Transport in metals:

- **Electron wave-packets transport charge:**
  \[ \frac{d\vec{k}}{dt} \approx -\frac{e}{\hbar} \vec{E} \]
  & more on this later, text ch. 13

- **Scattering:** allowed for electrons near Fermi surface; FS displaced under steady current flow.
  
- **Can apply standard Drude formula; more realistic picture in terms of excitations near FS.**

\[
\sigma = \frac{ne^2\tau}{m} = \frac{2}{3} g(\varepsilon_F)\varepsilon_F \frac{e^2\tau}{m} = \frac{g(\varepsilon_F)v_F^2e^2\tau}{3}
\]

(Expressed in terms of Fermi surface properties only)
Thermal transport:

\[ \kappa_{el} = \frac{1}{3} C \ell v \]

- \( v \) (mean speed) is Fermi velocity for good metals.
- Specific heat we have seen: \( C = \gamma T \)
- Generally electron + phonon contributions to \( \kappa \) add.

Wiedemann-Franz law (see ch. 1, prefactor 3/2 for classical gas)

\[
\frac{\kappa_{el}}{\sigma} = \frac{\pi^2}{3} \left( \frac{k_B}{e} \right)^2 T
\]

\[
c \approx \frac{1}{V} k_B T g(\varepsilon_F) \left( \frac{\pi^2}{3} \right) = \gamma T
\]

\[
\sigma = \frac{g(\varepsilon_F) v_F^2 e^2 \tau}{3}
\]
**Crystals:**  
*Reading:* Ch. 3, Ch. 4, Ch. 7.

Crystal = **Bravais lattice** + **Basis.**

- **Bravais lattice** = repeated set of points, \( \vec{R} = n_1 \vec{a}_1 + n_2 \vec{a}_2 + n_3 \vec{a}_3 \)
- **Basis** = identity & location of atoms “decorating” the lattice, at \( \vec{d}_i \)

- **Primitive Lattice vectors:** \( \vec{a}_1, \vec{a}_2, \vec{a}_3 \) (not a unique set for given lattice)
- **Primitive unit cell.** Space region, translated by all lattice vectors (“tiling”) will fill all space (not unique). Cell volume is unique: \( V = \vec{a}_1 \cdot \vec{a}_2 \times \vec{a}_3 \)
- **Wigner Seitz primitive cell:** region closer to a given Lattice Point than any other Lattice Point. Same point group symmetry as the lattice.
- **Conventional cell:** Larger than primitive cell but tiles space; chosen to show crystal symmetry. (Examples: FCC primitive cell is 4 times smaller than its conventional cubic cell. Silicon is FCC with basis of 2, cube contains 8 atoms.)
14 distinct Bravais lattices distinguished by symmetry:

**CUBIC**
- $a = b = c$
- $\alpha = \beta = \gamma = 90^\circ$

**TETRAGONAL**
- $a = b \neq c$
- $\alpha = \beta = \gamma = 90^\circ$

**ORTHORHOMBIC**
- $a \neq b \neq c$
- $\alpha = \beta = \gamma = 90^\circ$

**HEXAGONAL**
- $a = b \neq c$
- $\alpha = \beta = 90^\circ$
- $\gamma = 120^\circ$

**MONOCLINIC**
- $a \neq b \neq c$
- $\alpha = \gamma = 90^\circ$
- $\beta \neq 120^\circ$

**TRICLINIC**
- $a \neq b \neq c$
- $\alpha \neq \beta \neq \gamma \neq 90^\circ$

**4 Types of Unit Cell**
- $P$ = Primitive
- $I$ = Body-Centred
- $F$ = Face-Centred
- $C$ = Side-Centred

**7 Crystal Classes**
→ 14 Bravais Lattices
CsCl; Ionic
Cubic cell

“Honeycomb” structure
2D Hexagonal + basis

Repeated structure with Basis