

Quantum Mechanics II

Crystals (2)

Conductivity and Semi-Conductivity

Tristan Hübsch

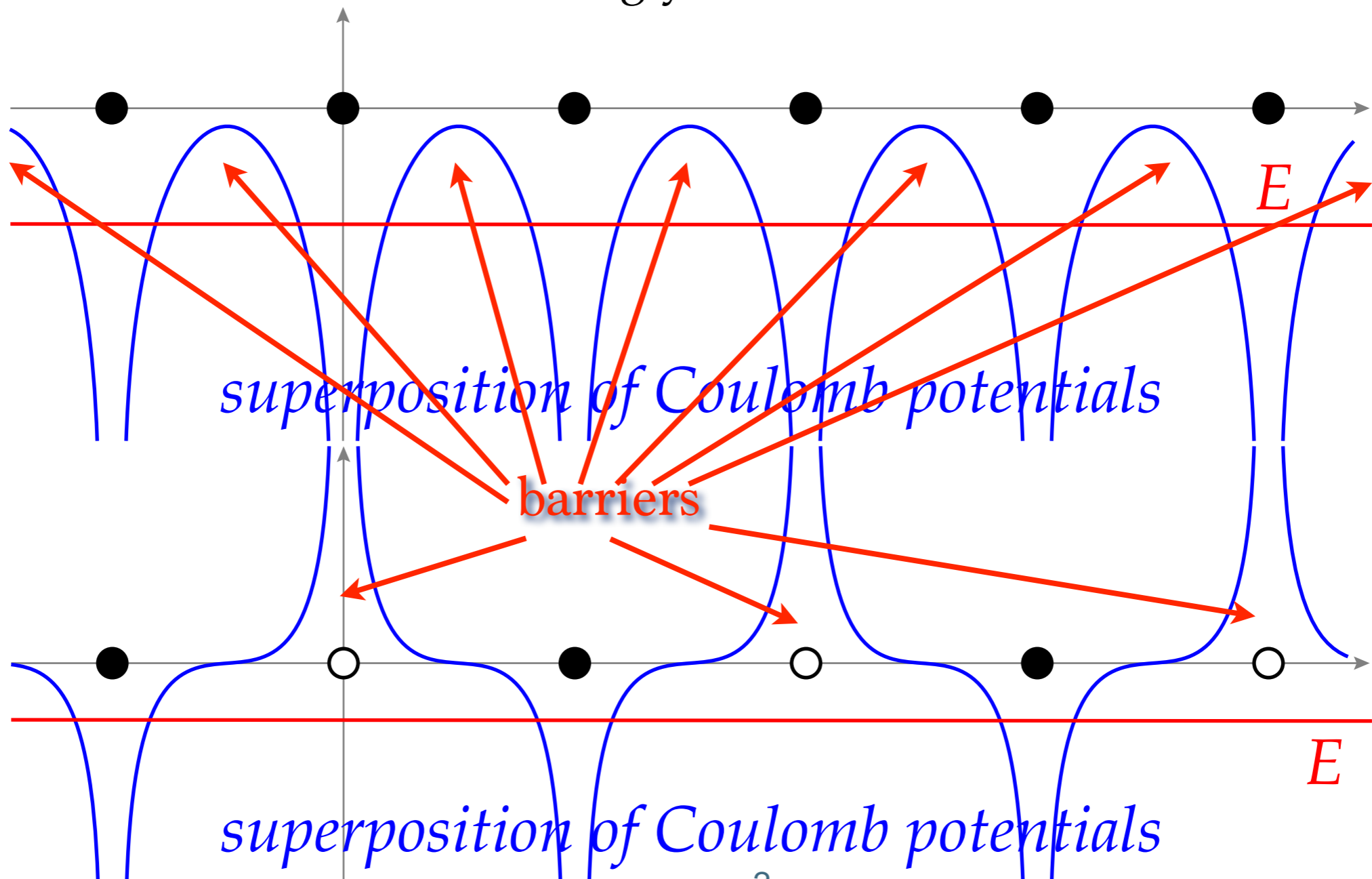
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<http://physics1.howard.edu/~thubsch/>

Crystals (2)

Conductivity and Semi-Conductivity

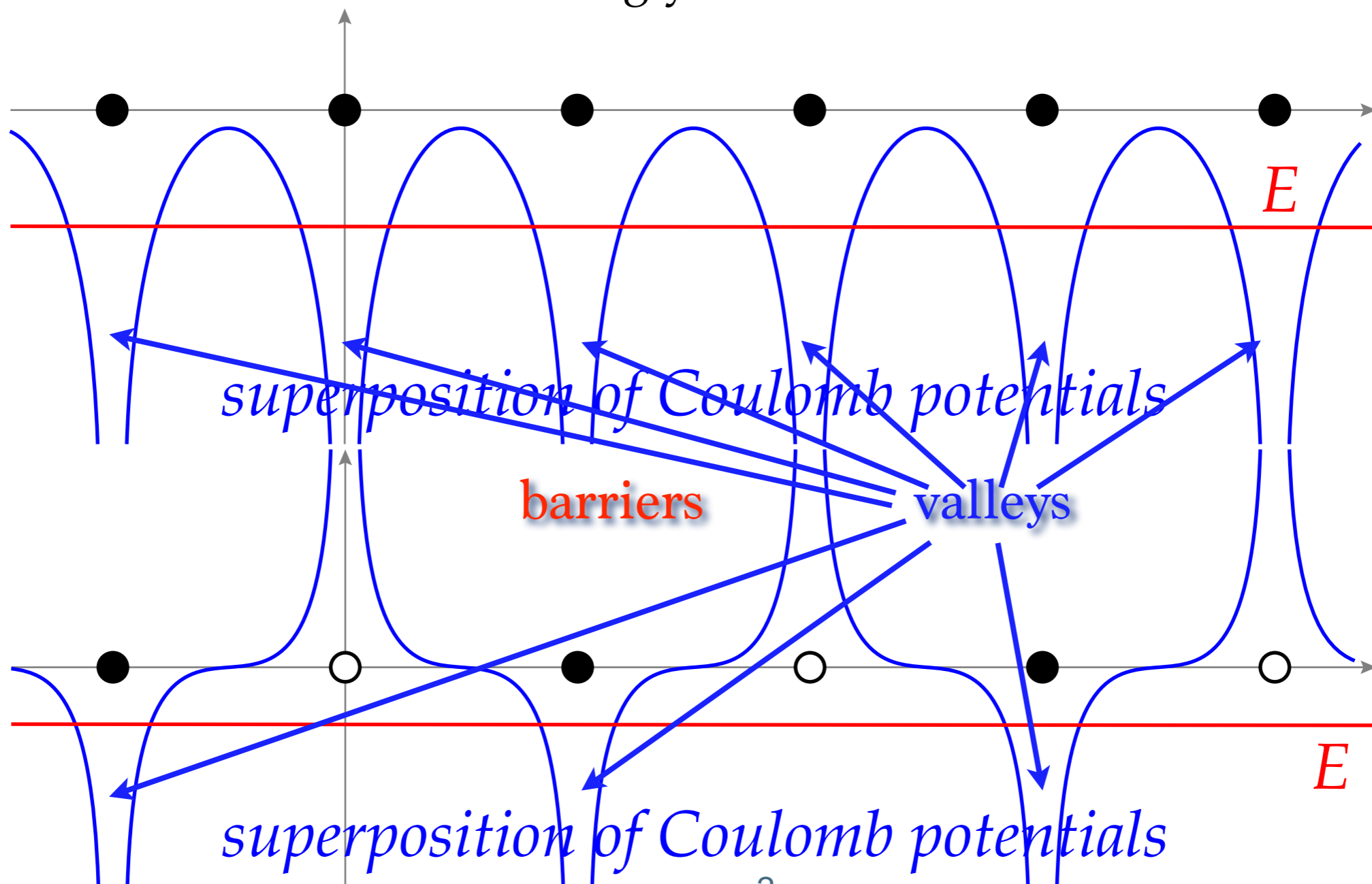
- Typical crystals have lattice sites
- with a few electrons less strongly bound electrons each...



Crystals (2)

Conductivity and Semi-Conductivity

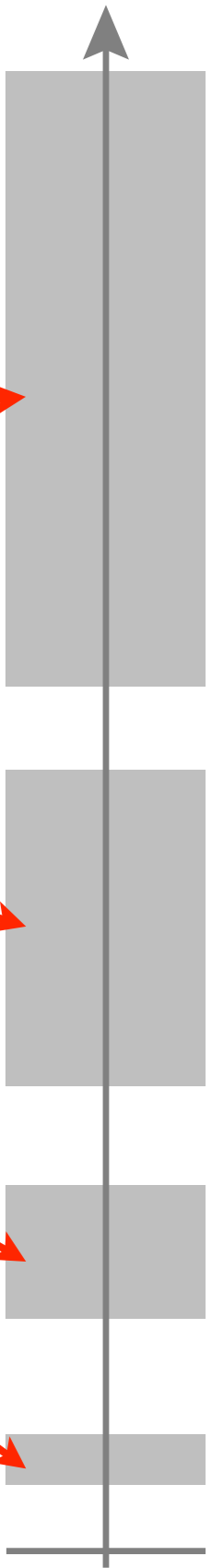
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Conductivity and Semi-Conductivity

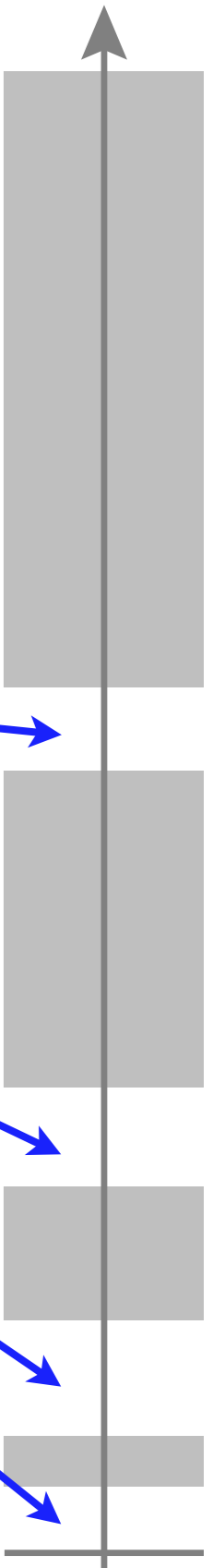
- Electrons in any crystal exhibit collective behavior
 - different from free electrons, determined by the underlying lattice
- States form
 - quasi-continuous bands



Crystals (2)

Conductivity and Semi-Conductivity

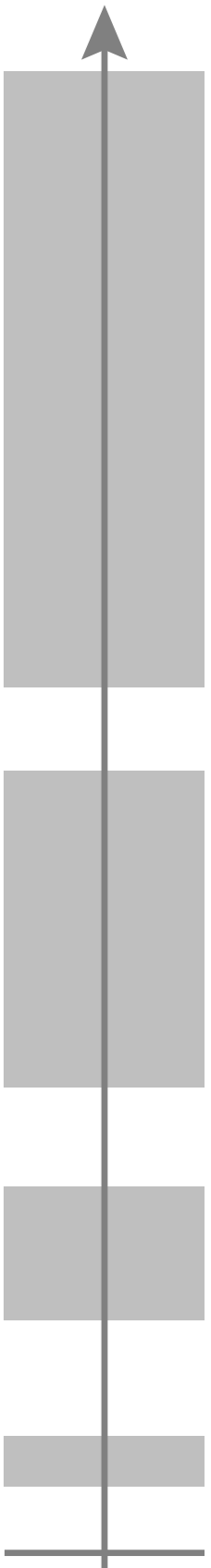
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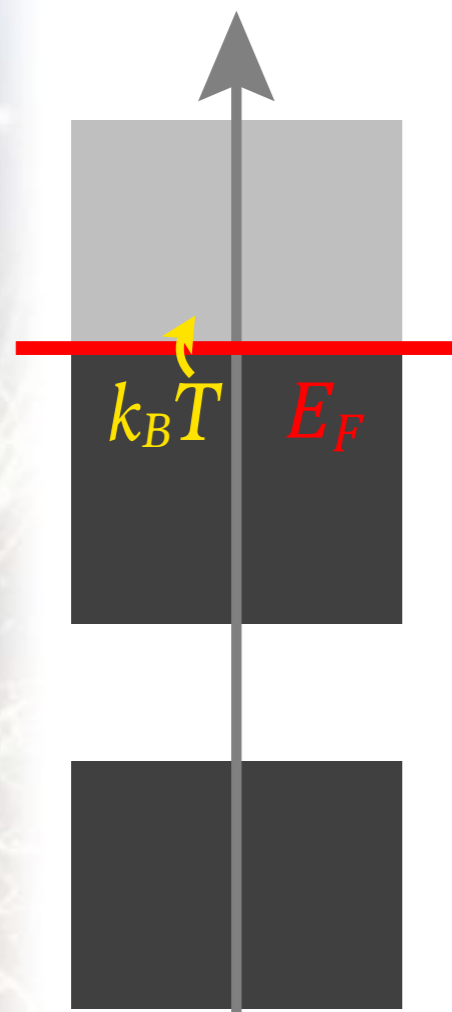
- Electrons in any crystal exhibit collective behavior
 - different from free electrons, determined by the underlying lattice
- States form
 - quasi-continuous bands
 - with finite gaps between them
- At $T=0\text{K}$, all electrons are in their lowest possible state
 - filling states up to E_F , because of Pauli's exclusion principle
- Conduction band = just above E_F
- Valence band = just below E_F
- The position of E_F is in relation to the bands and gaps determines the conducting properties



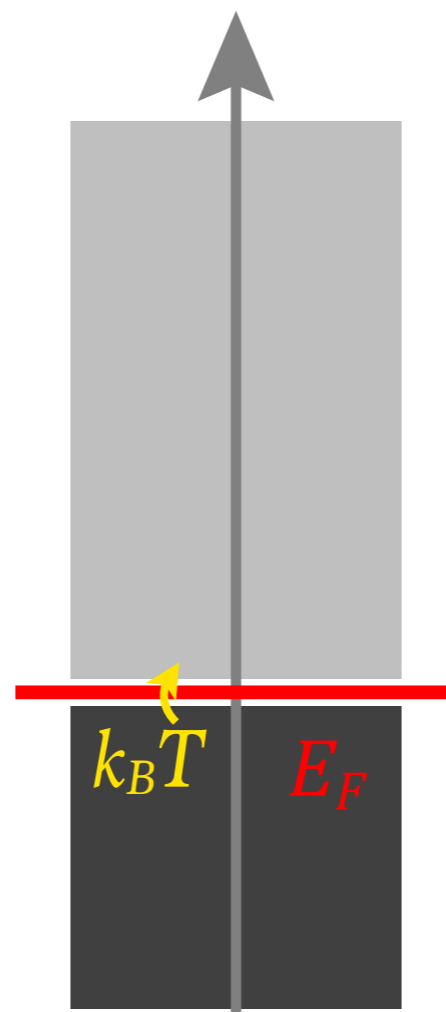
QM II Crystals (2)

Conductivity and Semi-Conductivity

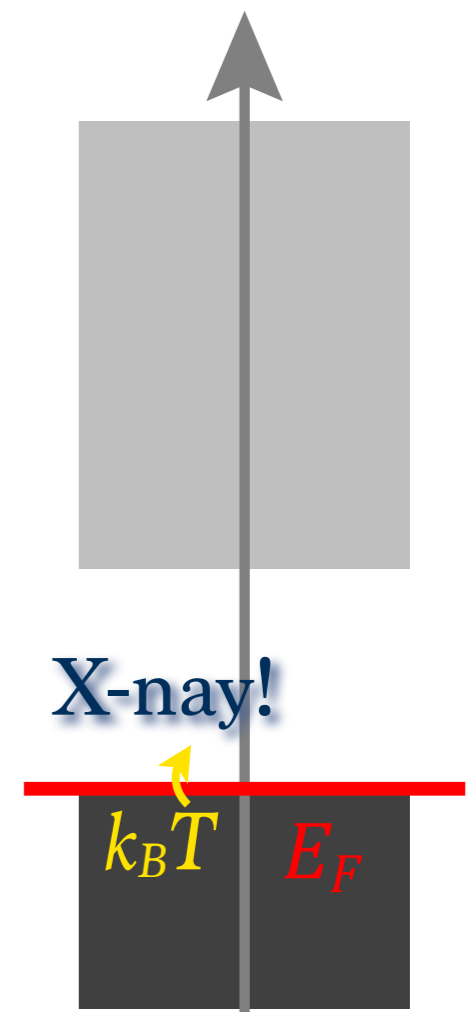
- The electrons' collective behavior depends on where E_F is in relation to the bands of quasi-continuous states and the gaps:



Conductor
(metal)



Semiconductor

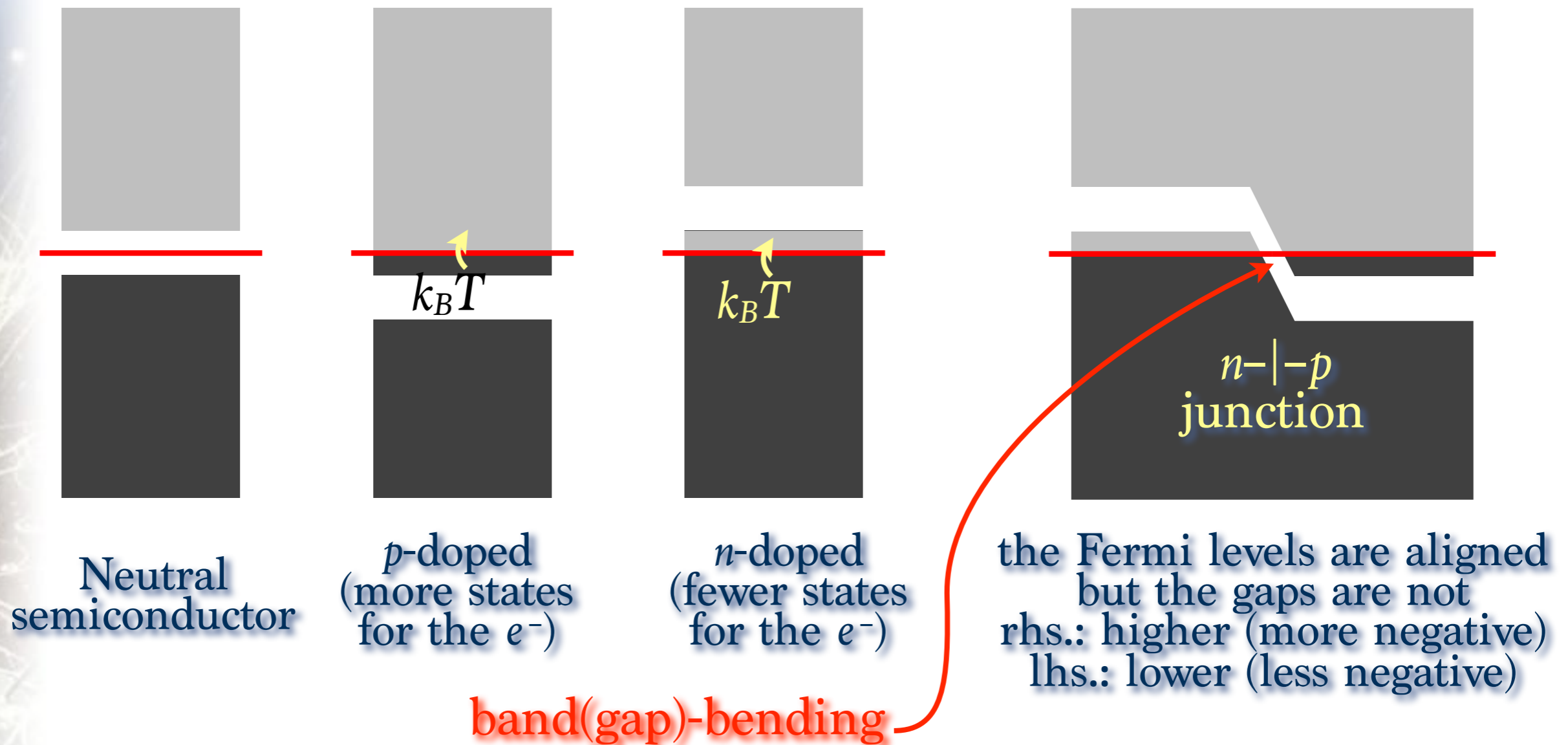


Insulator

Crystals (2)

Conductivity and Semi-Conductivity

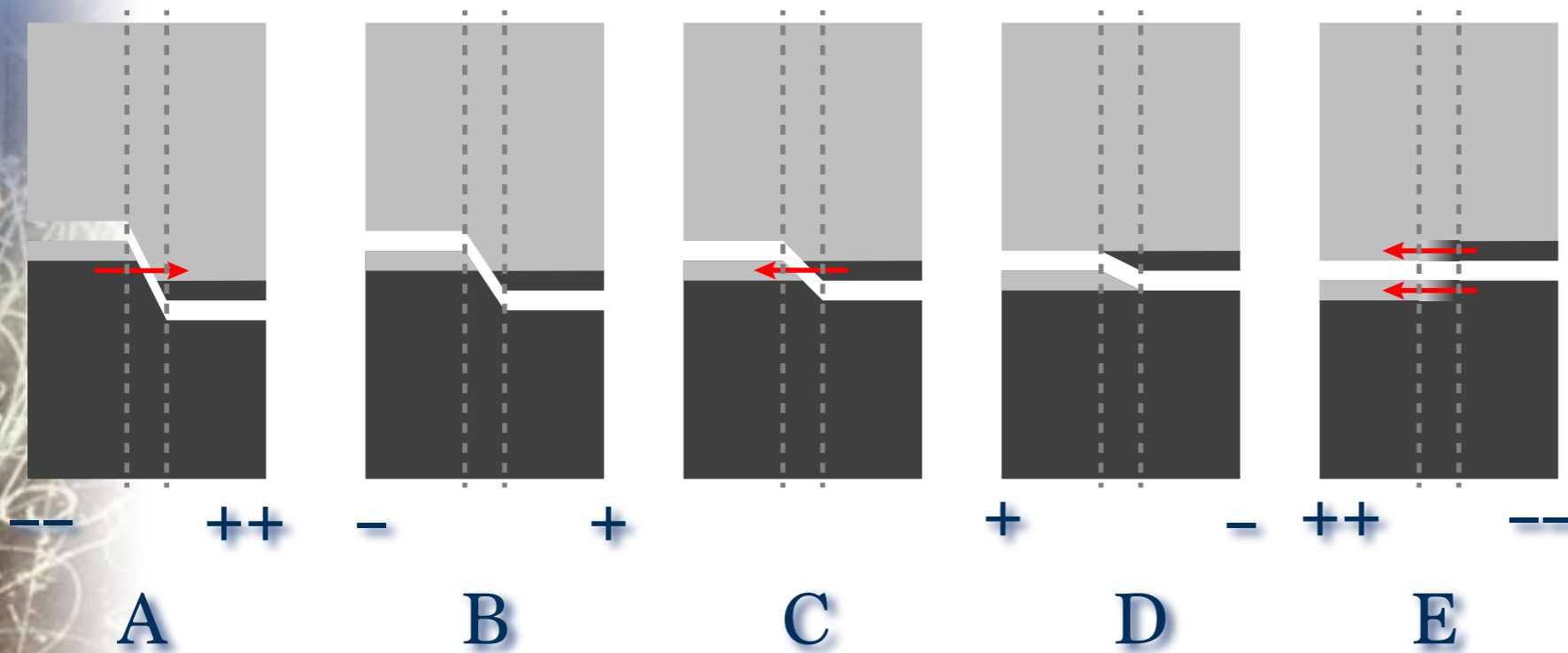
- The same semiconductor may be p - or n -doped
- ...which, respectively, lowers and rises the potential for electrons



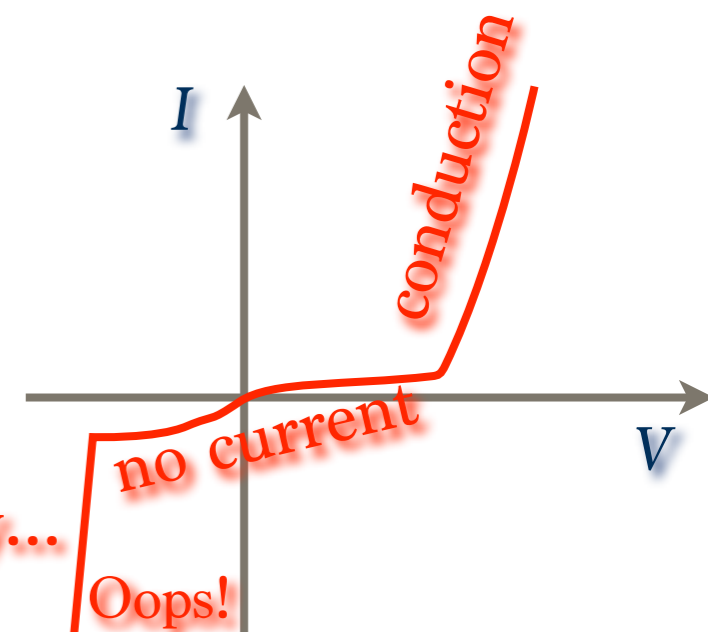
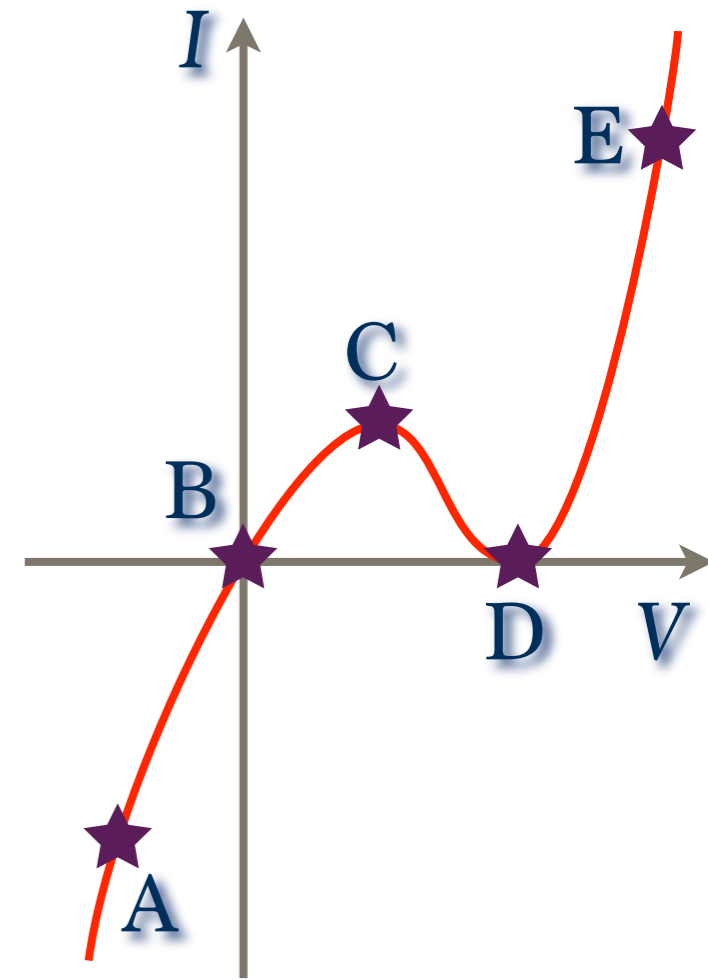
Crystals (2)

Conductivity and Semi-Conductivity

- Fusing an n - & a p -doped region with a thin interface and extra voltage applied to the sides:



Extra voltage: from increasing the band-bending to canceling it out (or even reversing)

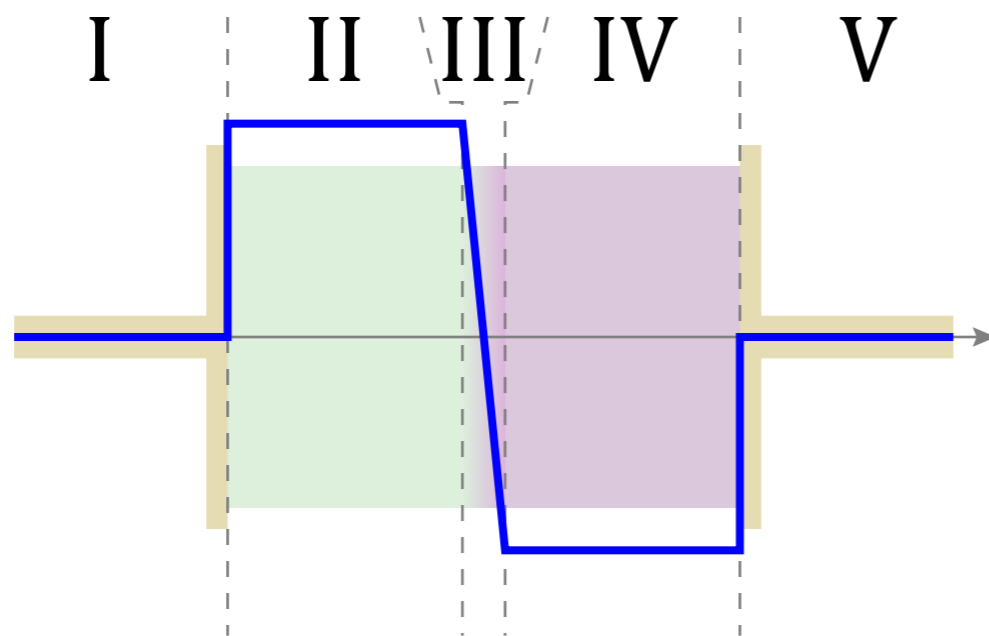


more realistically...

Crystals (2)

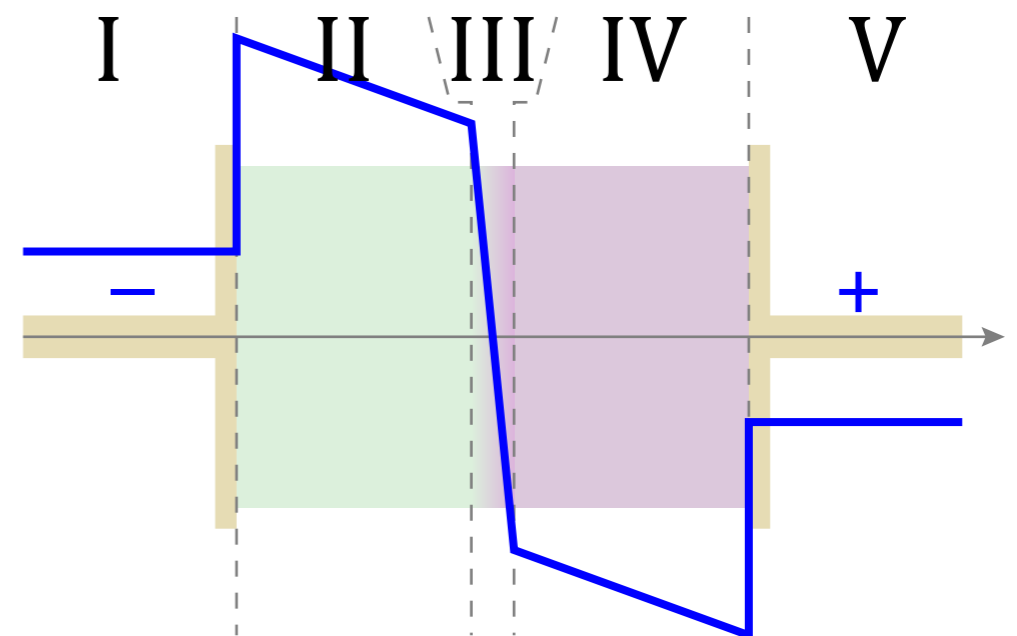
Conductivity and Semi-Conductivity

- In all this, the potential levels were assumed to be constant within a given region...
- More realistically



no external voltage

I, II, IV, V: trigonometric
 III: Airy



with external voltage

I, V: trigonometric
 II, III, IV: Airy

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*Now, go forth and
calculate!!!*

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