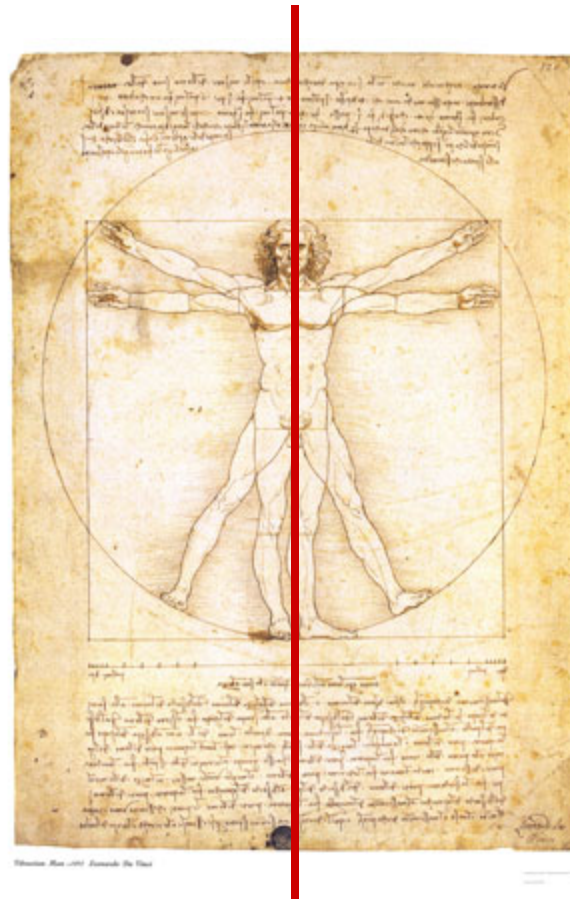
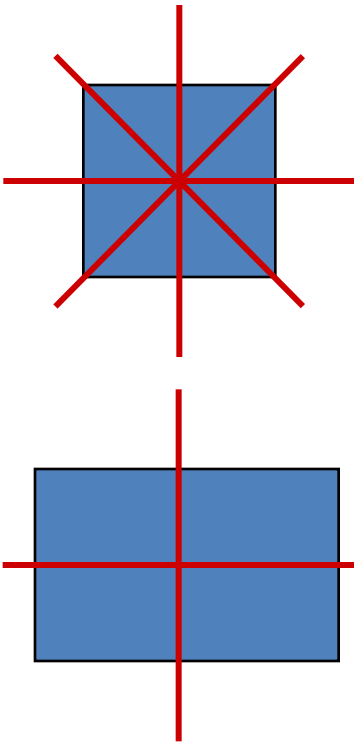
- 2-D Symmetry Operators
- 3-D Symmetry Operators

Symmetry

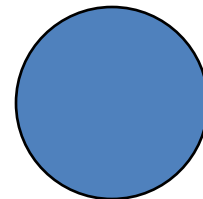
- ❑ Symmetry defines the order resulting from how atoms are arranged and oriented in a crystal
- ❑ Study the 2-D and 3-D order of minerals
- ❑ Do this by defining **symmetry operators** (there are 13 total) → actions which result in no change to the order of atoms in the crystal structure
- ❑ Combining different operators gives **point groups** – which are geometrically unique units.
- ❑ Every crystal falls into some point group, which are segregated into 6 major **crystal systems**

2-D Symmetry Operators

- Mirror Planes (m) – reflection along a plane

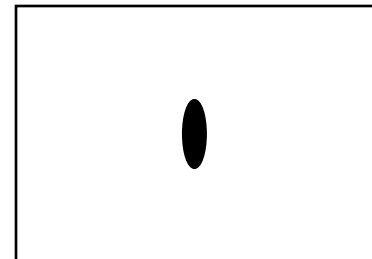
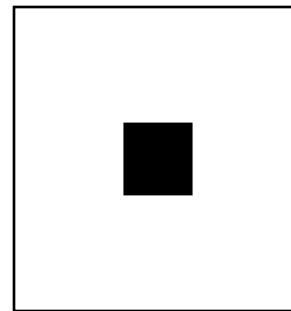
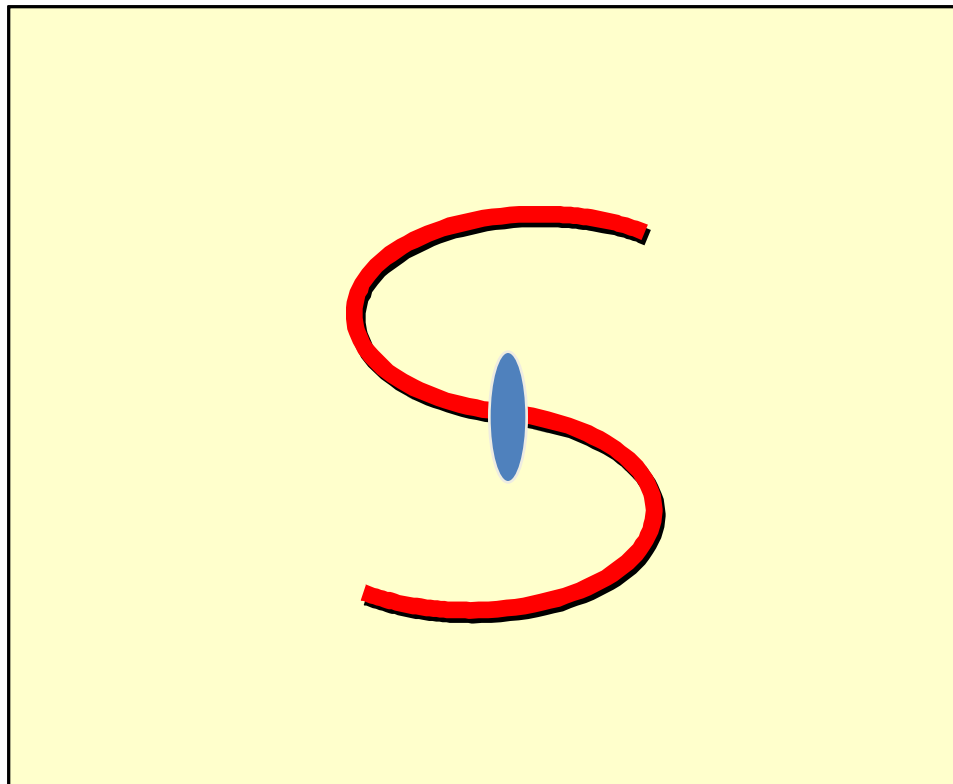


A line denotes
mirror planes




2-D Symmetry Operators


- Rotation Axes (**1, 2, 3, 4, or 6**) – rotation of 360, 180, 120, 90, or 60° around a rotation axis yields no change in orientation/arrangement



2-fold 

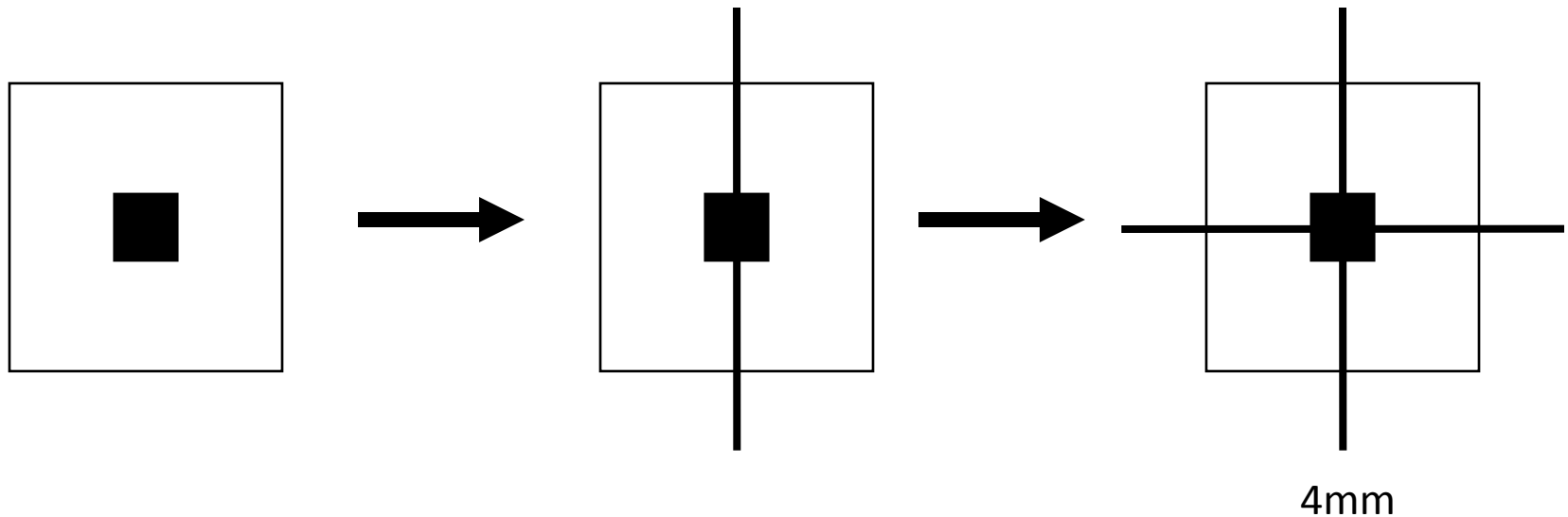
3-fold 

4-fold 

6-fold 

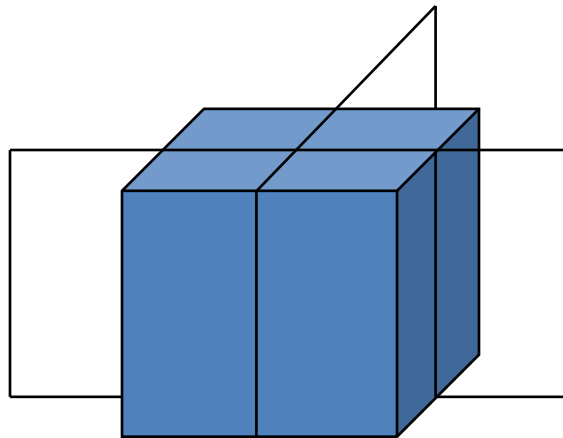
2-D Point groups

- All possible combinations of the 5 symmetry operators: m , 2 , 3 , 4 , 6 , then combinations of the rotational operators and a mirror yield $2mm$, $3m$, $4mm$, $6mm$
- Mathematical maximum of 10 combinations



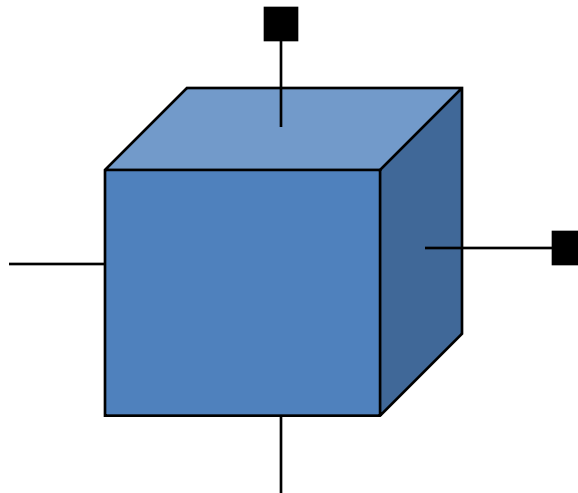
3-D Symmetry Operators

- Mirror Planes (m) – reflection along any plane in 3-D space



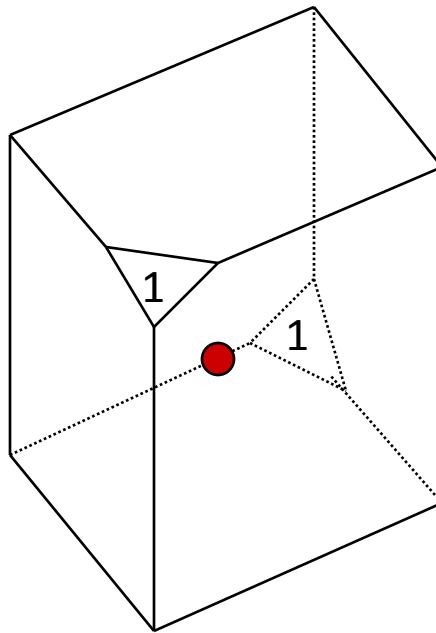
3-D Symmetry Operators

- Rotation Axes (1, 2, 3, 4, or 6 a.k.a. A_1 , A_2 , A_3 , A_4 , A_6)
 - rotation of 360, 180, 120, 90, or 60° around a rotation axis through any angle yields no change in orientation/arrangement



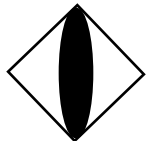
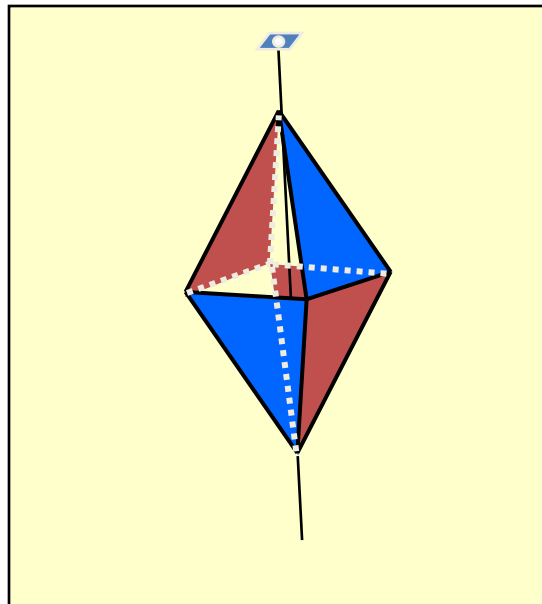
3-D Symmetry Operators

- Inversion (i) – symmetry with respect to a point, called an inversion center



3-D Symmetry Operators

- Rotoinversion ($\bar{1}, \bar{2}, \bar{3}, \bar{4}, \bar{6}$ a.k.a. $A_1, A_2, A_3, A_4, \bar{A}_6$) – combination of rotation and inversion. Called bar-1, bar-2, etc.
- $\bar{1}, \bar{2}, \bar{6}$ equivalent to other functions



3-D Symmetry Operators

- Mirror planes \perp rotation axes (x/m) – The combination of mirror planes and rotation axes that result in unique transformations is represented as $2/m$, $4/m$, and $6/m$
- **3-D** symmetry element combinations
 - a. Rotation axis parallel to a mirror
 - Same as 2-D
 - $2 \parallel m = 2mm$
 - $3 \parallel m = 3m$, also $4mm$, $6mm$
 - b. Rotation axis \perp mirror
 - $2 \perp m = 2/m$
 - $3 \perp m = 3/m$, also $4/m$, $6/m$
 - c. Most other rotations + m are impossible

REFERENCES

- Introduction To Solid State Physics- Kittel
- Elementary Solid state Physics- Omar
- Solid state Physics- S. O. Pillai

THANK YOU !