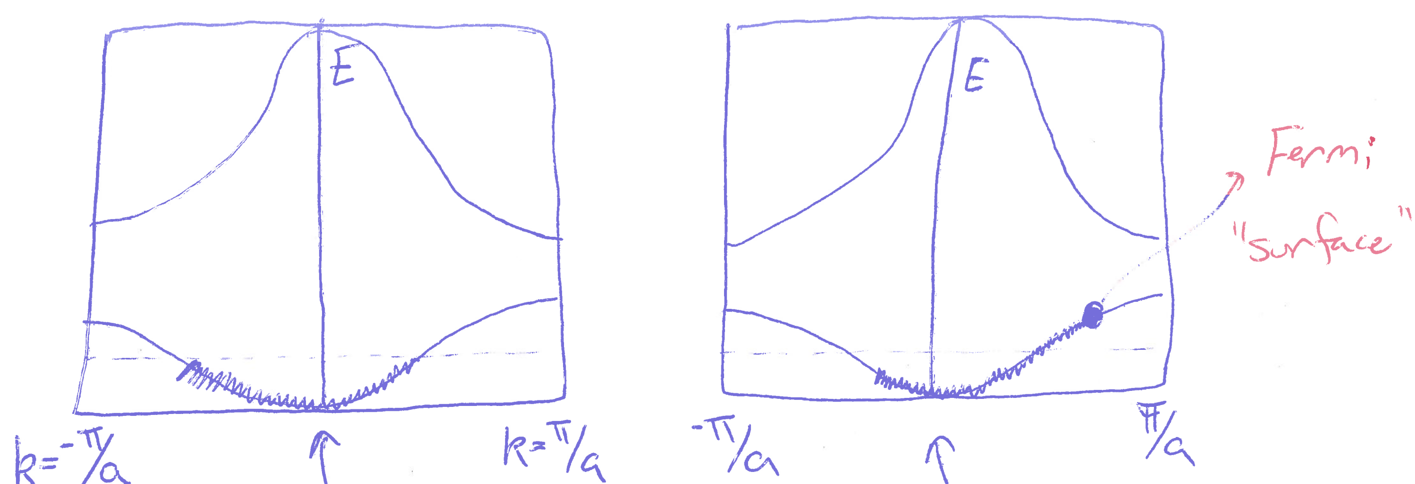
Wed. Nov. 14

- We did not quite finish our discussion of Bloch's theorem or solving for the Schrödinger equation for the "Dirac comb"
- Please see online notes for getting started with the HW problem
- We will discuss today different classes of materials with respect to electronic properties
- Let's start in 1D again:



half filled band

E-field applied

- more e^-'s with wavenumbers k moving to the right
- electric current $N(k_+) > N(k_-)$

- Note that the boundary between occupied & unoccupied states in 1D are two points at the ends of the dispersion curve
- Scaling up to 3D, the boundary is the Fermi surface

- Ohm's law states that current is proportional to an applied electric field

$$\vec{J} = \sigma \vec{E}, \quad \sigma \equiv \text{conductivity}$$

& $\sigma = \infty$ for a perfect conductor

- Simple example Sodium, Na

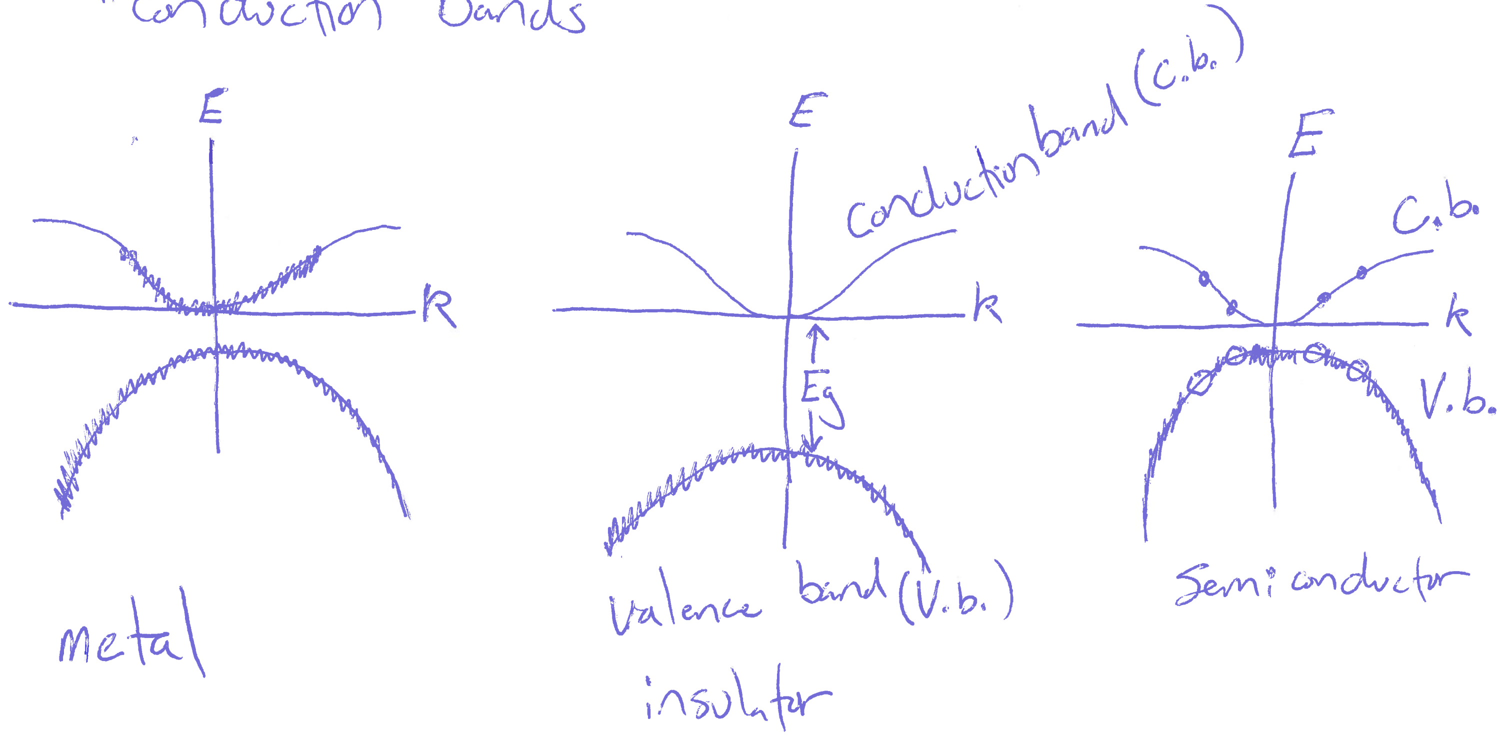
- inner bands are full: 1s, 2s, 2p
- because these are full, they do not contribute to the current

- valence band, 3s, can hold $2N$ electrons, where N is the # of Na atoms & the factor of 2 is for spin up/down ($\uparrow$ & $\downarrow$), but we only have $1e^-$ in this band for Na

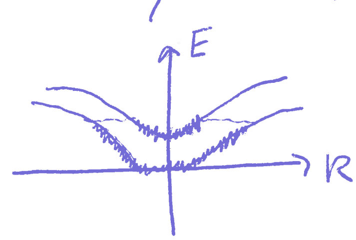
- therefore, the number of valence electrons for Na is 'N' + the band is exactly half-full

- in simple terms, a metal has partially filled bands. one can think of many energy states electrons can move into

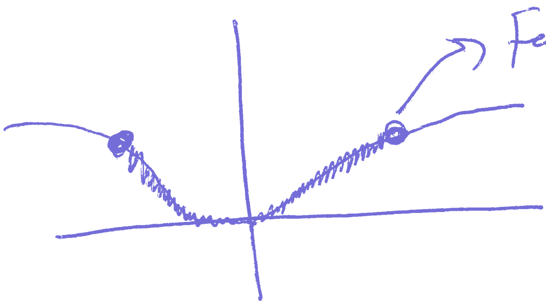
- insulators have full bands
- semiconductors have partially filled "conduction bands"



- in metals, bands may overlap as well



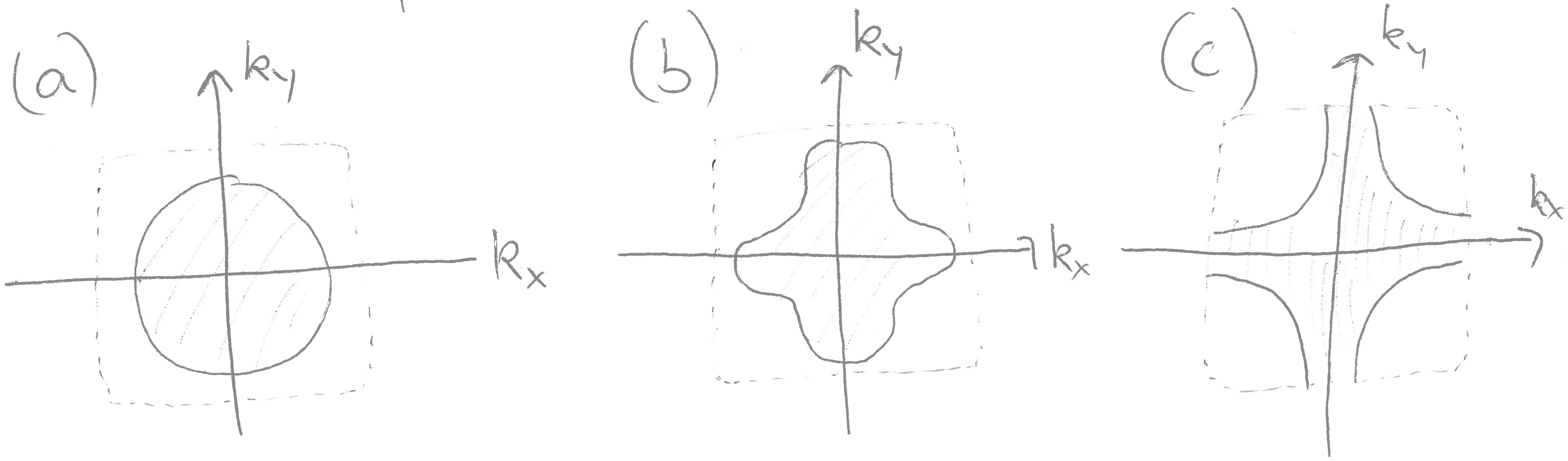
- We see now why covalently bonded solids are often insulators: the valence electrons are part of the bond + thus cannot easily escape
- insulators are often described by the "tight-binding model" which we will pass over
- recall our discussion of the free electron model
- free electrons: $E = \hbar^2 k^2 / 2m$, where $\vec{k} = k_x \hat{i} + k_y \hat{j} + k_z \hat{k}$
- the states fill up a sphere of radius $\vec{k}_F$, where $\vec{k}_F$ is the fermi level
- in 1D, we saw the $E \propto k^2$ is modified by the lattice



Fermi "surface" in 1D are 0D points

- for a metal of valence 1, $E \propto k^2$ since no states are close to the boundary ($k = \pm \pi/a$)

- let's look at the effect of adding a periodic potential on the Fermi surface

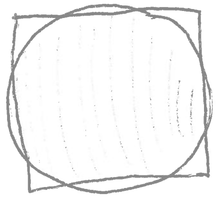


- dashed line is the first Brillouin zone for the square lattice, metal element with one valence e^-
- (a) is for the free electron
- (b) is for a weak periodic potential
- (c) is for a strong " "

- shaded area in a-c is exactly 1/2 of the first B.Z.

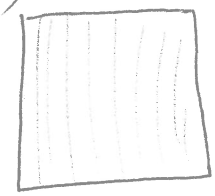
- let's look at a divalent atom:

(a)



- no potential

(b)



- periodic potential

- areas of fermi sea are equal to first BZ

- for (b), the first BZ is completely full, so we have an insulator

- why does this occur?
  - at the boundary, states within first BZ are "pushed" down
  - states outside are "pushed" up
  - so the former is energetically favorable, while the latter is not