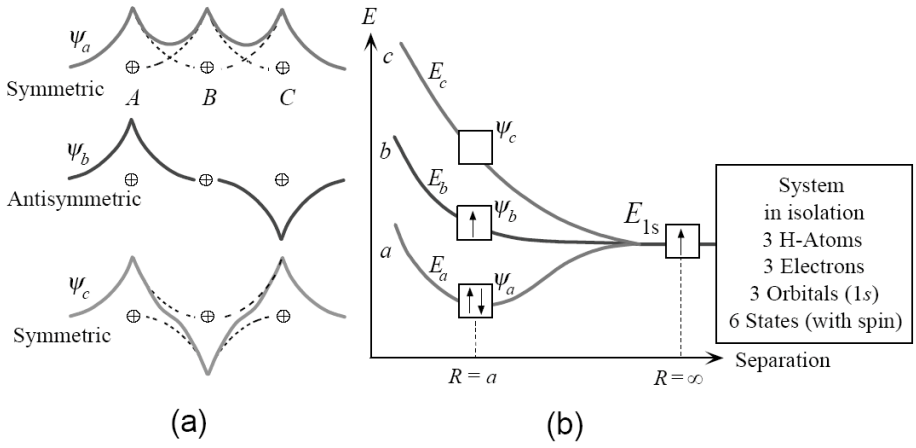
# 4.2 Band theory of solids

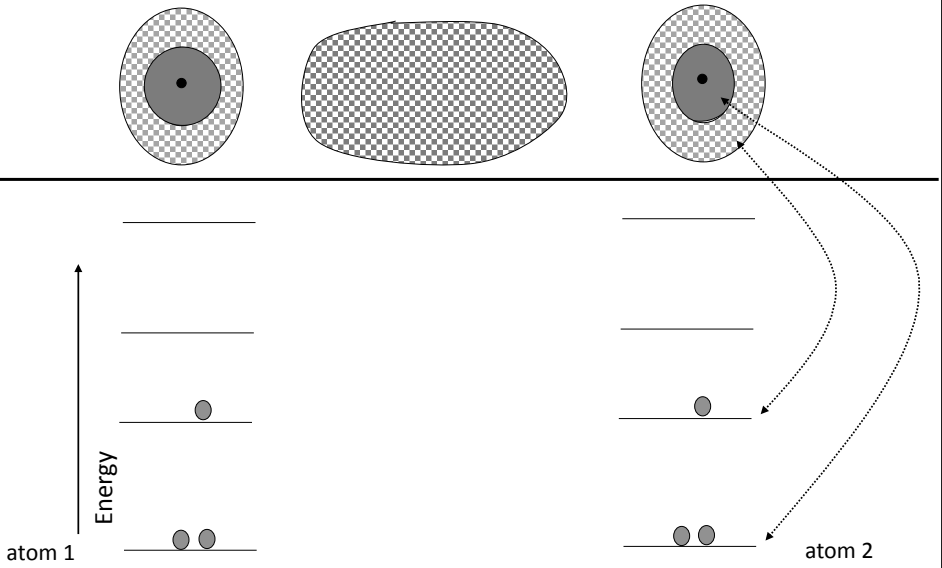




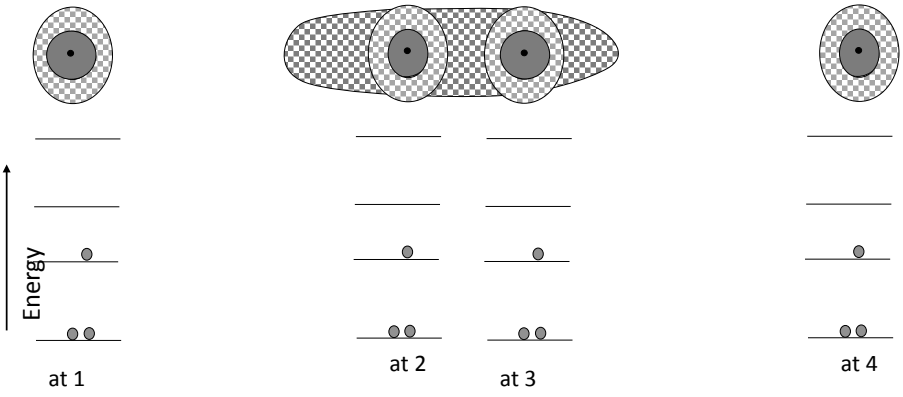

(a) Three molecular orbitals from three $\psi_{1s}$ atomic orbitals overlapping in three different ways.
(b) The energies of the three molecular orbitals in a system with three H atoms.

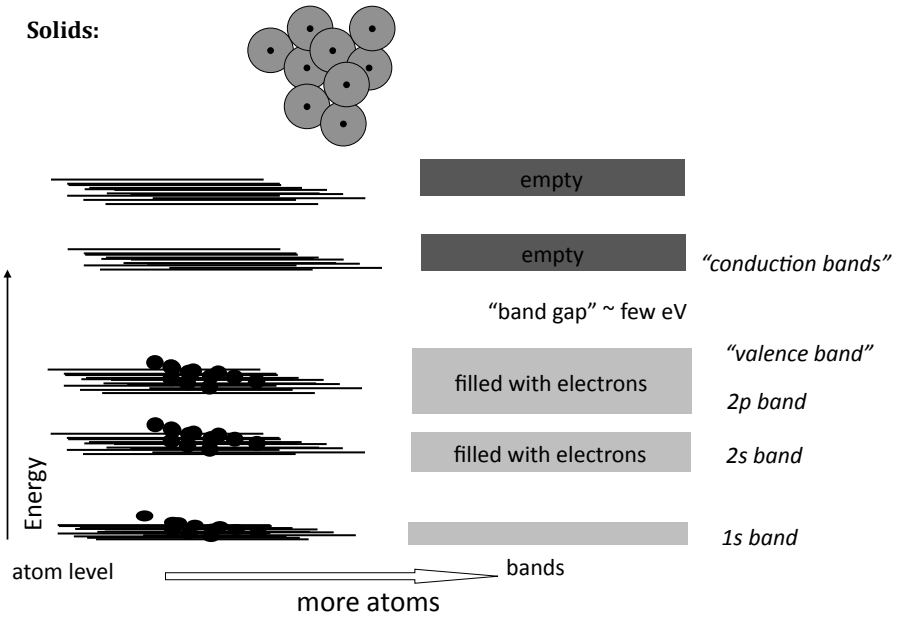
From *Principles of Electronic Materials and Devices, Third Edition*, S.O. Kasap (© McGraw-Hill, 2005)

## Multi-electron atoms:



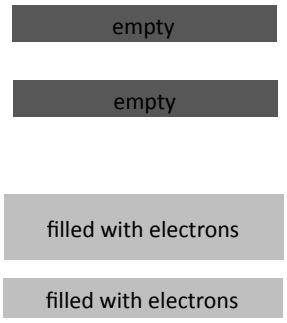




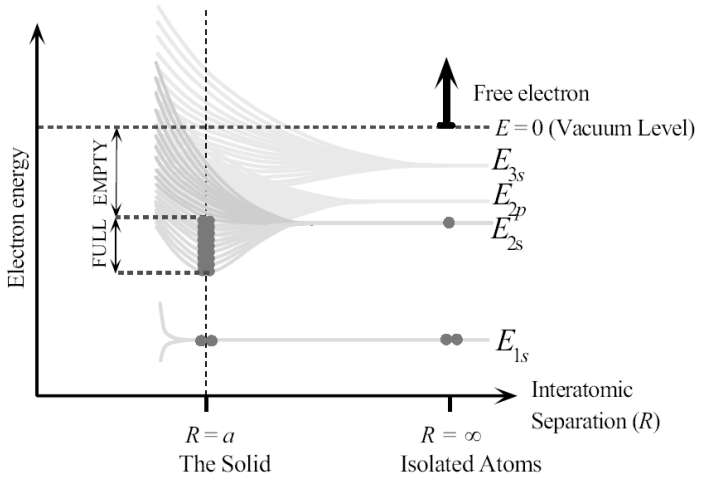



If a material has this energy band diagram, is it most likely to be a metal or an insulator?

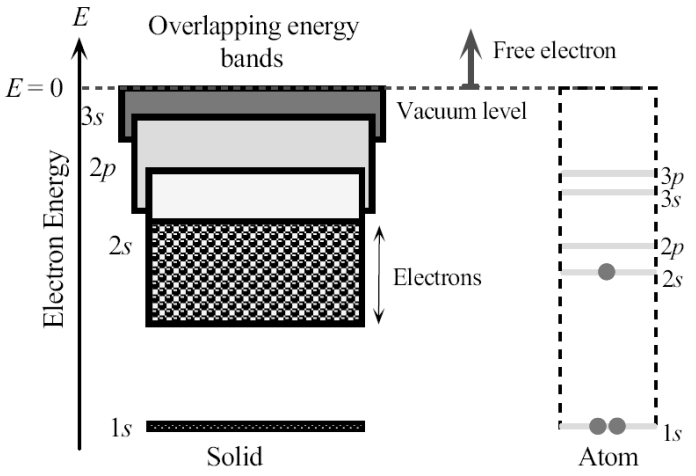


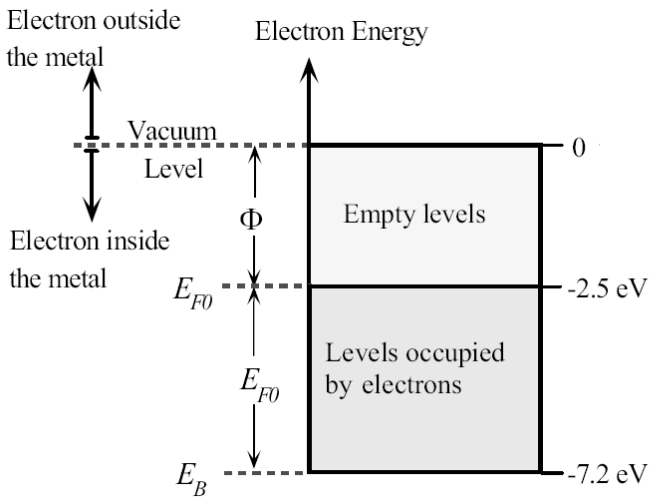

A. Metal
B. Insulator

Why?


Free electron
$E = 0$ (Vacuum Level)
$E_{3s}$
$E_{2p}$
$E_{2s}$
$E_{1s}$
EMPTY
FULL
Electron energy
Interatomic Separation ($R$)
$R = a$
The Solid
$R = \infty$
Isolated Atoms



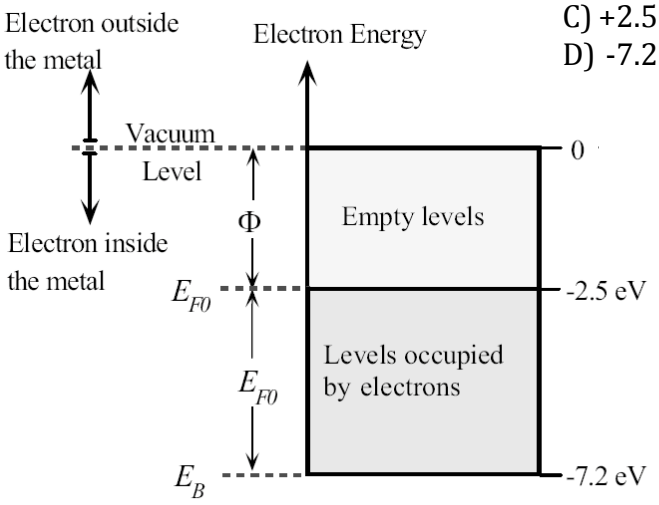

$E$
Overlapping energy bands
Free electron
$E = 0$
Vacuum level
$3s$
$2p$
$2s$
Electrons
Electron Energy
$1s$
Solid
$3p$
$3s$
$2p$
$2s$
$1s$
Atom






## What is the work function?

A) 0 eV
B) -2.5 eV
C) +2.5 eV
D) -7.2 eV



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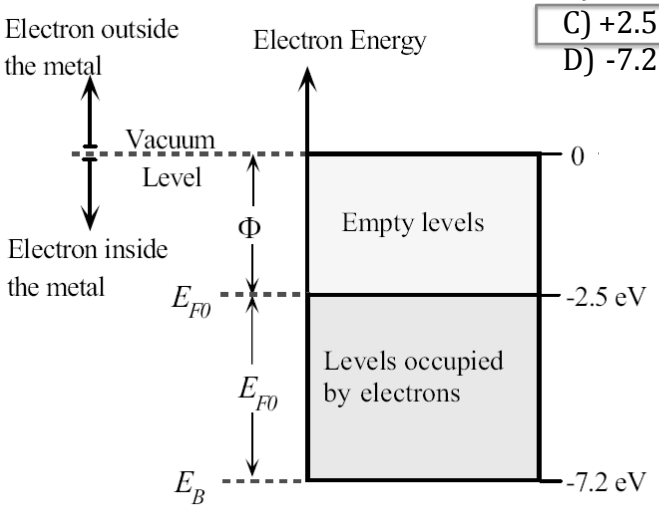
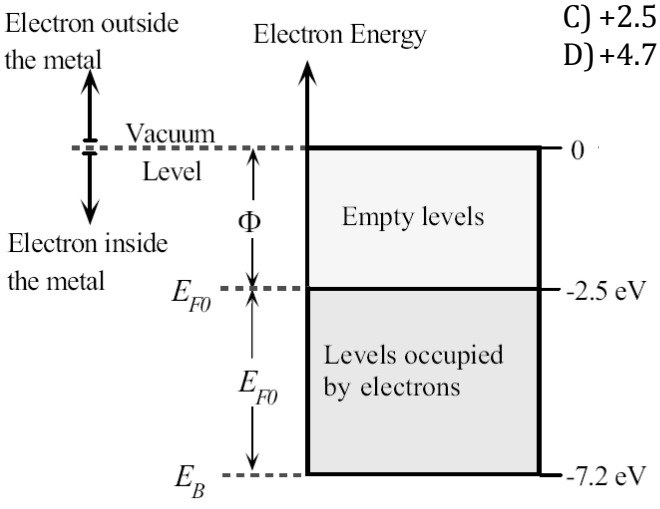





## What is the Fermi energy?

A) -7.2 eV
B) -2.5 eV
C) +2.5 eV
D) +4.7 eV



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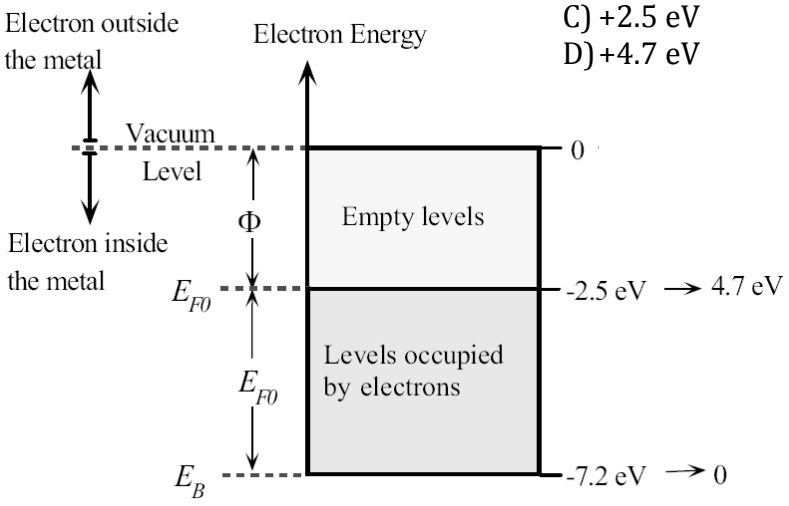
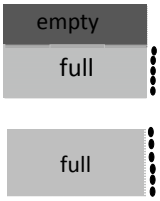


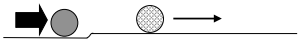



What is the difference between Fermi energy and work function?

## Conductor (metal):




The electron is like a ball rolling on almost flat ground:

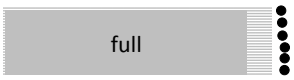


Electron can move easily

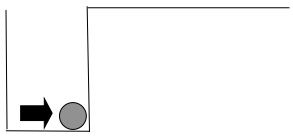


## Insulator:


ENERGY gap- no ALLOWED levels



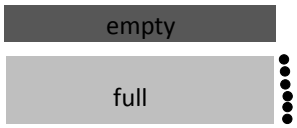

Electron is in a pit,



It can't move without a big boost.

## Semiconductor:

Half way in between a conductor and an insulator.



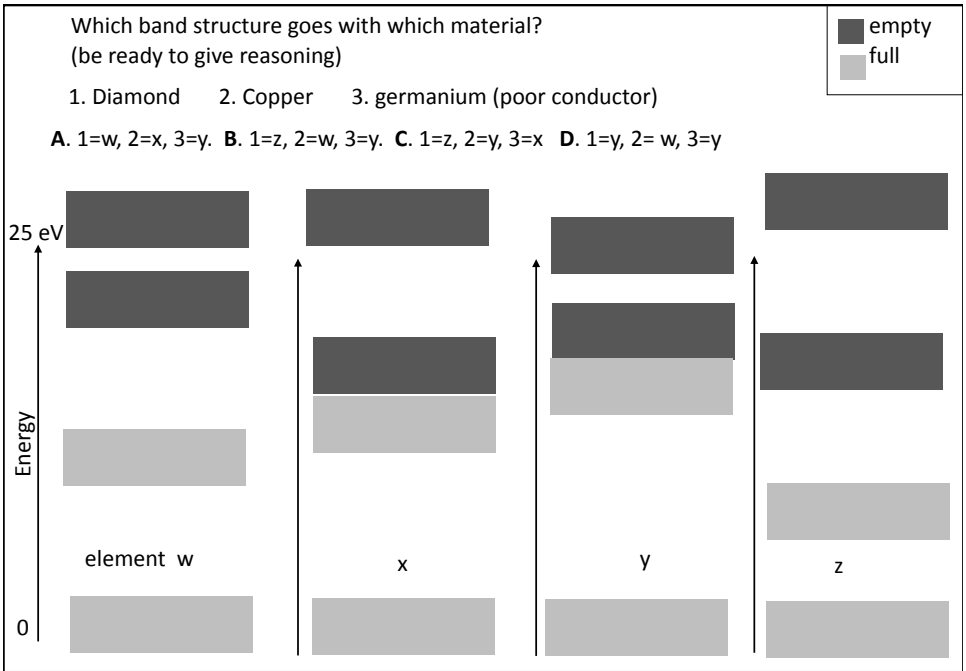

Little gap to empty levels, shallow pit.



Which band structure goes with which material?
(be ready to give reasoning)

1. Diamond 2. Copper 3. germanium (poor conductor)

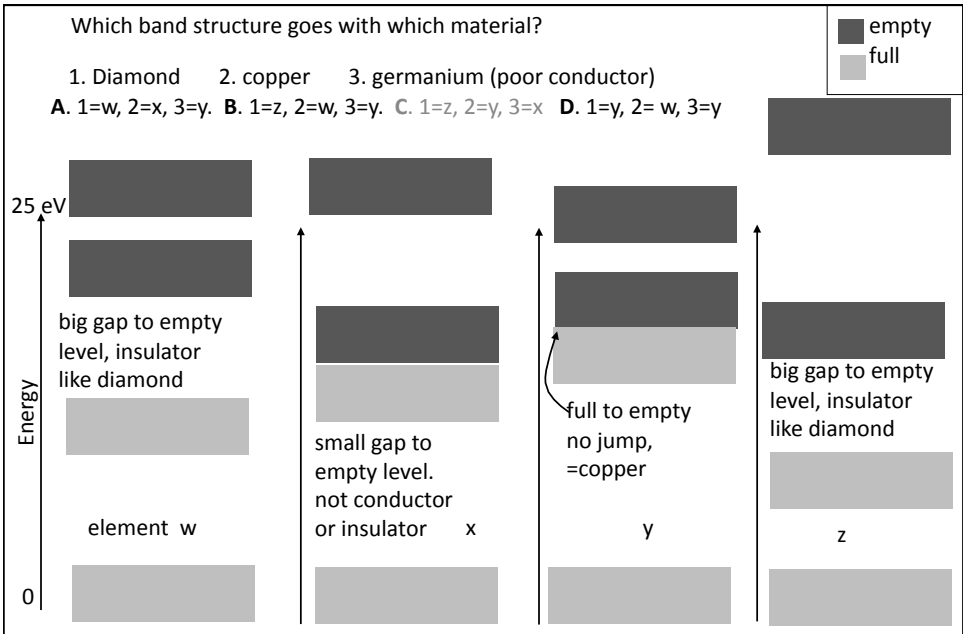
**A**. 1=w, 2=x, 3=y. **B**. 1=z, 2=w, 3=y. **C**. 1=z, 2=y, 3=x **D**. 1=y, 2= w, 3=y



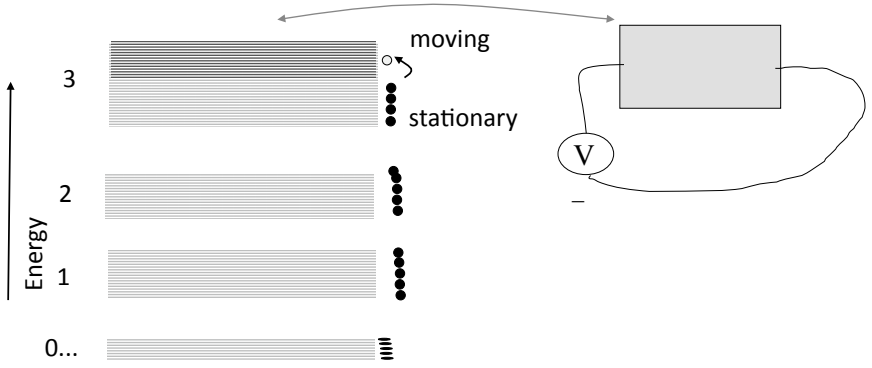
Which band structure goes with which material?

1. Diamond 2. copper 3. germanium (poor conductor)

**A**. 1=w, 2=x, 3=y. **B**. 1=z, 2=w, 3=y. **C**. 1=z, 2=y, 3=x **D**. 1=y, 2= w, 3=y

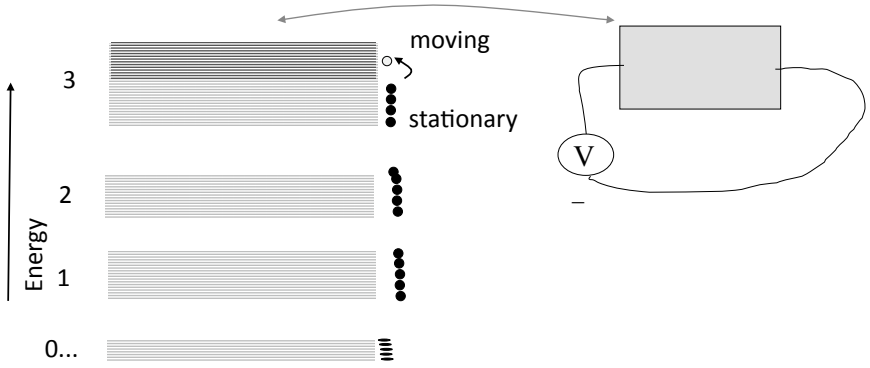





If you apply a voltage to the material (at room temperature), which electrons will move?

A. all of them in bands 1,2,3
B. only top one in band 3
C. all of them in band 3
D. only the top few in band three
E. none of them will move

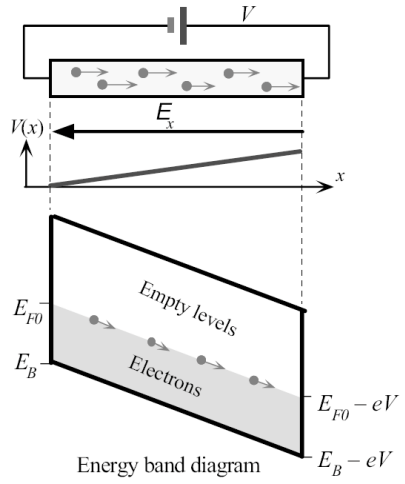



d. only the top few in band 3.

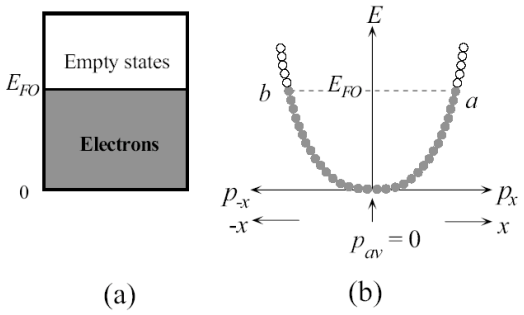


Engineering:

Physics:



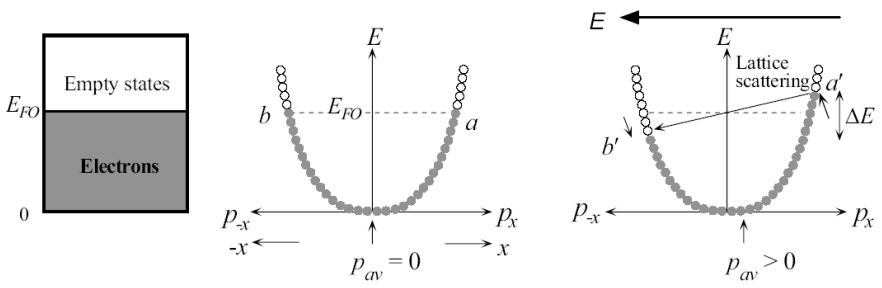
$E = KE = p^2/2m$




(a) (b)



$E = KE = p^2/2m$




(a) (b) (c)