Superconductors Review Sheet

History of Superconductors

- 1908 – Onnes liquefies Helium
- 1911 – Mercury loses resistance below 4.2 K
- 1933 – Meissner Effect discovered
- 1957 – BCS theory
- 1962 – Josephson Effect
- 1986 – High Temperature Superconductors

Type I versus Type II Superconductors

	Type I	**Type II**
Typically composed of	Metals	Compounds and alloys
Critical temperature (typically)	(Lower) <30K	(Higher) > 90K
Response to magnetic field	Perfect diamagnetism	Allows penetration of magnetic field
Theory	BCS	N/A (no conclusive theory)

Factors affecting superconducting state

- Critical (1) temperature, (2) magnetic field, (3) current density

BCS theory

- Cooper pairs form when an electron attracts positive ions in the metal lattice and cause the ions to bend inward. This creates a positive net charge that attracts a second electron, which creates a "cooper pair"
- Cooper pairs condense and form a boson.
- At the critical temperature, there is not enough energy to change the state of the boson and thus, there is not enough energy for the collisions that cause resistance

Perfect diamagnetism/Meissner effect

- Internal magnetic field of zero (i.e. a magnetic susceptibility of -1)
- Magnetic field canceled by surface currents
- Unlike a (hypothetical) "perfect conductor" which would be permanently magnetized if a field is applied while the temperature is reduced below the critical temperature, superconductors will immediately cancel field once temperature drops below the critical temperature

Applications of Superconductors

- Maglev trains: Train and track exert opposing magnetic field, using superconducting magnets, to keep train "floating"
  - PROS: More energy efficient, Higher speeds, More environmentally friendly
  - CONS: Expensive, Need magnetic shielding, Louder
- Josephson Juncture/SQUIDS
  - Thin insulating oxide barrier between two superconductors, which cooper pairs travel through without resistance
    - DC effect: current flows in absence of voltage difference
    - AC effect: current oscillates with characteristic frequency proportional (or inversely proportional) to applied voltage
  - Used for: voltage-to-frequency converter, Single electron transistor, Qubits in quantum computing, and SQUIDS
  - SQUIDS: a superconducting ring with two Josephson junctures that is used to detect very small changes in magnetic flux (i.e. for brain imaging)
- Particle Accelerators
  - Used for beam transport, acceleration, bubble chamber magnets (to ID/analyze particle interaction)
  - Superconductors are useful because the magnetic field is more precise, stronger and can be cheaper to run