Drude theory assumption

Drude's model, proposed by Paul Drude in 1900, is a classical theory that attempts to explain the electrical and thermal conductivity of metals. It is based on several assumptions and simplifications, which makes it a relatively simple model for understanding the behavior of free electrons in metals.

Assumptions made in Drude's model

1. Free electron approximation: The model assumes that the conduction electrons in a metal can be treated as a gas of free, non-interacting particles. The positive ion cores are treated as a fixed, uniform background.

2. Classical treatment: The electrons are treated as classical particles obeying Newton's laws, and quantum mechanics is not considered.

3. Collisions: Drude's model assumes that electrons collide with the ion cores and experience random changes in their direction and velocity. These collisions are characterized by an average time between collisions, called the relaxation time or mean free time.

4. Independent collisions: The model assumes that the collisions are independent, and an electron's motion between collisions is not affected by its previous collisions.

Where Drude's theory succeeds

1. Ohm's law: Drude's model successfully explains Ohm's law, which states that the current density (J) is proportional to the applied electric field (E). This relationship is described by the conductivity (σ): $J = \sigma E$.

2. Wiedemann-Franz law: The model predicts the relationship between electrical and thermal conductivities, given by the Wiedemann-Franz law. The law states that the ratio of the thermal conductivity (κ) to the electrical conductivity (σ) is proportional to the temperature (T): $\kappa/\sigma = LT$, where L is the Lorentz number.

3. Hall effect: Drude's model provides a qualitative explanation for the Hall effect, a phenomenon where a transverse electric field is generated in response to an applied magnetic field in a conductor.

Where Drude's theory fails

1. Heat capacity: The model incorrectly predicts that the heat capacity of metals should be the same as the heat capacity of free electrons. In reality, the heat capacity of metals is much smaller than the model's prediction.

2. Electronic contribution to specific heat: Drude's model fails to predict the correct temperature dependence of the electronic contribution to the

specific heat of metals. This discrepancy is resolved by considering quantum mechanics and the Fermi-Dirac distribution, which is incorporated in the more advanced Sommerfeld model.

3. Conductivity dependence on temperature: The model does not adequately explain the temperature dependence of electrical conductivity in metals.

4. The reasons for the successes and failures of Drude's model are mainly due to its underlying assumptions and simplifications. While these assumptions work well for some phenomena, they do not capture the full complexity of electron behavior in metals, particularly when quantum mechanics become important. More advanced models, such as the Sommerfeld model and the Bloch theory, address these limitations and provide a more accurate description of the electronic properties of metals.