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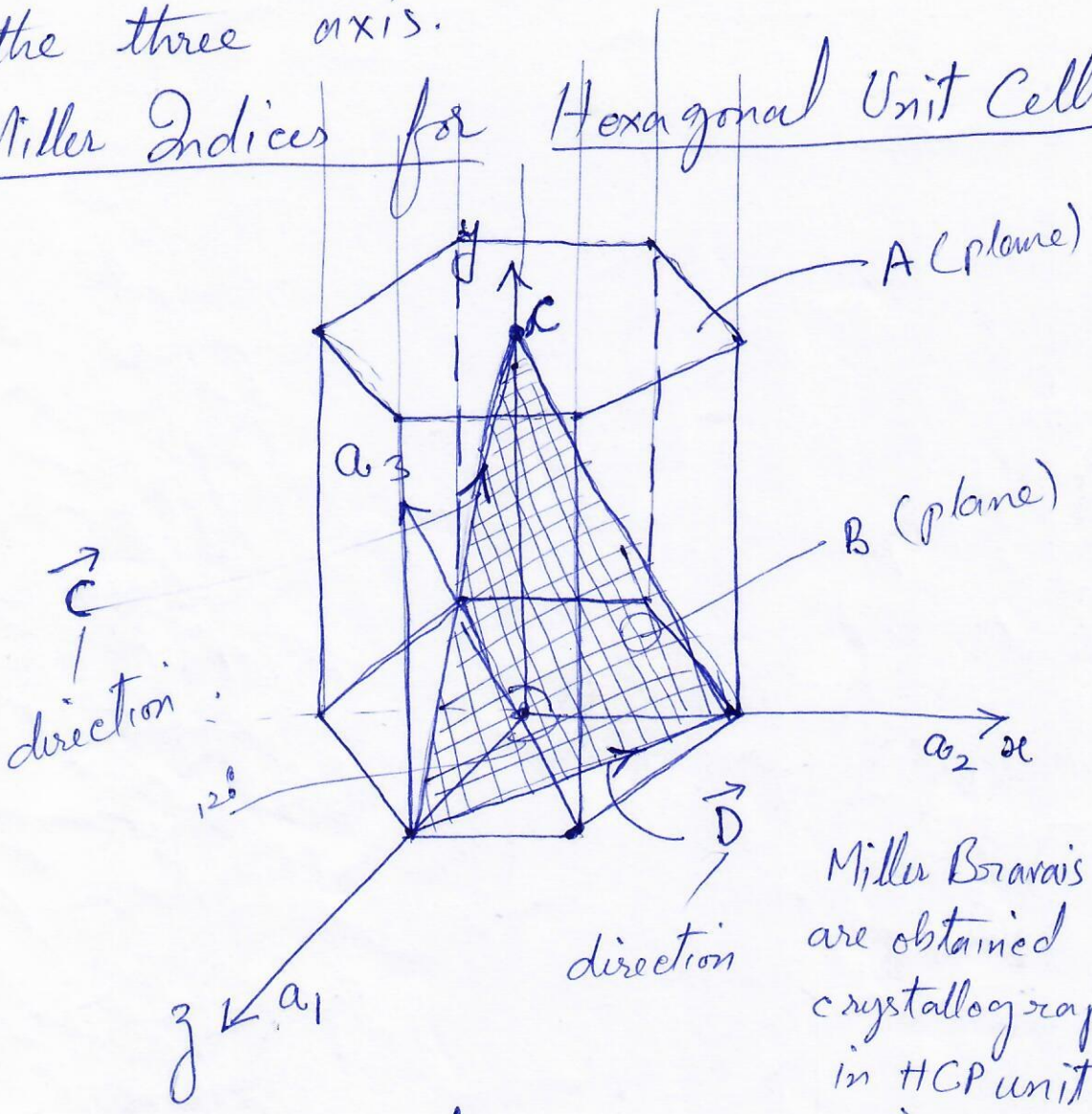
For planes it is to be seen that plane makes ~~the~~ what intercepts with the three axis.

## Miller Indices for Hexagonal Unit Cells




Miller Bravais indices are obtained for crystallographic planes in HCP unit cells by using a four-axis coordinate system.

Axis used are — 4

$a_1, a_2, a_3, c$

$a_3$ — being redundant

so four intercepts are found

i,e (h k i l)

$a_1$ $a_2$ $a_3$ $c$

# EXAMPLE

Determine the Miller Bravais indices for Planes A and B and directions $\vec{C}$ and $\vec{D}$

## Plane A

(a) $a_1 = a_2 = a_3 = \infty$, $c = 1$ $\Rightarrow$ ∥ to $a_1, a_2, a_3$ & cuts z at c=1

(b) $\frac{1}{a_1} = \frac{1}{a_2} = \frac{1}{a_3} = 0$, $\frac{1}{c} = 1$

(c) no fractions to clear

(d) Miller indices (0 0 0 1)

## Plane B

(a) $a_1 = 1, a_2 = 1, a_3 = -\frac{1}{2}, c = 1$

$h_1 + h_2$

$h + k = -i$ or $i = -(h+k)$

$\frac{1}{a_1} + \frac{1}{a_2} = \frac{1}{h} + \frac{1}{k}$

(b) $\frac{1}{a_1} = 1, \frac{1}{a_2} = 1, \frac{1}{a_3} = -2, \frac{1}{c} = 1$

$a_3 = \frac{1}{i} = \frac{1}{-2}$

(c) No fractions to clear

(d) $(1\ 1\ \bar{2}\ 1)$

## Direction C

(a) Two points are 0,0,1 and 1,0,0

(b) 0,0,1 − 1,0,0 = −1,0,1

(c) No fractions to clear

Direction D

(a) Two points are 0, 1, 0 and 1, 0, 0

(b) 0, 1, 0 − 1, 0, 0 = −1, 1, 0

(c) No fractions to clear or integers to reduce

(d) $[\bar{1}\ 1\ 0]$

## Anisotropic Behavior

Because of differences in atomic arrangement in the planes and directions within a crystal, the mechanical properties also vary with direction. A material is anisotropic if its properties depend on the crystallographic direction along which property is measured.

Crystal is isotropic if properties are identical along all crystal directions.

Variation of modulus of elasticity (GPa) with crystal direction

| Material | [100] | [111] | Random |
|---|---|---|---|
| Al | 64 | 77 | 70 |
| Cu | 68 | 195 | 127 |
| Fe | 134 | 283 | 210 |

## Inter planar Spacing

The distance between two adjacent parallel planes of atoms with the same Miller indices is called the inter planar spacing $d_{hkl}$. The inter planar spacing in cubic materials is given by the general equation,

$$d_{hkl} = \frac{a_0}{\sqrt{h^2+k^2+l^2}}$$

where $a_0$ is the lattice parameter and hkl represent the Miller indices of the adjacent planes being considered.

## Example

Calculate the distance between (111) planes in gold, which has a lattice parameter of $4.0786\,\text{Å}$

$$d_{111} = \frac{4.0786}{\sqrt{1^2+1^2+1^2}} = \frac{4.0786}{\sqrt{3}} = 2.355\,\text{Å}$$