Estrutura dos Metais

Conceitos fundamentais de CM

- Estrutura
- Nanoestrutura
- Microestrutura
- Macroestrutura
- Cristais
- Materiais mono ou policristalinos (grãos)
- Metalografia (microestrutura)

Células Unitárias

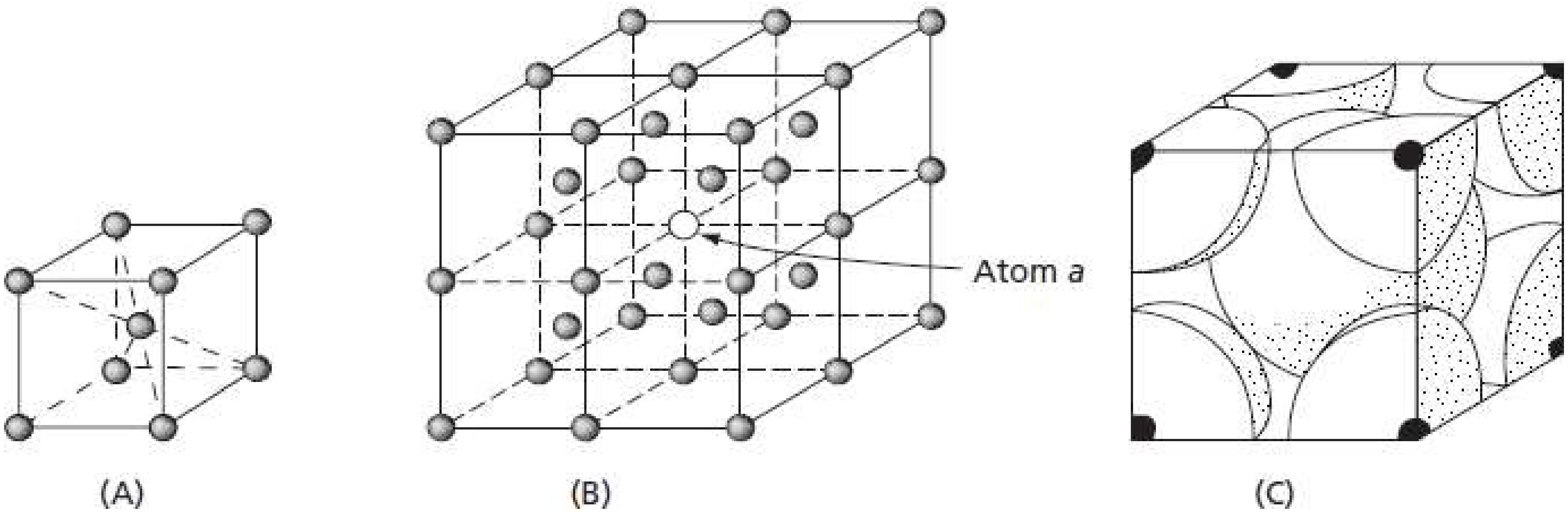


FIG. 1.1 **(A)** Body-centered cubic unit cell. **(B)** Eight unit cells of the body centered cubic lattice. **(C)** Cut view of a unit cell

Células Unitárias

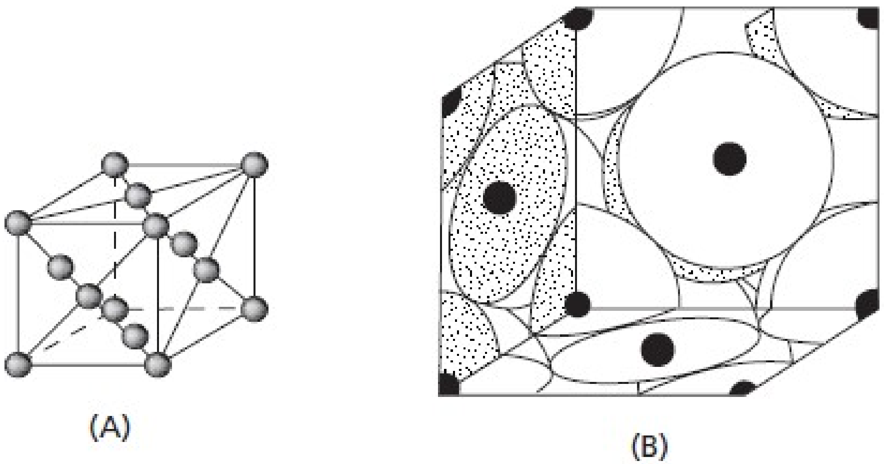
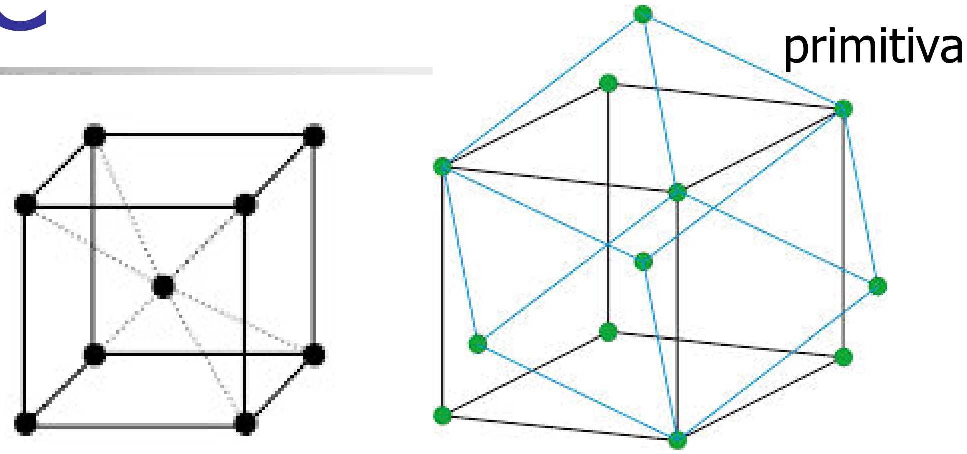
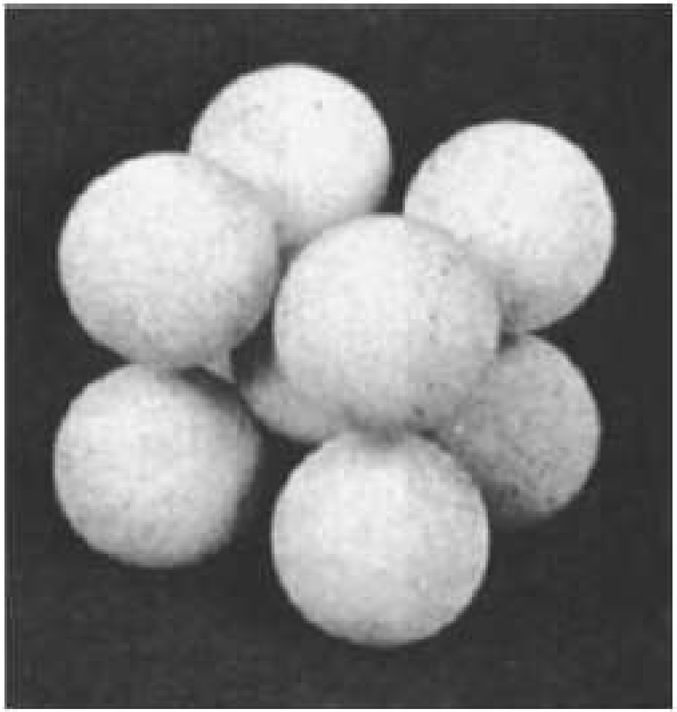


FIG. 1.2 (A) Face-centered cubic unit cell. **(B)** Cut view of a unit cell

Estrutura CCC



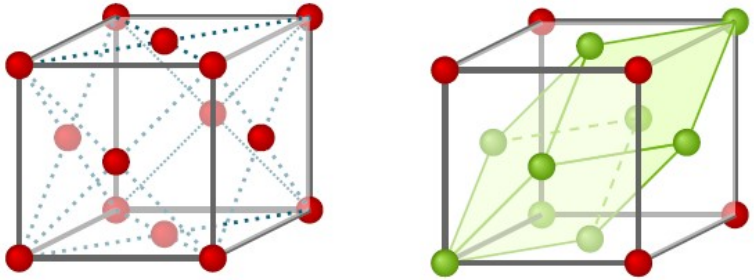


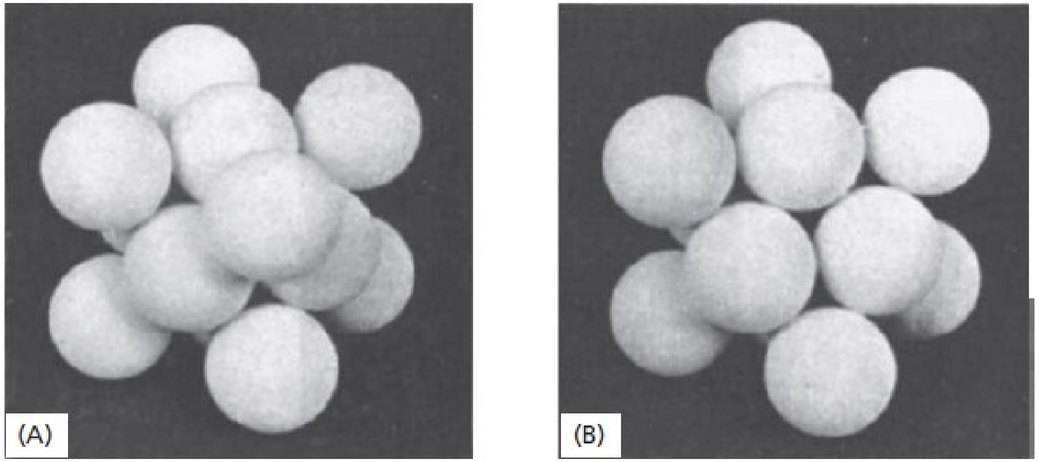
NC = ?
Átomos por célula unitária?
FE = ?
Direção mais compacta?
Plano mais compacto?

FIG. 1.3 Hard-ball model of the body-centered cubic unit cell

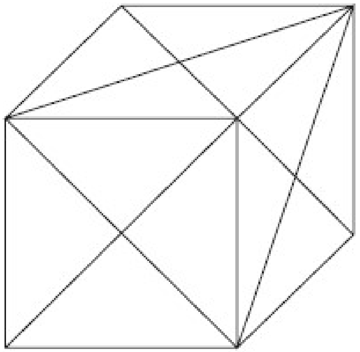
Estrutura CFC

primitiva





NC = ?
Átomos por célula unitária?
FE = ?
Direção mais compacta?
Plano mais compacto?



(C)

FIG. 1.4 **(A)** Face-centered cubic unit cell (hard-ball model). **(B)** Same cell with a corner atom removed to show an octahedral plane. **(C)** The six-face diagonal directions

Plano compacto no CFC

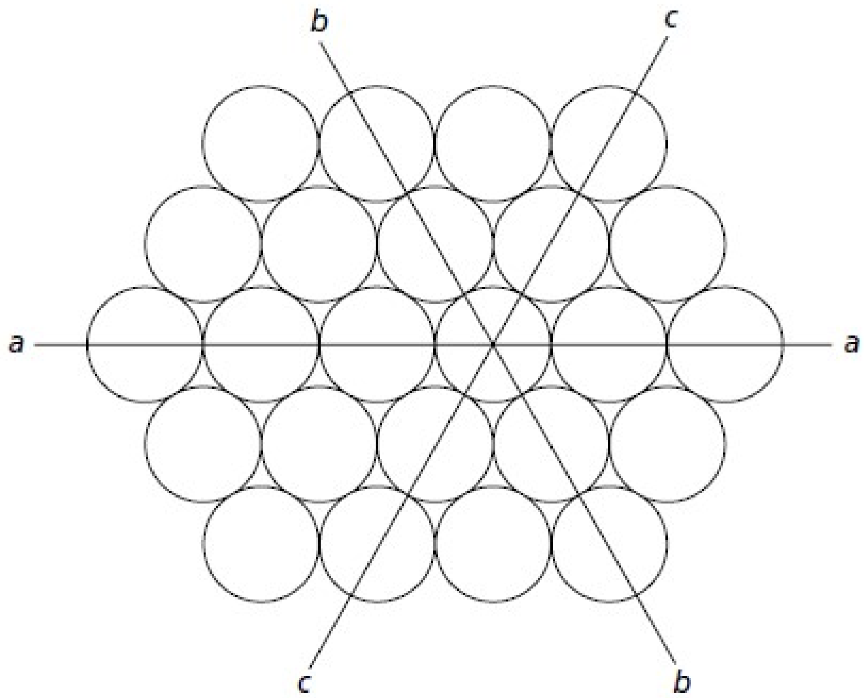
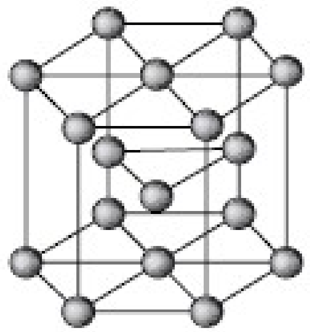


FIG. 1.5 Atomic arrangement in the octahedral plane of a face-centered cubic metal. Notice that the atoms have the closest possible packing. This same configuration of atoms is also observed in the basal plane of close-packed hexagonal crystals. The close-packed directions are *aa, bb,* and *cc*

Estrutura Hexagonal Compacta (HCP)



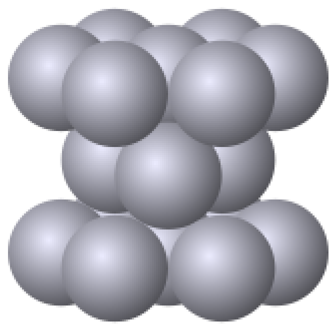
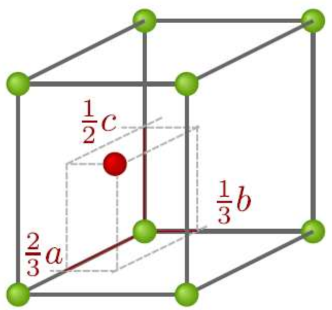
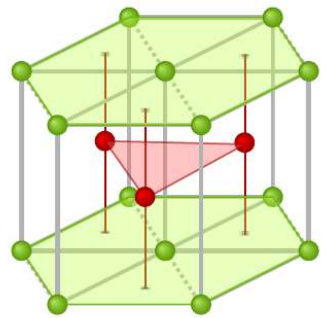


FIG. 1.6 The close-packed hexagonal unit cell

primitiva





NC = ?

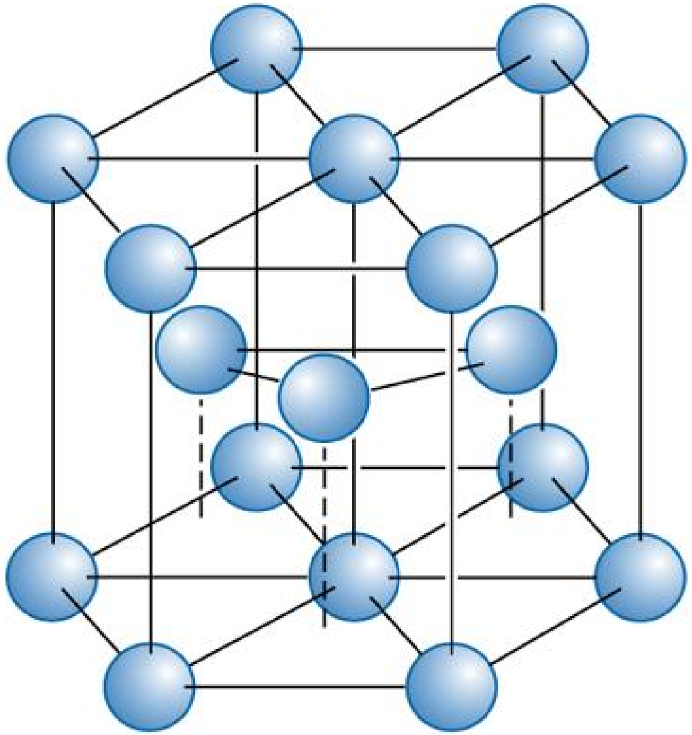
Átomos por célula unitária?

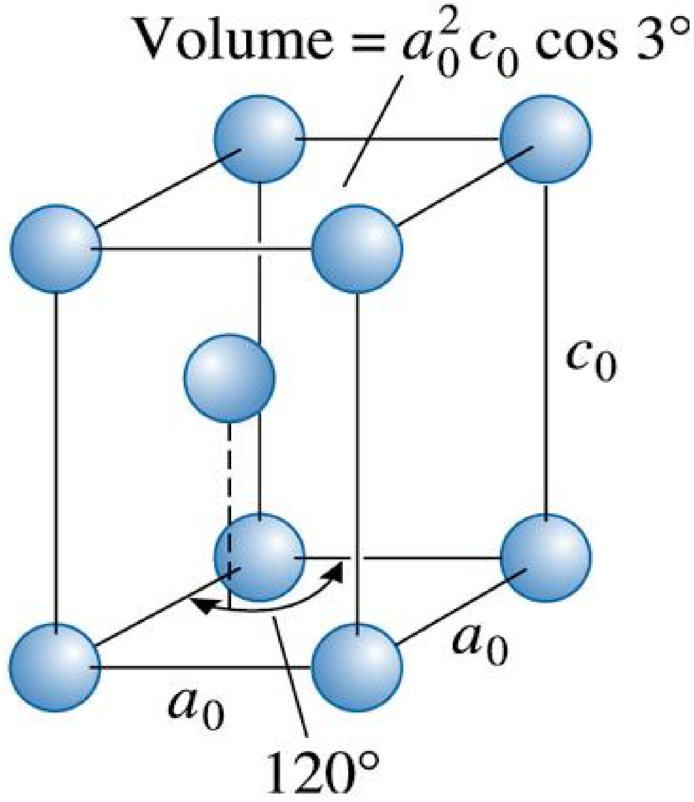
FE = ?

Direção mais compacta?

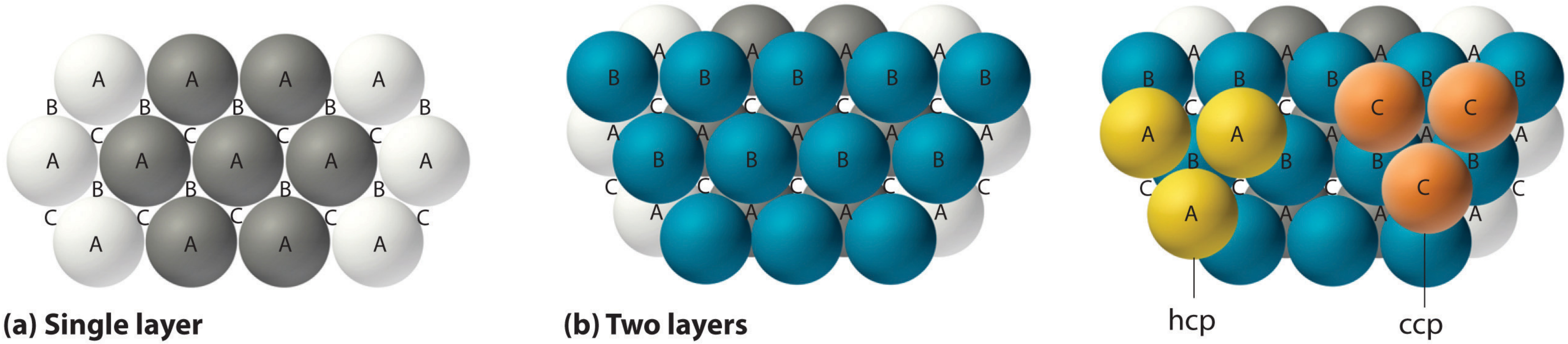
Plano mais compacto?

Estrutura hexagonal compacta (HCP)

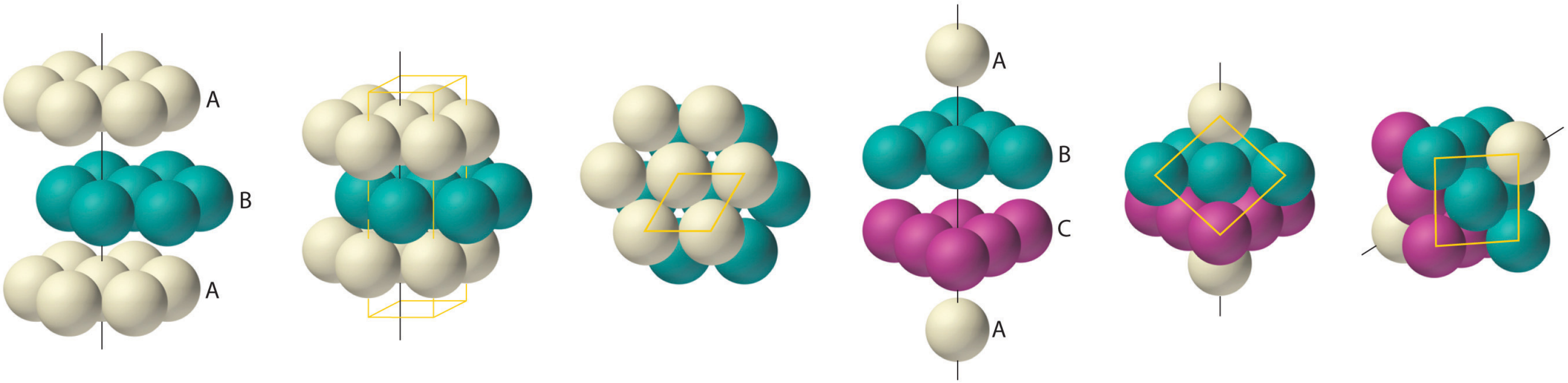




CFC x HCP

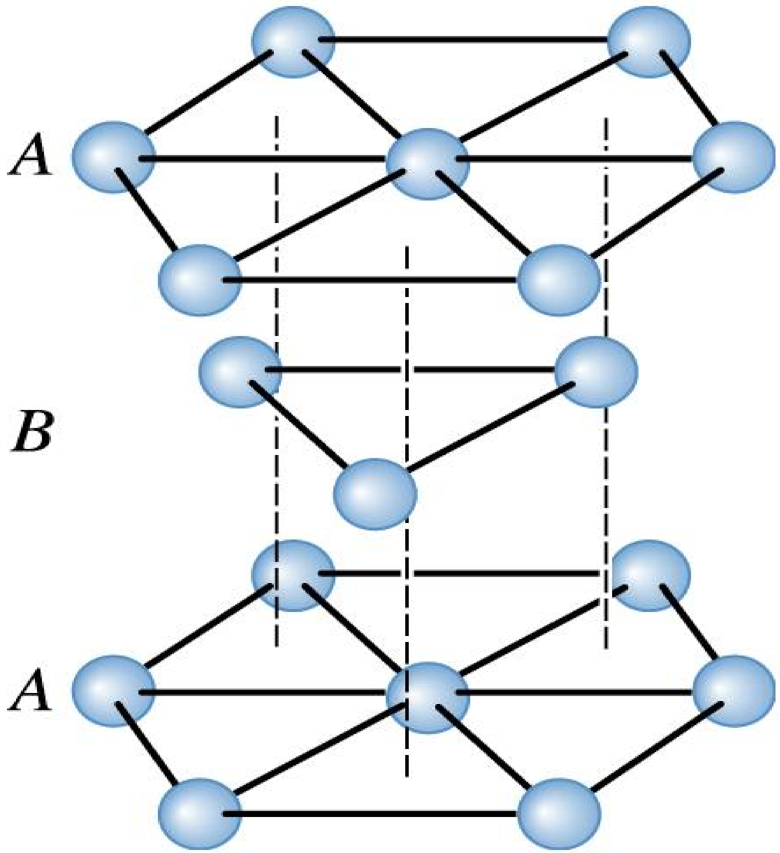


(a) Single layer (b) Two layers (c) Three layers

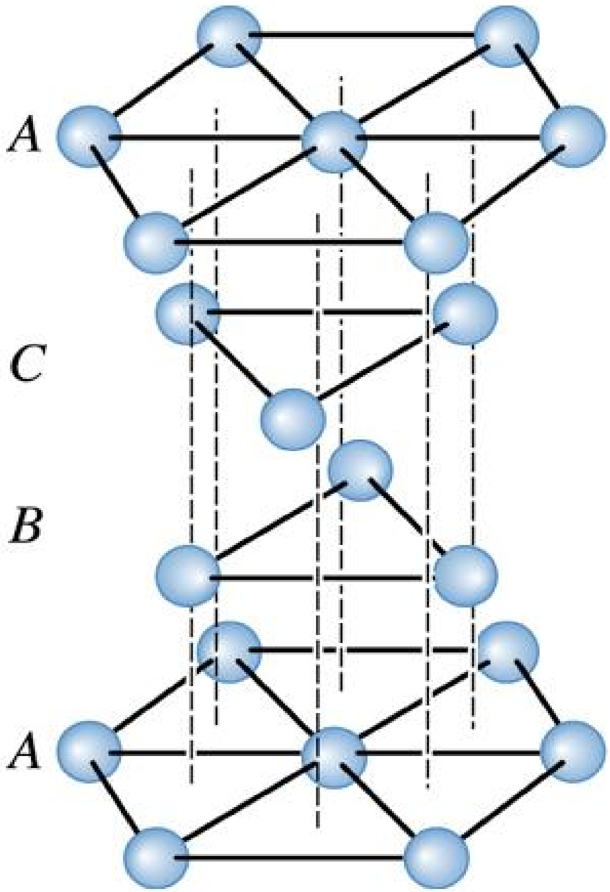


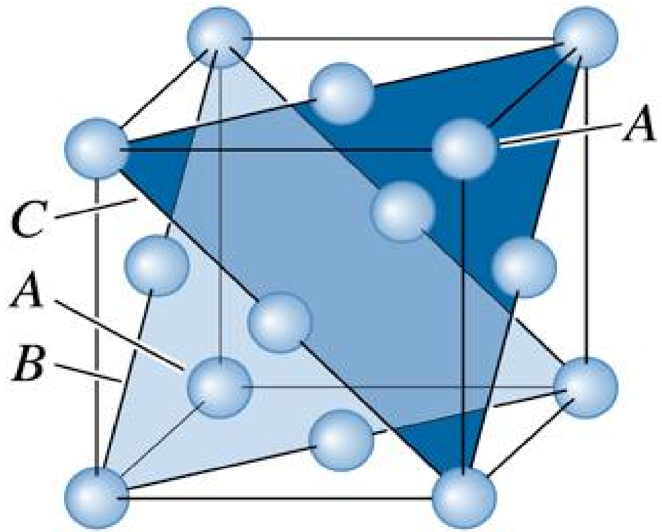
(a) Hexagonal close-packed (hcp) (b) Cubic close-packed (ccp)

HCP: empilhamento de planos compactos



CFC: empilhamento de planos compactos





Anisotropia

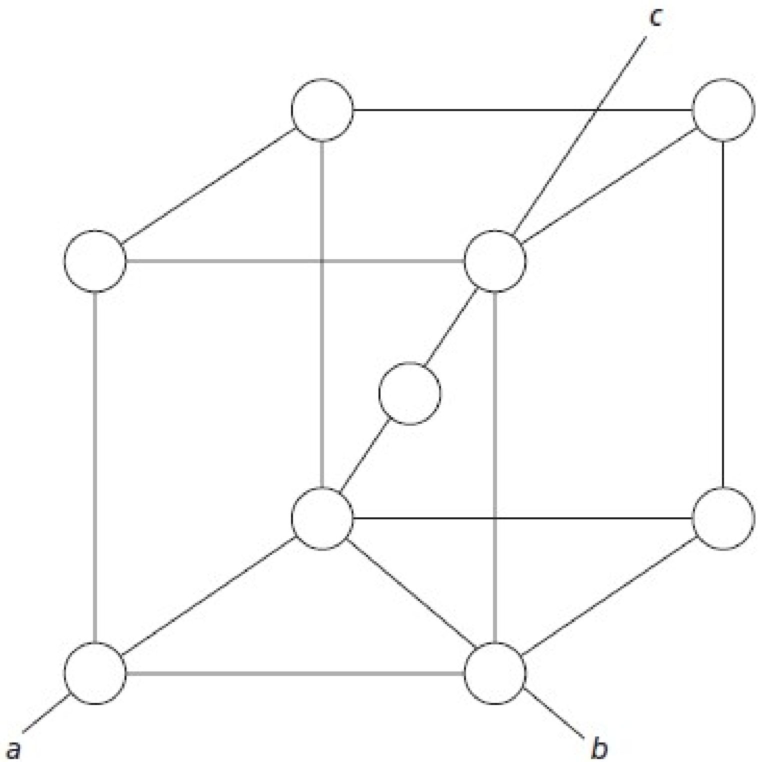


FIG. 1.8 The most important directions in a body-centered cubic crystal

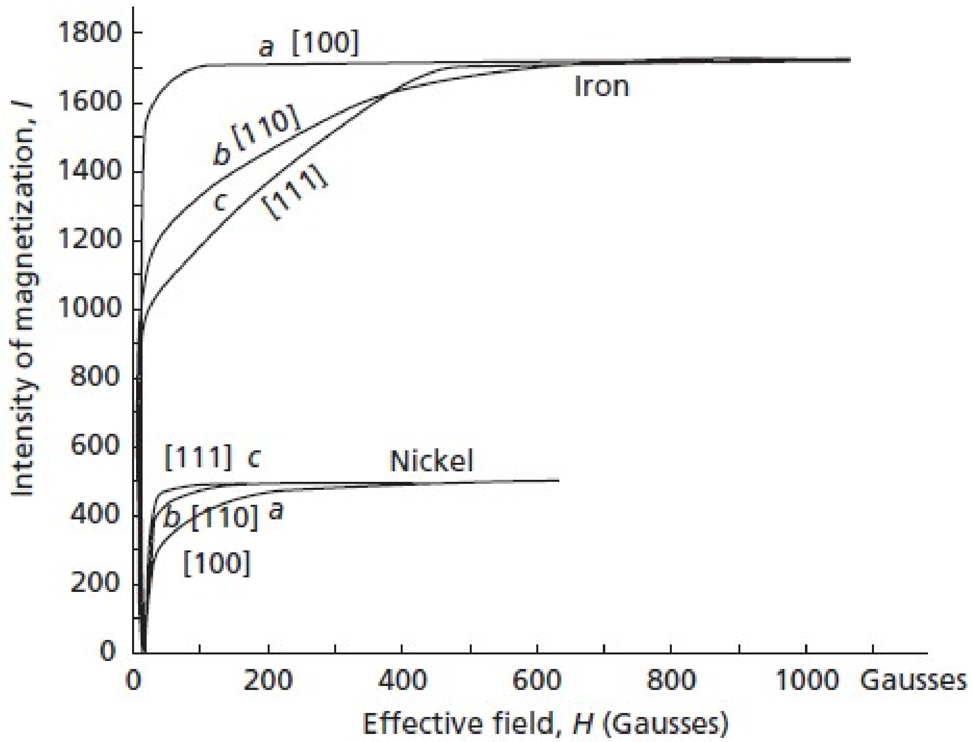


FIG. 1.9 An iron crystal is much easier to magnetize along an *a* direction of Fig. 1.8 than along a *b* or *c* direction. The opposite is the case for nickel[2,3]

Textura

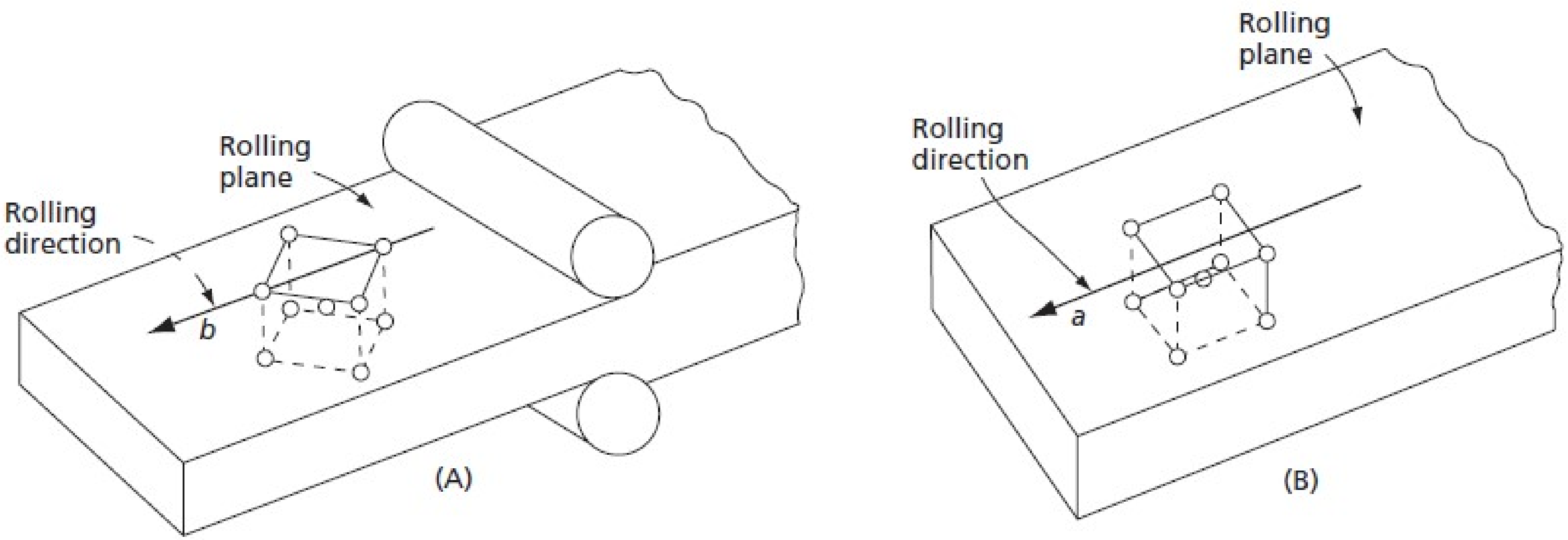
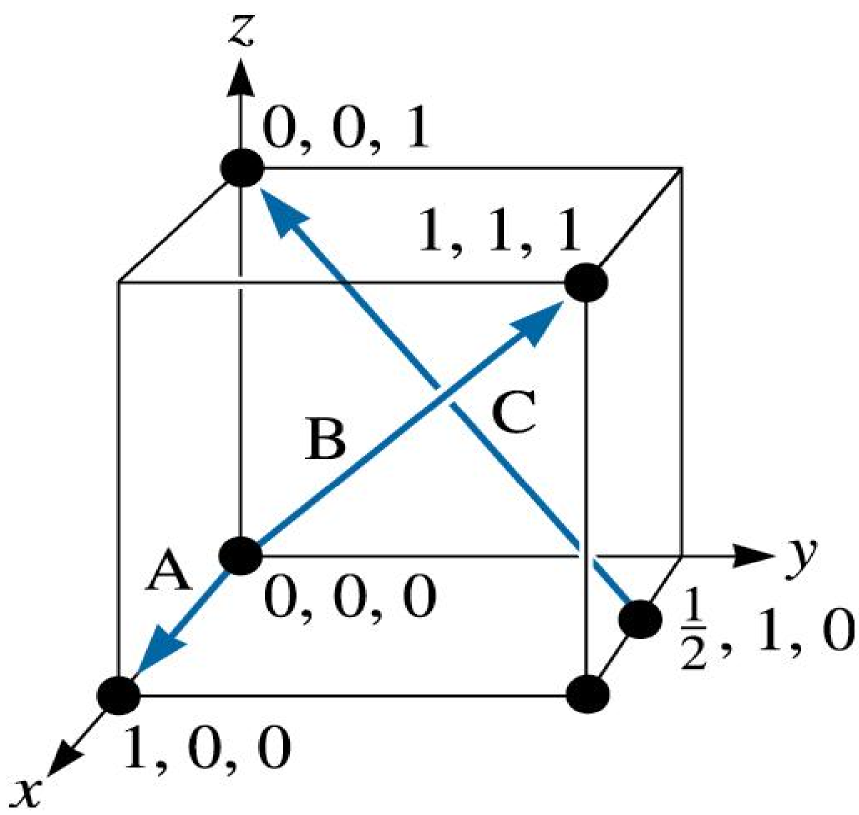


FIG. 1.10 Two basic crystalline orientations that can be obtained in rolled plates of body-centered cubic metals

Índices de Miller: Direções



Notação empregada:
Índices de Miller
[hkl] e <hkl>

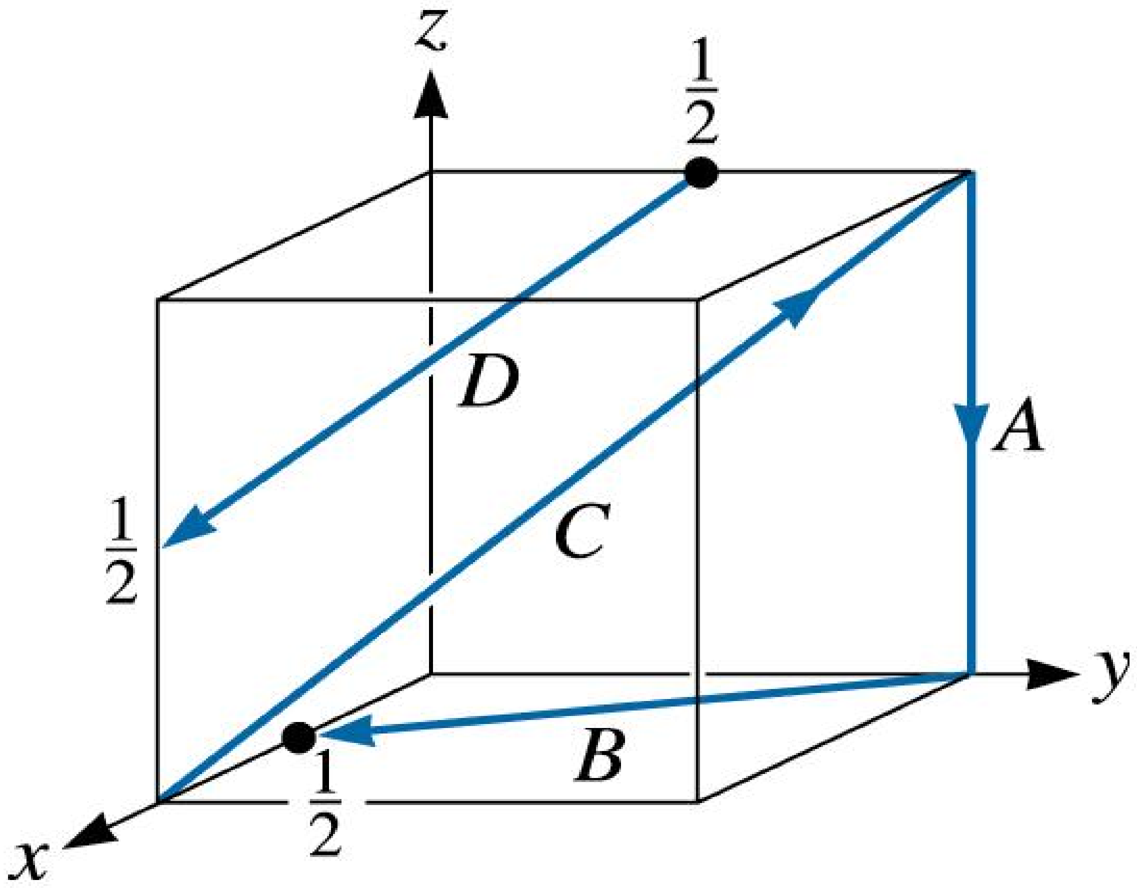


Figure 3.48 Directions in a cubic unit cell for Problem 3.51

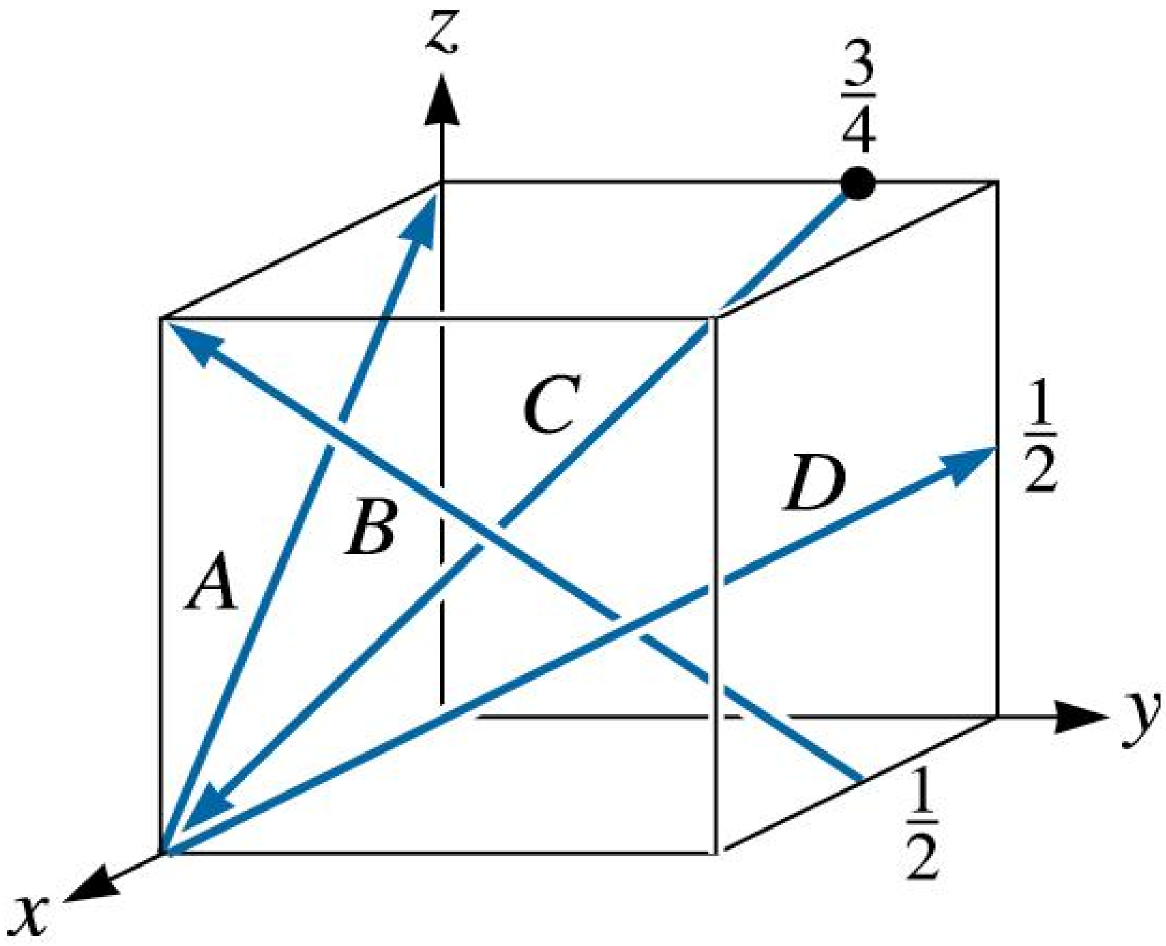
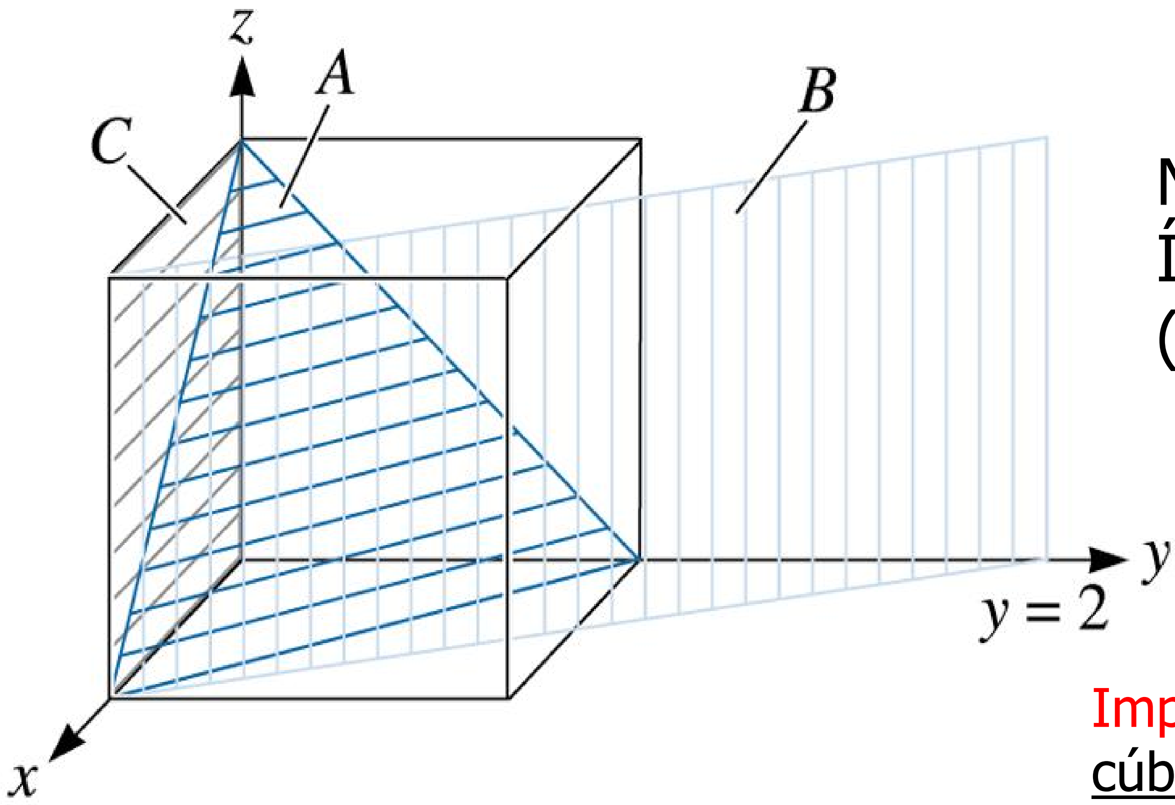


Figure 3.49 Directions in a cubic unit cell for Problem 3.52.

Índices de Miller: Planos



Notação empregada:
Índices de Miller
(hkl) e {hkl}

Exemplos: CCC e CFC

Importante: no sistema cúbico as direções [hkl] são perpendiculares aos planos (hkl)

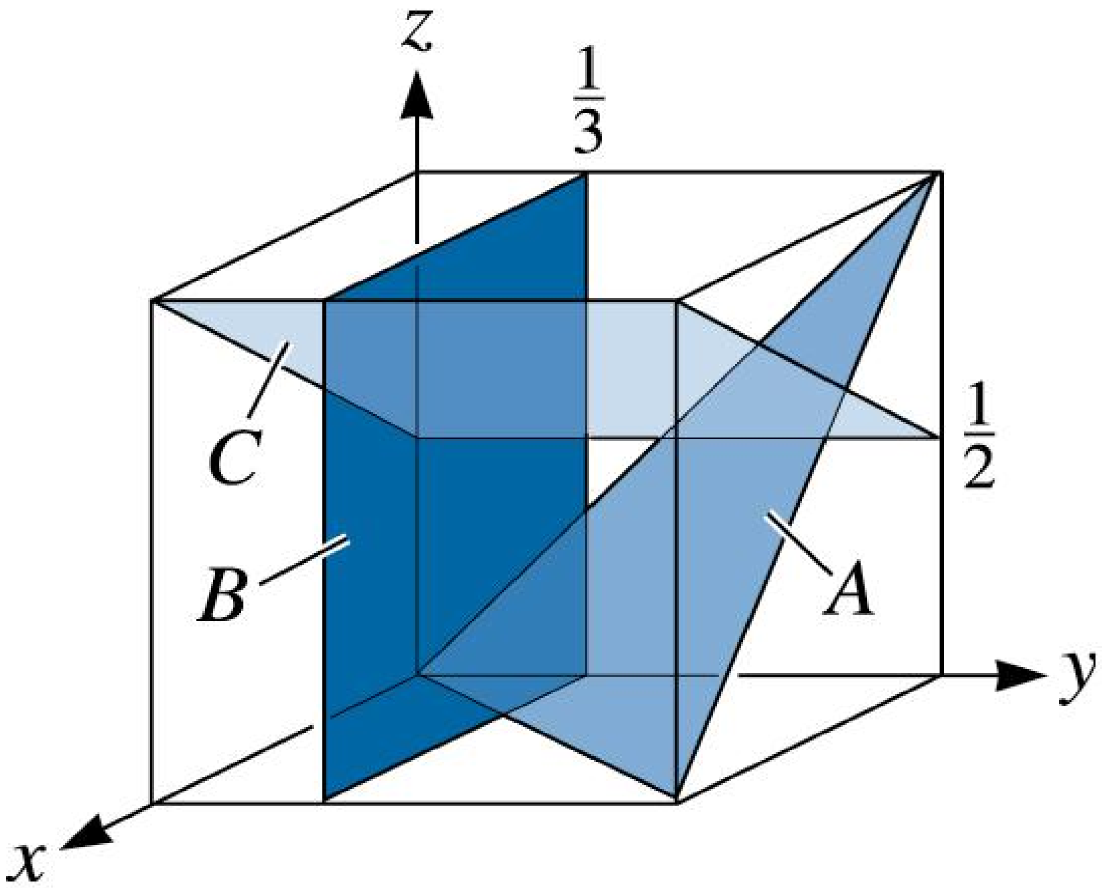


Figure 3.50 Planes in a cubic unit cell for Problem 3.53.

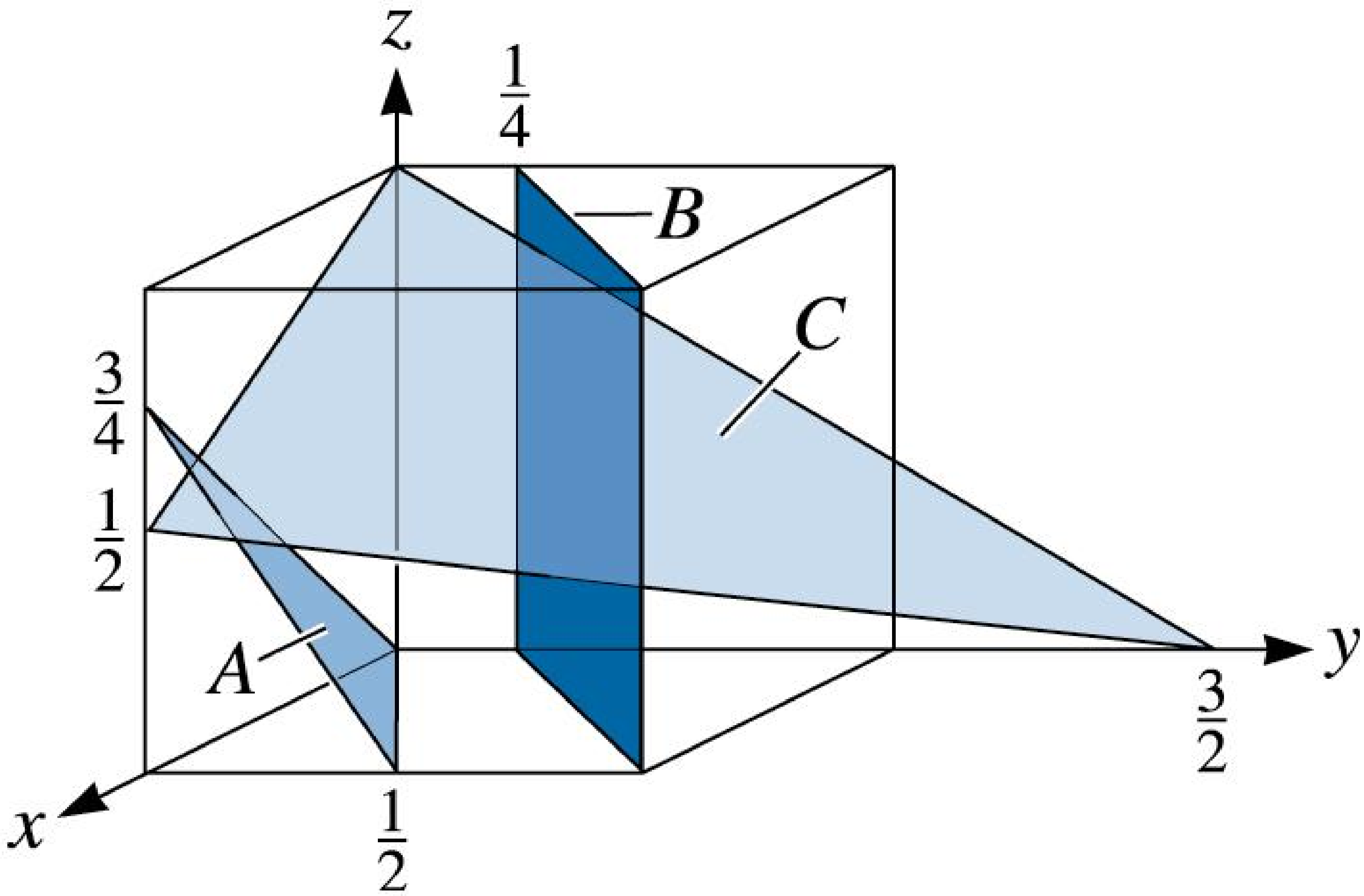
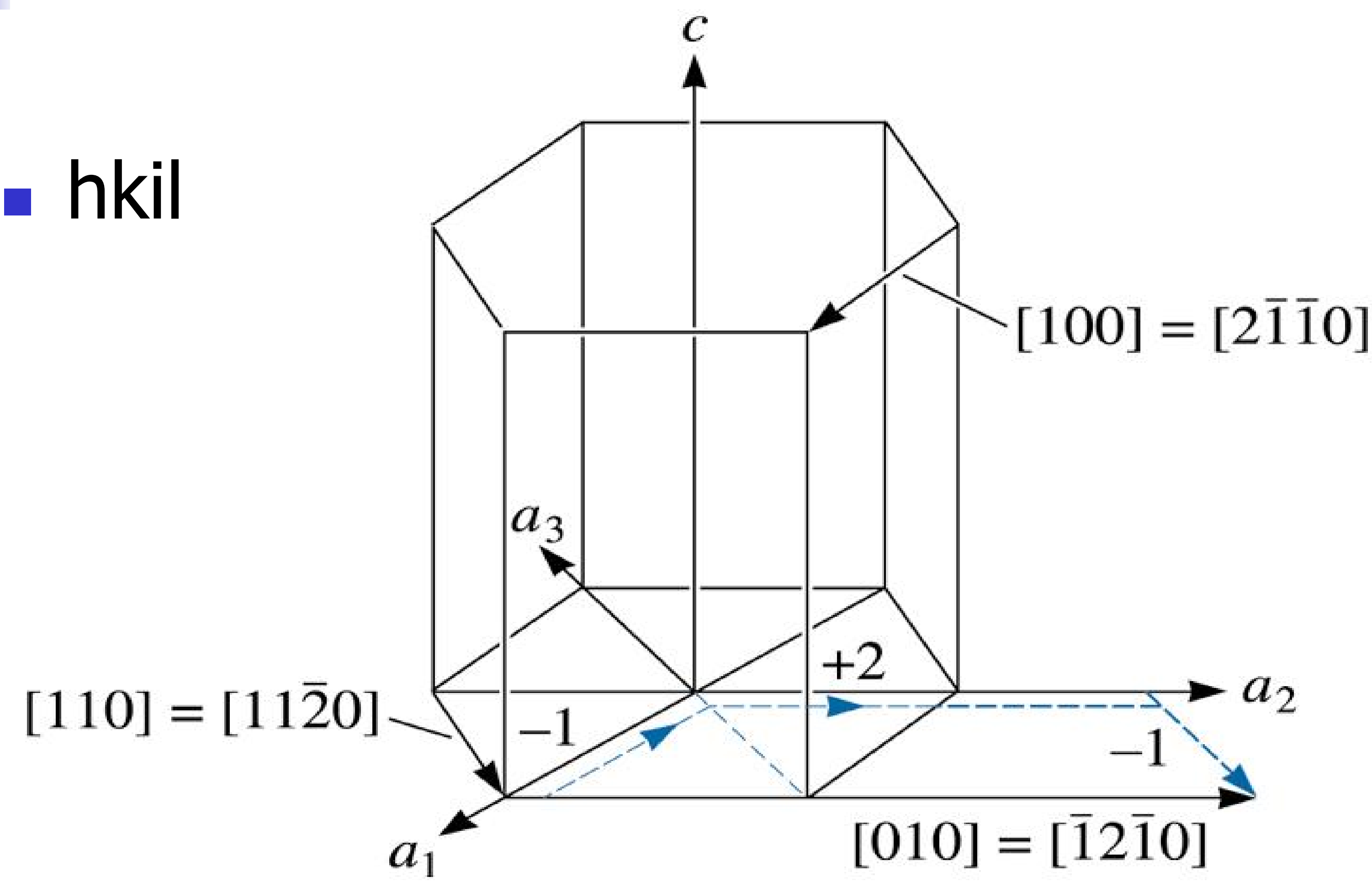


Figure 3.51 Planes in a cubic unit cell for Problem 3.54.

Índices de Miller-Bravais
Sistema hexagonal

- hkil



Índices no sistema hexagonal

- Por que usar a notação de Miller-Bravais de 4 índices?
  - Planos equivalentes possuem índices similares
  - As direções [hkil] são perpendiculares aos planos (hkil), de maneira similar ao que acontece no sistema cúbico.

Conversões de índices

- Miller-Bravais para Miller
  - Direções: [uvtw] para [u’v’w’]
    - u’=u-t, v’=v-t e w’=w
  - Planos: (hkil) para (h’k’l’)
    - h’=h, k’=k e l’=l
- Miller para Miller-Bravais
  - Direções: [uvw] para [u’v’t’w’]
    - u’=(2u-v)/3, v’=(2v-u)/3, t’=-(u+v)/3=-(u’+v’) e w’=w
  - Planos: (hkl) para (h’k’i’l’)
    - h’=h, k’=k, i’=-(h+k) e l’=l

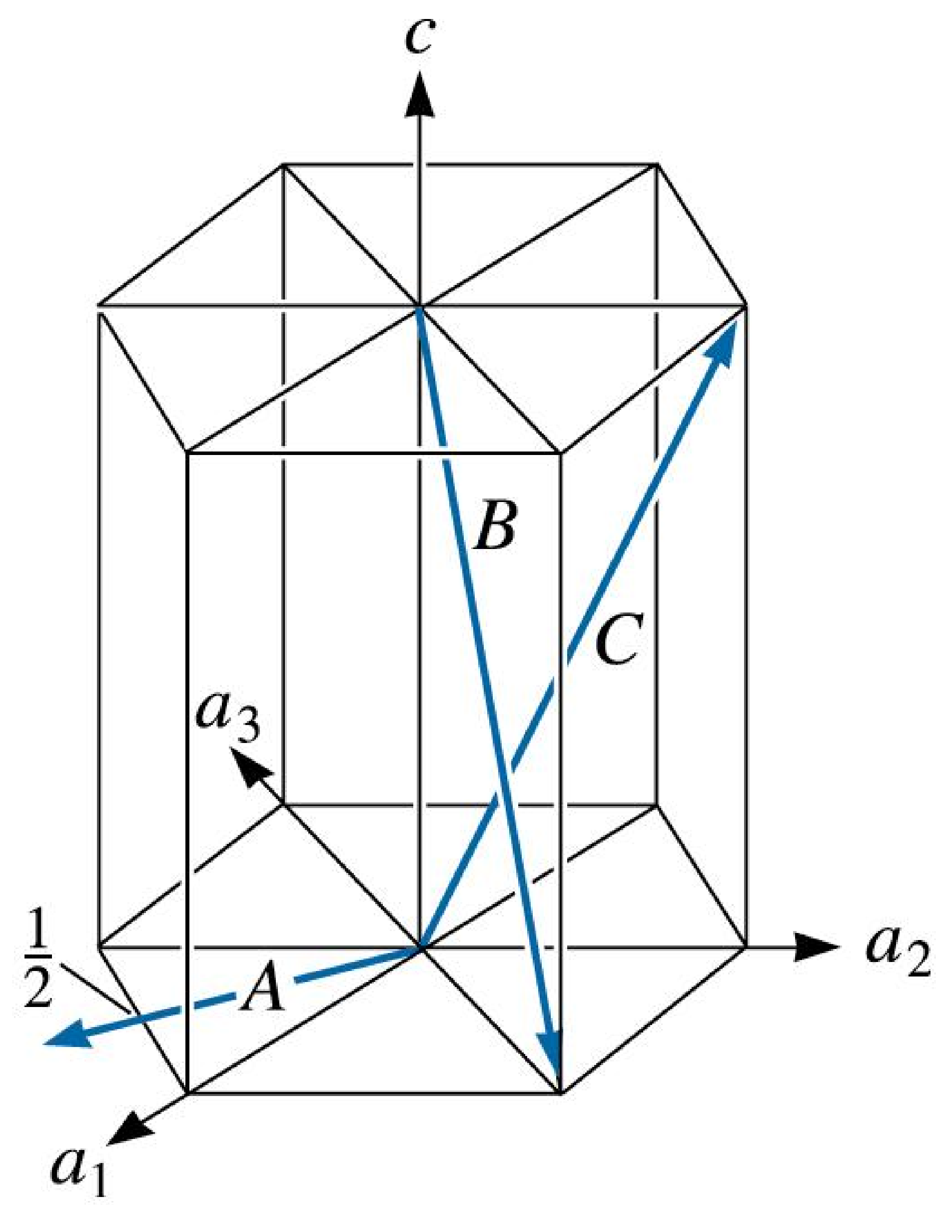


Figure 3.52 Directions in a hexagonal lattice for Problem 3.55.

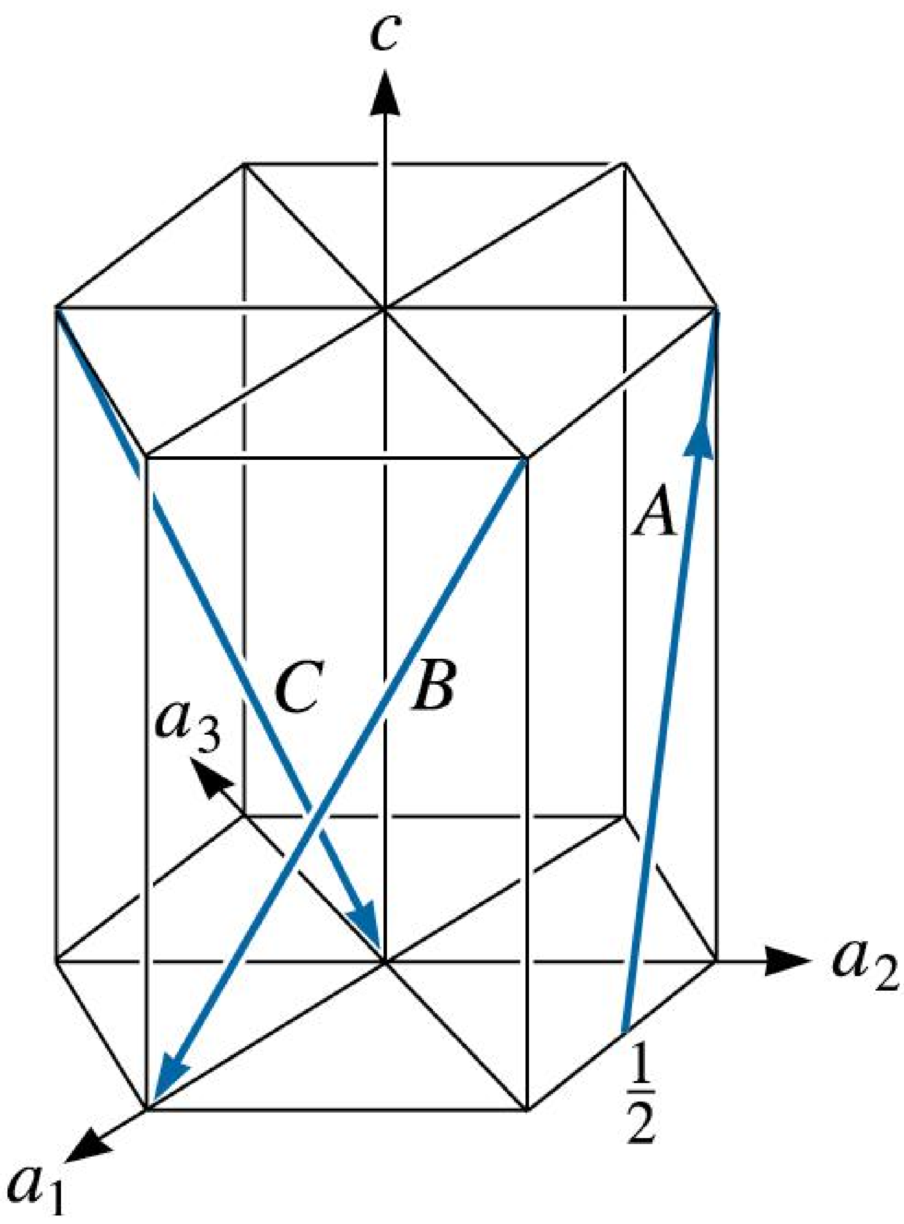
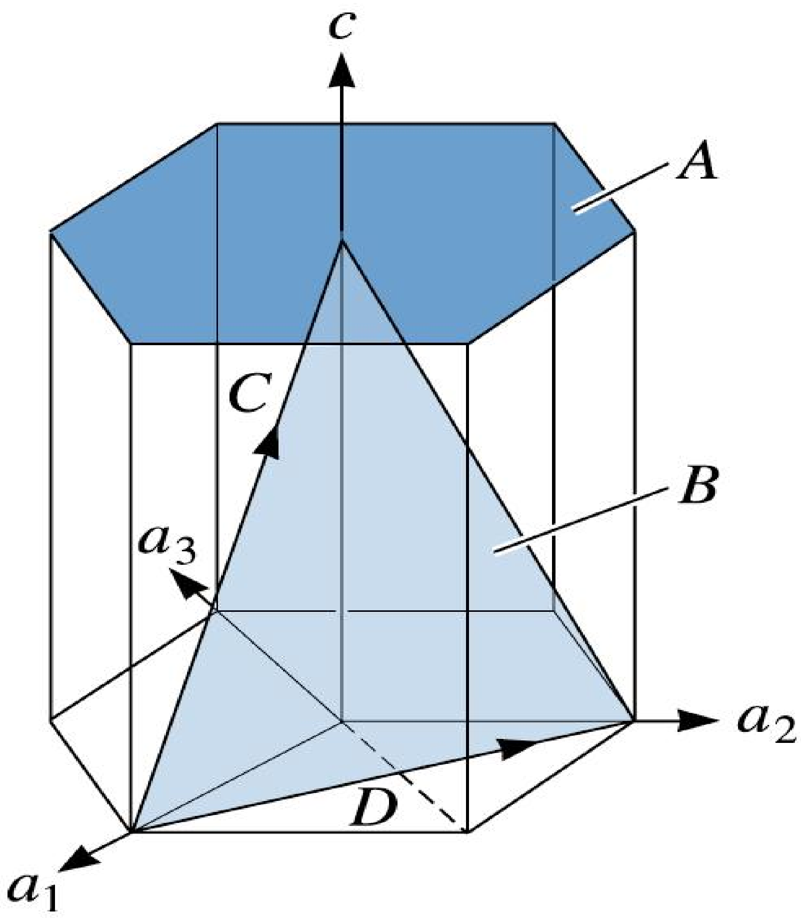


Figure 3.53 Directions in a hexagonal lattice for Problem 3.56.

Planos (sist. Hexagonal)



Exemplos

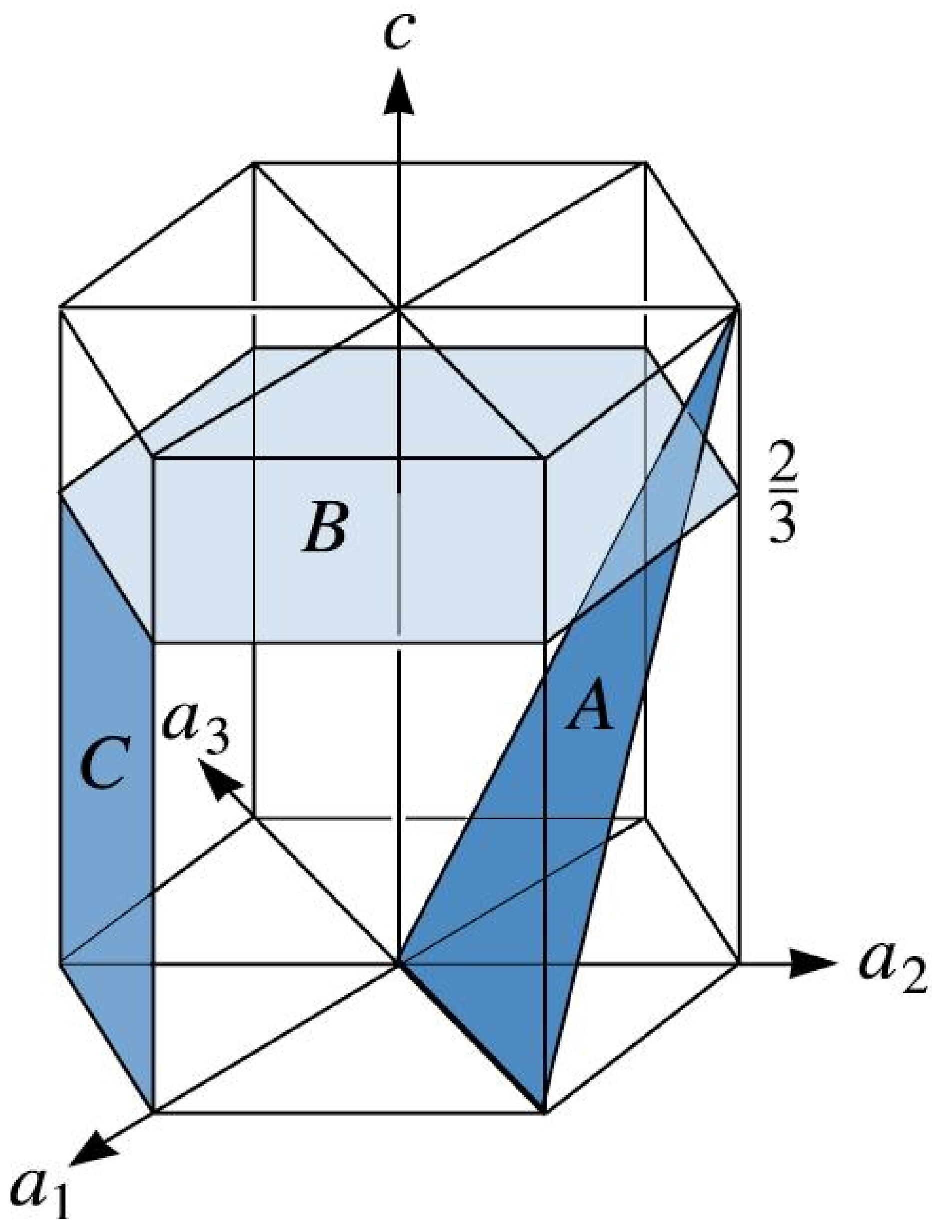


Figure 3.54 Planes in a hexagonal lattice for Problem 3.57.

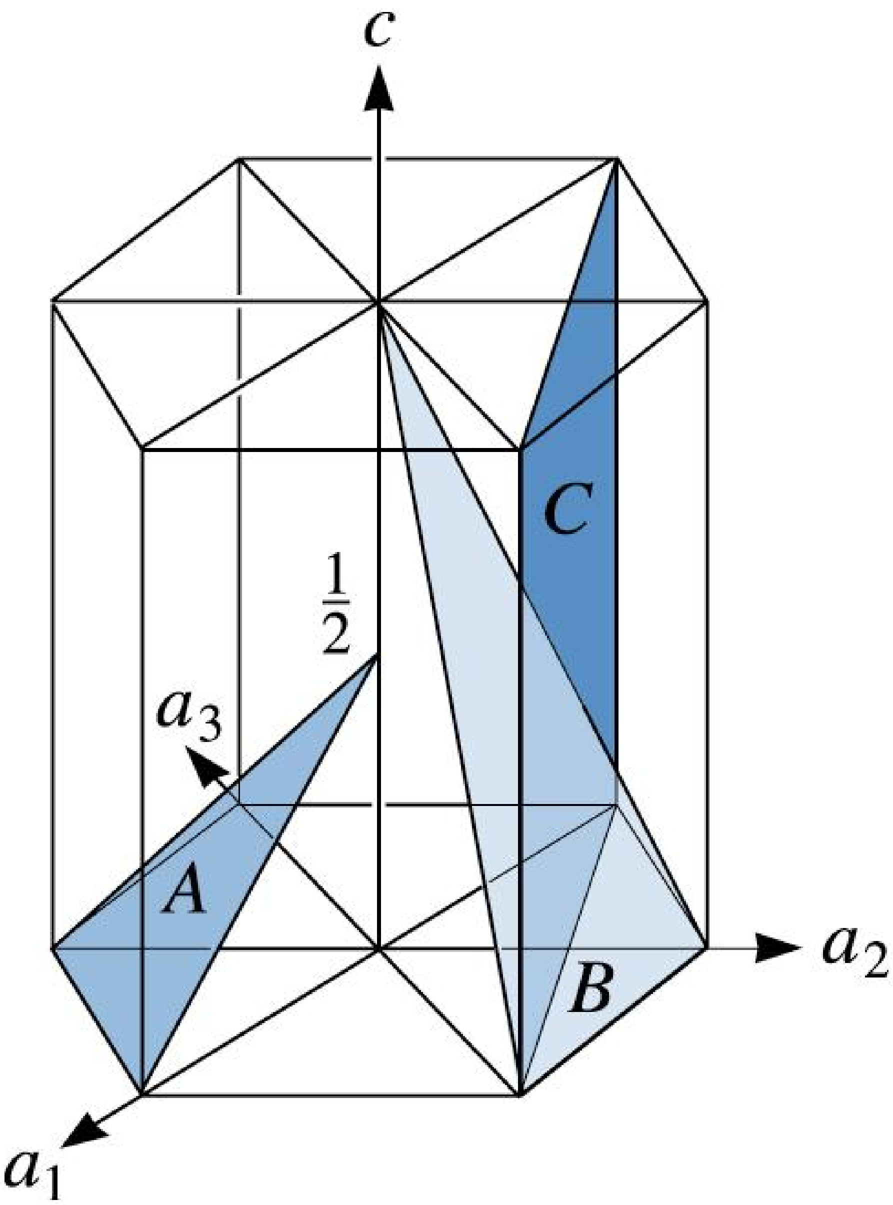
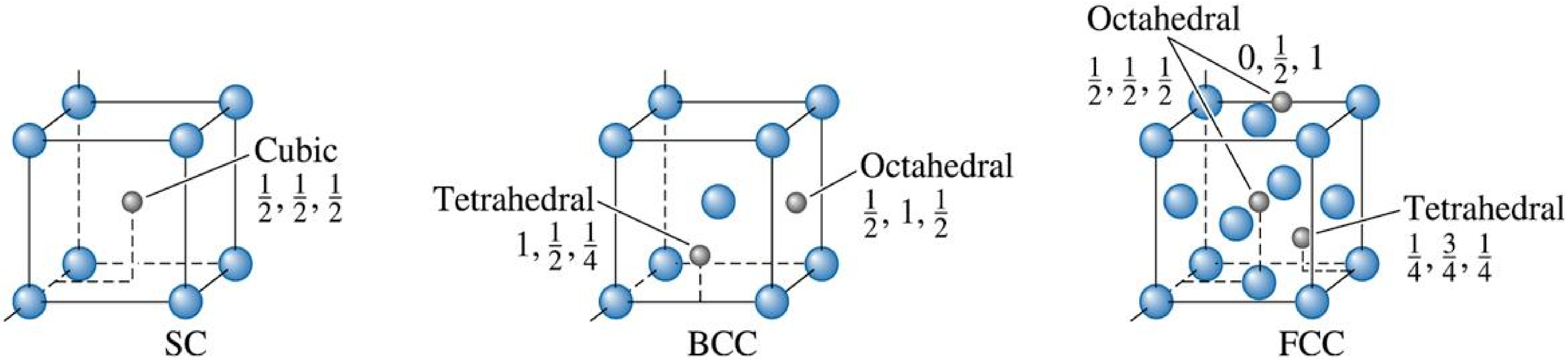
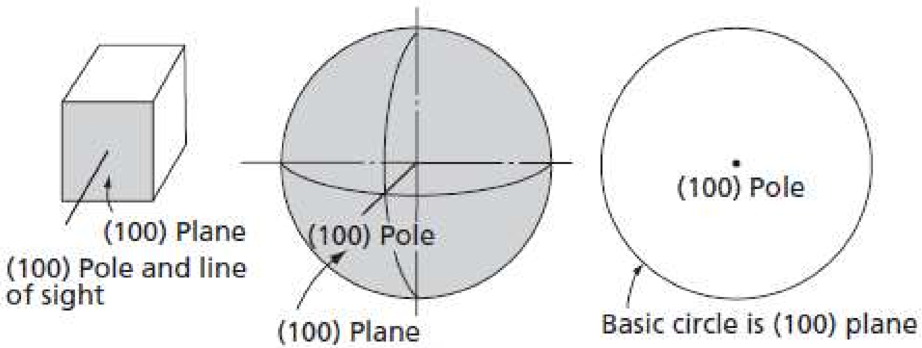


Figure 3.55 Planes in a hexagonal lattice for Problem 3.58.

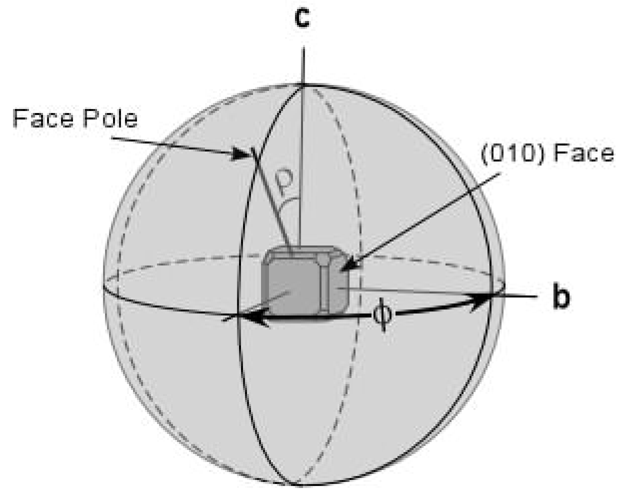
Interstícios

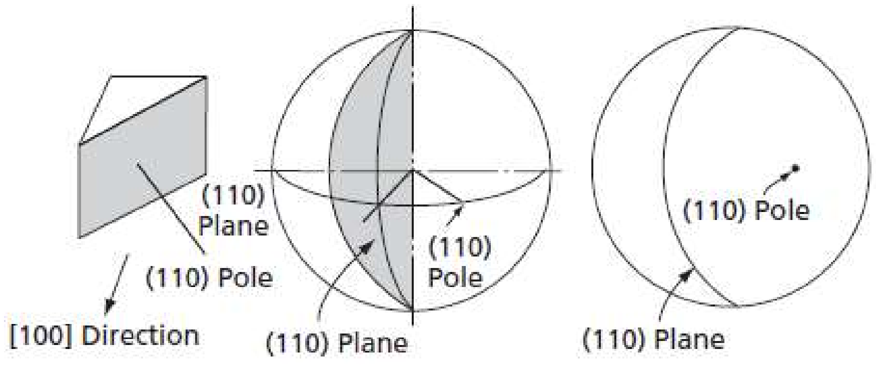


Projeção estereográfica

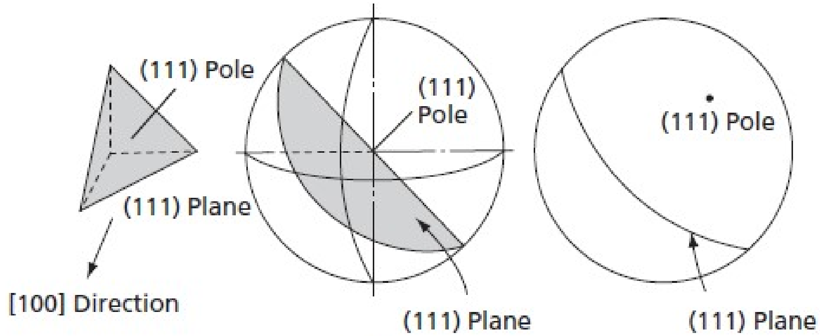


(A)





(B)



(C)

Eixo de zona

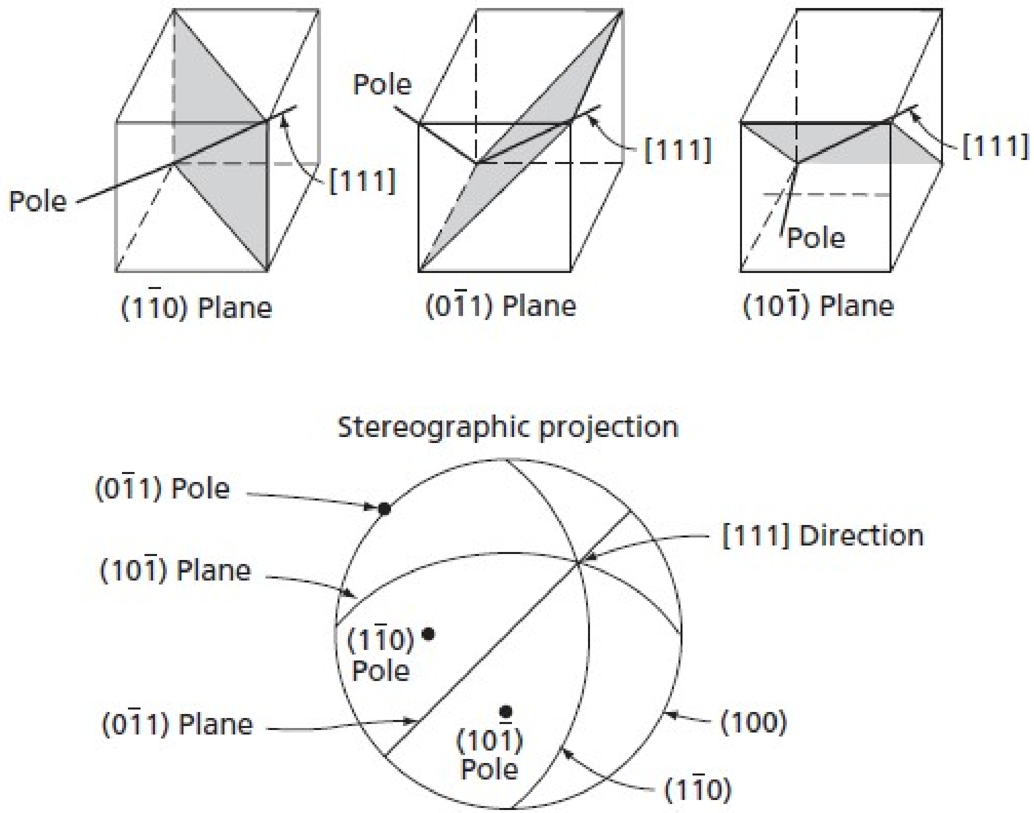


FIG. 1.23 Cubic system, zone of planes the zone axis of which is the [111] direction. The three {110} planes that belong to this zone are illustrated in the figures

Eixo de zona

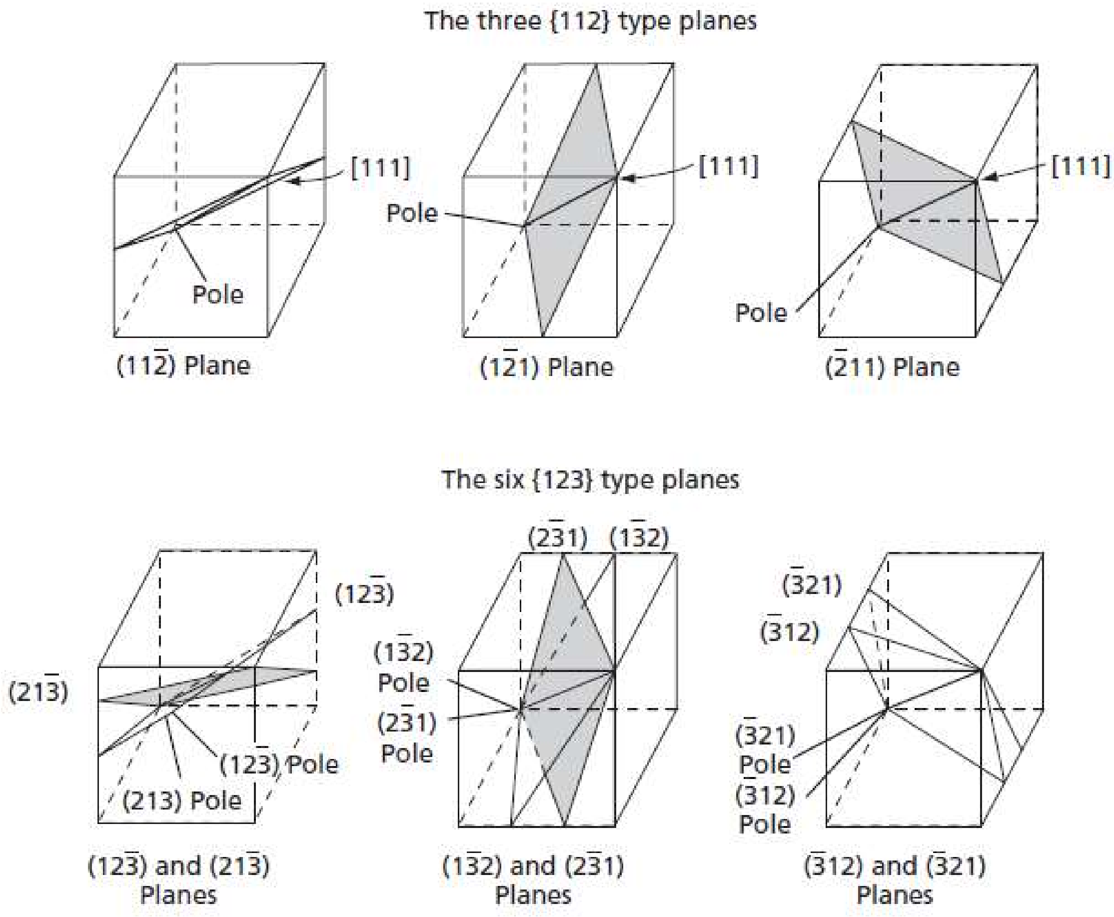


FIG. 1.24 The {112} and {123} planes that have [111] as their zone axis

Eixo de zona

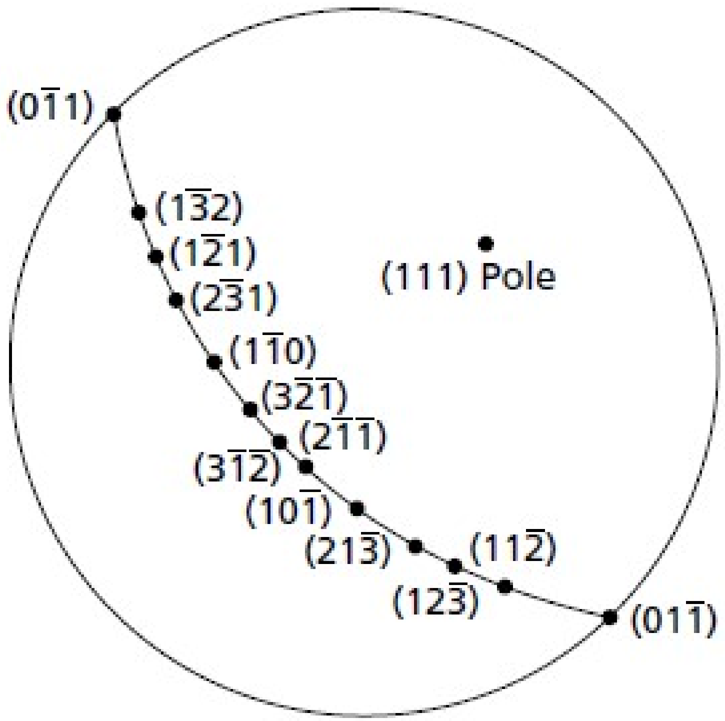


FIG. 1.25 Stereographic projection of the zone containing the 12 planes shown in Figs. 1.23 and 1.24. Only the poles of the planes are plotted. Notice that all of the planar poles lie in the (111) plane

Rede de Wulff

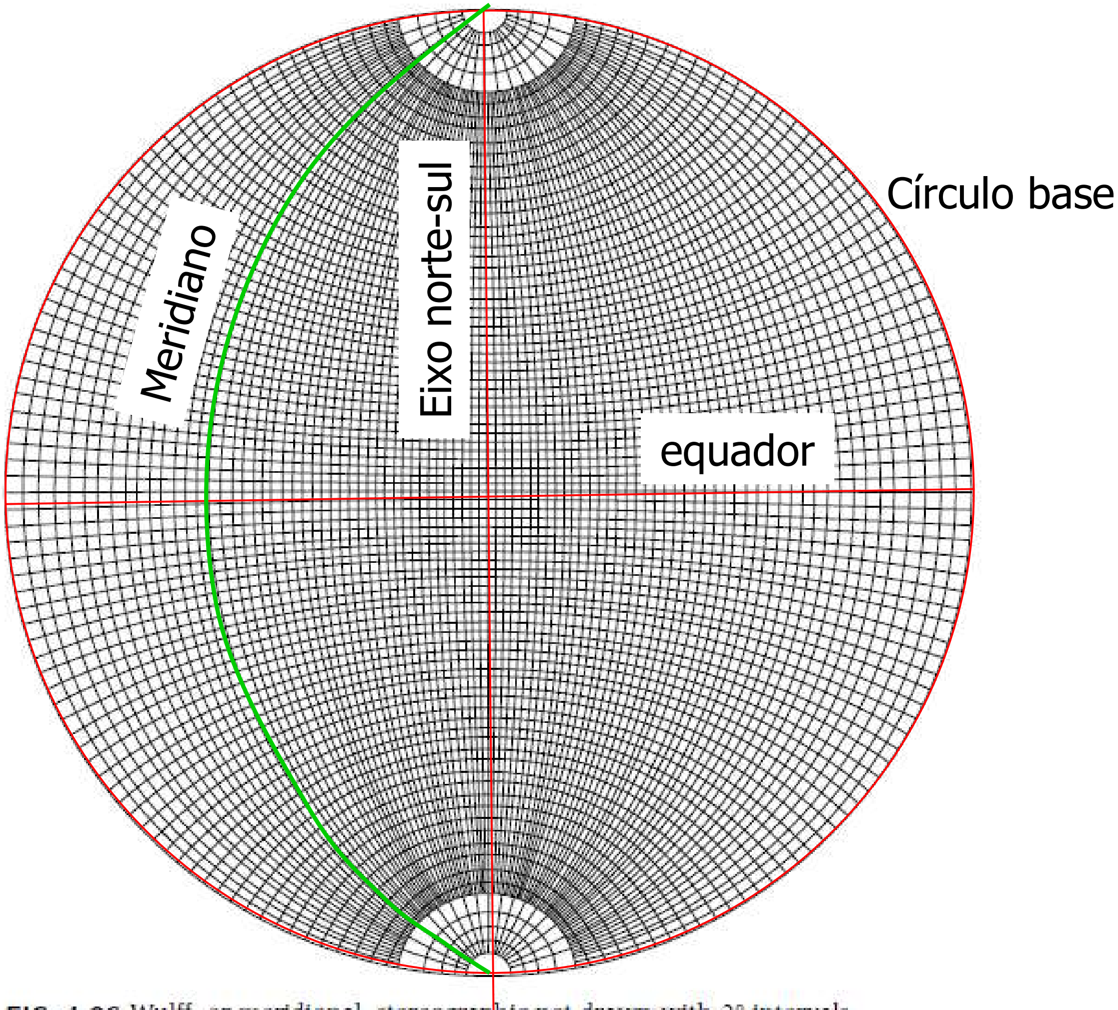


FIG. 1.26 Wulff, or meridional, stereographic net drawn with 2° intervals

Rotação em torno do centro

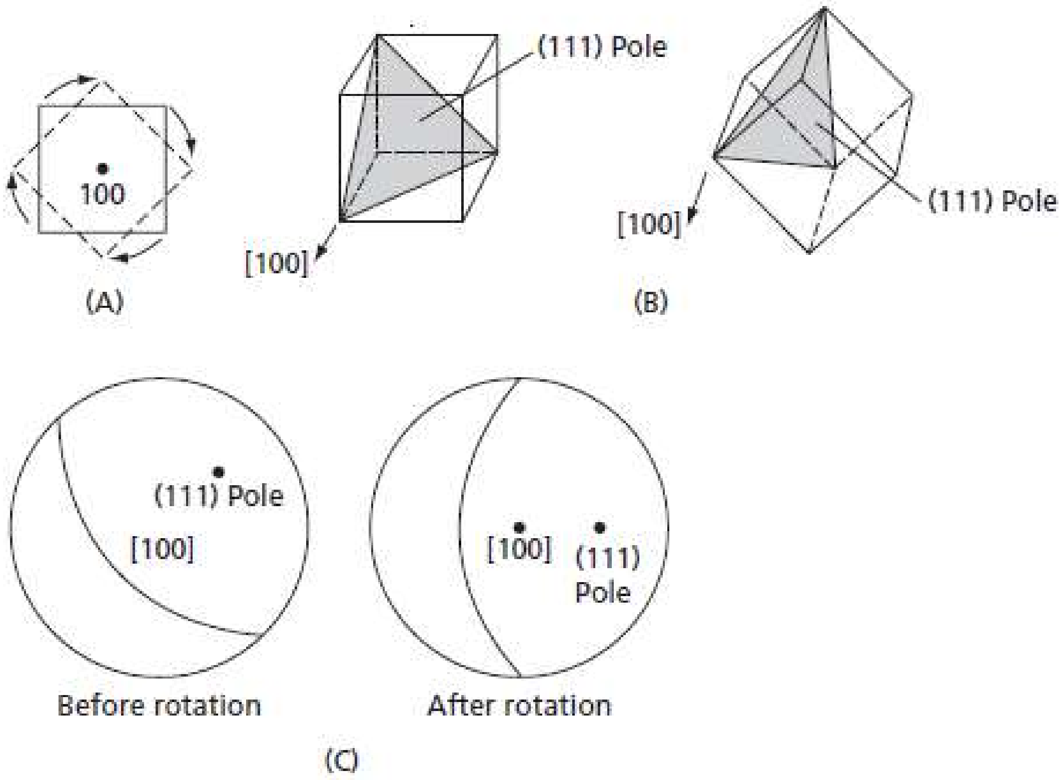


FIG. 1.27 Rotation about the center of the Wulff net. **(A)** The effect of the desired rotation on the cubic unit cell. Line of sight [100]. **(B)** Perspective view of the (111) plane before and after the rotation. **(C)** Stereographic projection of the (111) plane and its pole before and after rotation. Rotation clockwise 45° about the [100] direction

Rotação em torno do eixo norte-sul

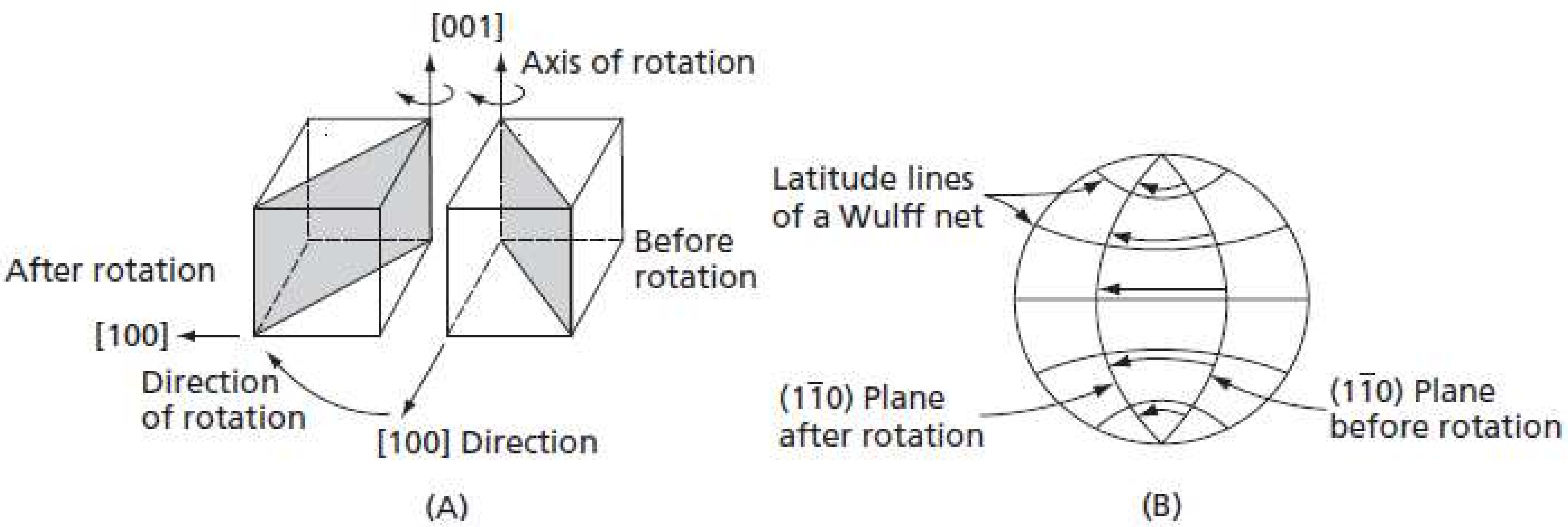


FIG. 1.28 Rotation about the north-south axis of the Wulff net. **(A)** Perspective views of the unit cell before and after the rotation showing the orientation of the (1$\bar{1}$0) plane. **(B)** Stereographic projection showing the preceding rotation. For the sake of clarity of presentation, only the (1$\bar{1}$0) plane is shown. The rotation of the pole is not shown. Also, the meridians of the Wulff net are omitted

Projeção padrão do sistema cúbico

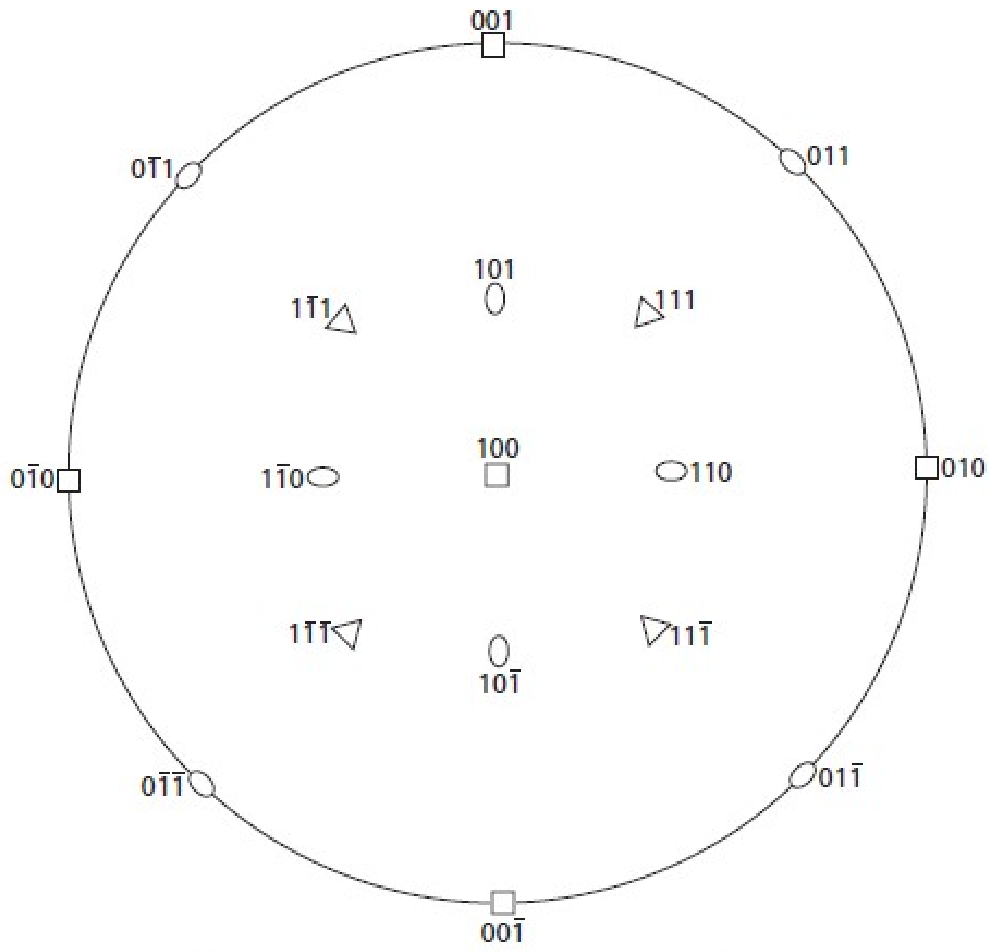


FIG. 1.30 A 100 standard stereographic projection of a cubic crystal

Projeção padrão do sistema cúbico

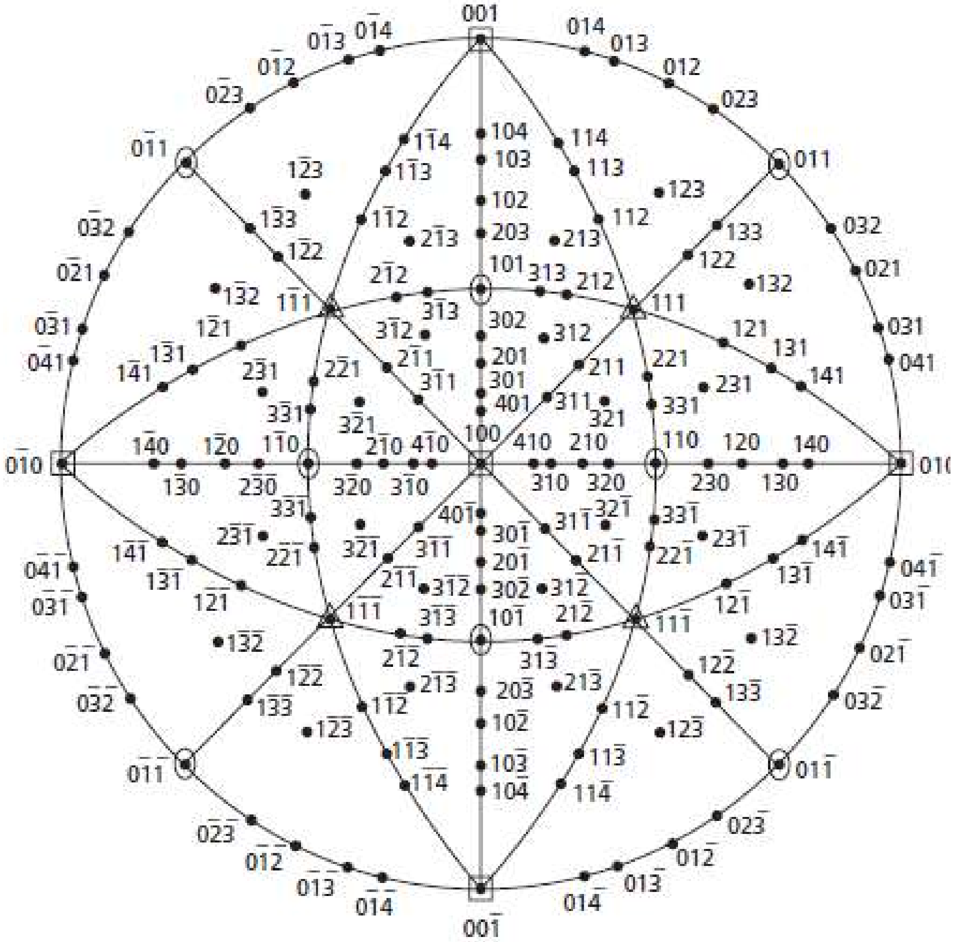


FIG. 1.31 A 100 standard stereographic projection of a cubic crystal showing additional poles

Projeção padrão do sistema cúbico

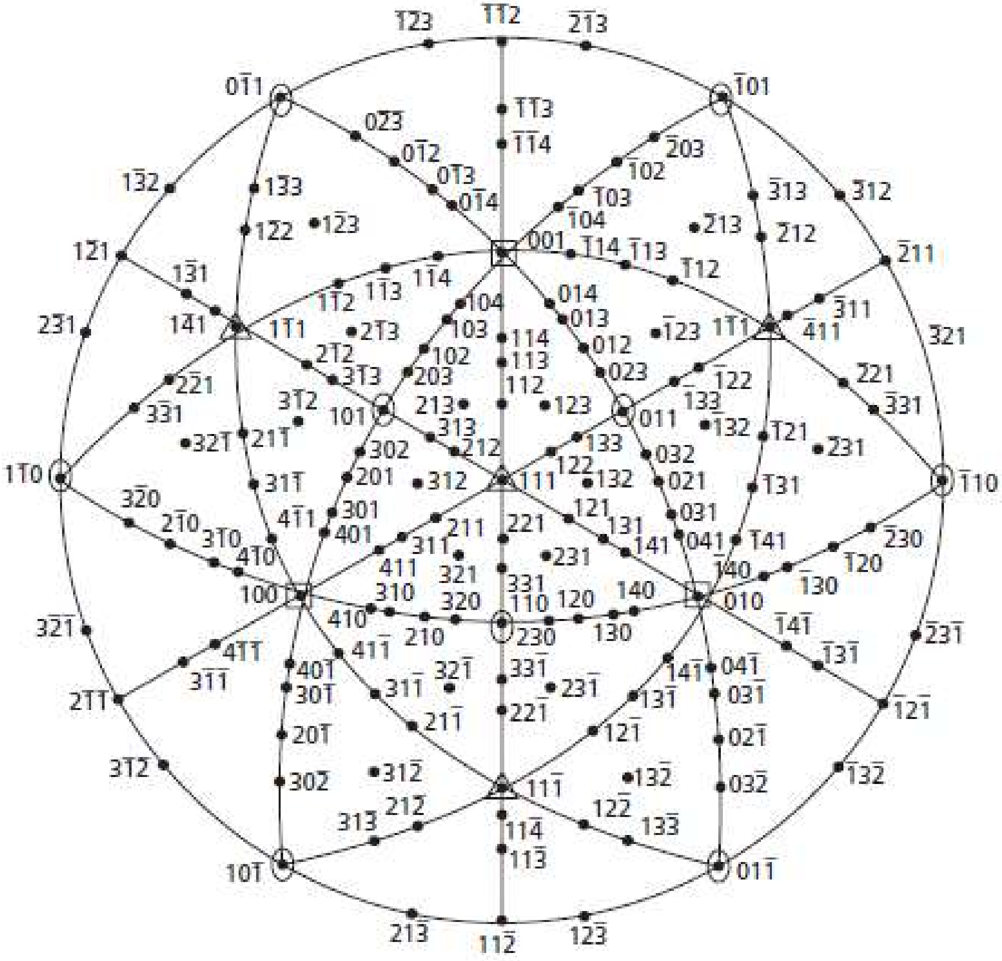


FIG. 1.32 A 111 standard projection of a cubic crystal

Projeção padrão do sistema cúbico

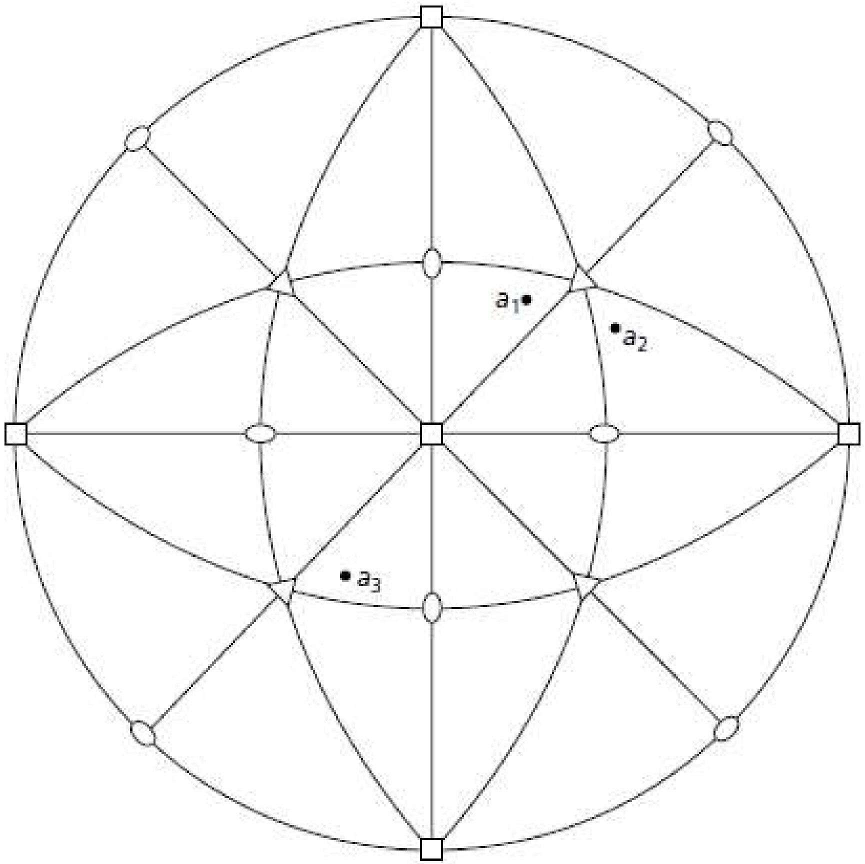


FIG. 1.33 The crystallographic directions a_1, a_2, and a_3 shown in this standard projection are equivalent because they lie in similar positions inside their respective standard stereographic triangles

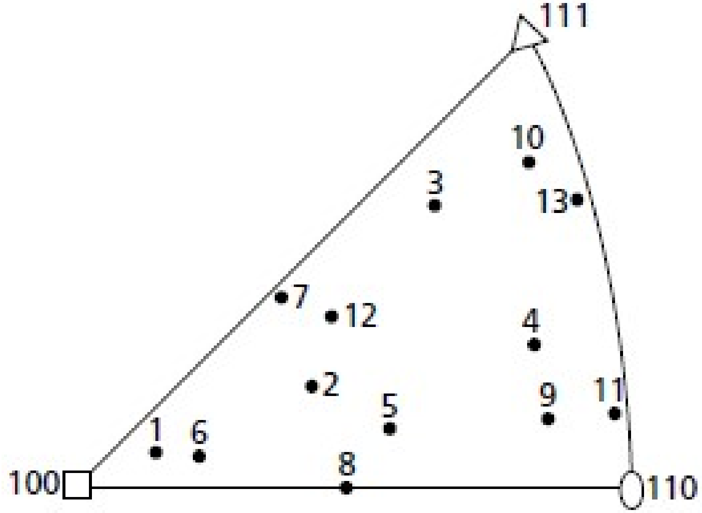


FIG. 1.34 When it is necessary to compare the orientations of a number of crystals, this often can be done conveniently by plotting the crystal axes in a single stereographic triangle, as indicated in this figure