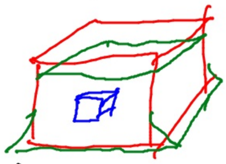
1. Solid State Physics – solids, bonding, cells, point lattice, basis

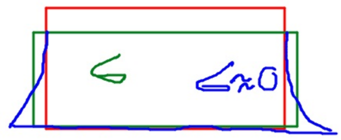
The branch of physics that deals with solids is called solid-state physics, and is the main branch of condensed matter physics (which also includes liquids). Materials science is primarily concerned with the physical and chemical properties of solids. Solid-state chemistry is especially concerned with the synthesis of novel materials, as well as the science of identification and chemical composition.

solid?

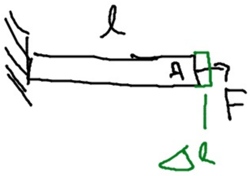


liquid?

pitch



Hook's laws



$F = k \Delta l$

$\frac{F}{A} = \frac{kl}{A} \frac{\Delta l}{l}$

stress σ — E — strain

$\varepsilon_e = \frac{\Delta l}{l}$

Young modulus

$\sigma = E \cdot \varepsilon_e$

$\frac{d\sigma}{dt} = E \frac{d\varepsilon_e}{dt}$

$\frac{1}{E}\frac{d\sigma}{dt} = \frac{d\varepsilon_e}{dt}$

Newtonian fluid

ε_v strain

$\frac{\Delta l}{l}$

$\frac{d\varepsilon_v}{dt} = \frac{1}{\mu}\sigma$ — τ stress

$\varepsilon = \varepsilon_e + \varepsilon_v$

$$\frac{d\varepsilon}{dt} = \frac{1}{E}\frac{d\sigma}{dt} + \frac{1}{\mu}\sigma$$

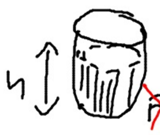
$= 0$

F turned on

$\frac{d\varepsilon}{dt} = 0$

$\sigma(t) = \sigma_0 e^{-t/\tau}$

relaxation time



$p = \rho g h$

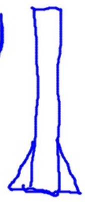
$F = \int p(h)\, dA$

$\sigma = \varepsilon E$

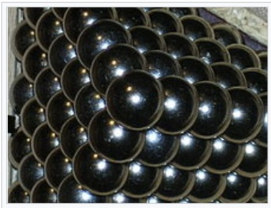
solid $t \ll \tau$

liquid $t \gtrsim \tau$

cathedral glass



$\tau > 100$ years



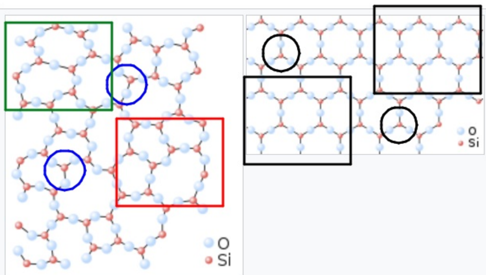
Model of closely packed atoms within a crystalline solid.

long range ordering

crystalline

short range ordering

amorphous



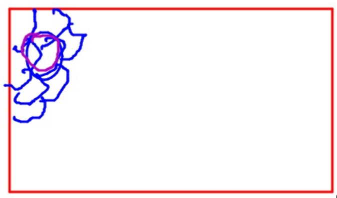
Schematic representation of a random-network glassy form (left) and ordered crystalline lattice (right) of identical chemical composition.

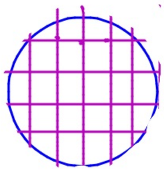
$50\,\mu m = 5 \cdot 10^{-6}$

1000, 1000, 1000

10^9 atoms

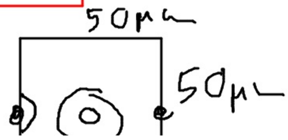
$5\,nm = 5 \cdot 10^{-9}$





micro crystals

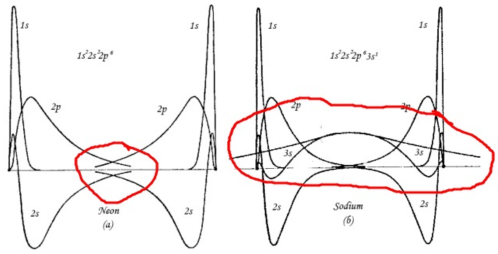
crystalline



conductivity

conductors — electricity, current, metals

insulators — no current



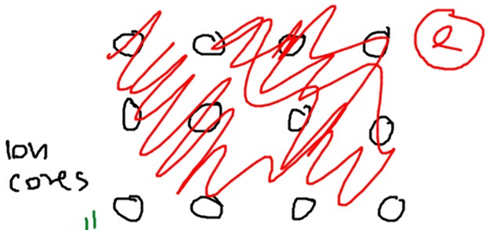
small or no overlap — insulator

high overlap — conductor

Bonding in crystals

covalent, ionic, hydrogen, molecular

metallic



ideal crystal

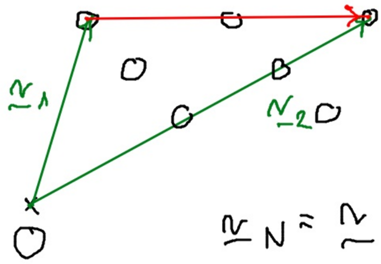
infinite ← "large enough"

perfect crystal

Crystal structures

long range ordering

R lattice vector



of lattice

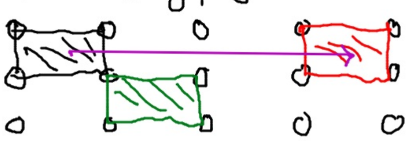
$\underset{\sim}{r}_N = \underset{\sim}{r}_1 + \underset{\sim}{R}_{1N} \Rightarrow$ Bravais lattice

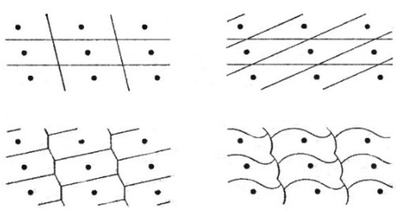
$\underset{\sim}{r}_M = \underset{\sim}{r}_N + \underset{\sim}{R}_{1N'}$, $\underset{\sim}{R}_{1N'} = \underset{\sim}{R}_{NM}$

symmetry

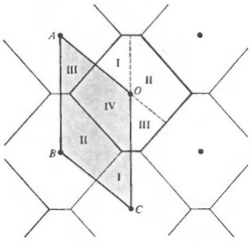
translational symm.

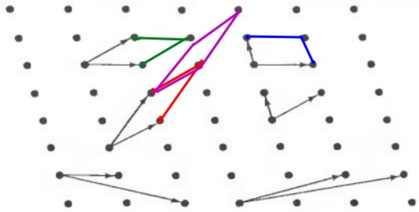
(elementary) cell





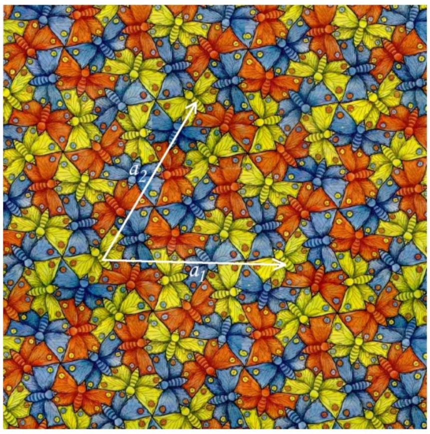
unit cell

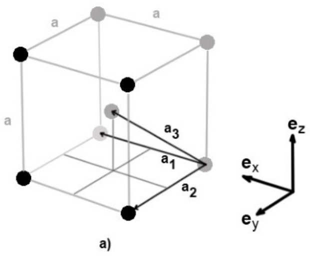




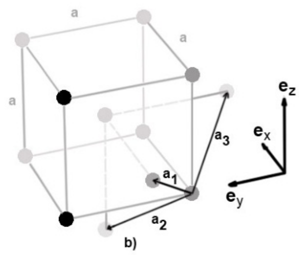
lattice vectors

unit cell





$\underline{a}_1, \underline{a}_2, \underline{a}_3$ lattice vectors



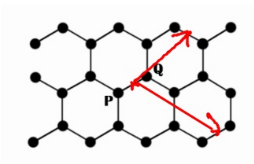
body centered cubic

bcc lattice

$\underline{r}' = \underline{r} + \underline{R}$

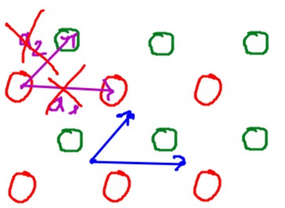
not a Bravais lattice: ← crystal looks the same from each lattice points

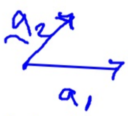
crystal ≡ translational symmetry



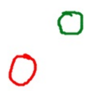
hexagonal lattice

P & Q not equivalent





point lattice



basis

crystal = point lattice + basis