ENGINEERING PHYSICS

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ENGINEERING PHYSICS

Unit III : Application of Quantum Mechanics to Electrical transport in Solids

➢ ***Suggested Reading***

1. *Fundamentals of Physics, Resnik and Halliday, Chapter 41*
2. *Solid state Physics, S.O Pillai, Chapter 6*
3. *Concepts of Modern Physics, Arthur Beiser, Chapters 9 &10*
4. *Learning material prepared by the Department-Unit III*

➢ ***Reference Videos***

1. *Physics Of Materials-IIT-Madras/lecture-26.html*

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Unit III : Application of Quantum Mechanics to Electrical transport in Solids

Class #29

- ***Relation between electrical conductivity and thermal conductivity (Wiedemann-Franz law and Lorenz number)***

- ***Drawbacks of quantum free electron theory***

Relation between electrical conductivity & thermal conductivity

Electrical or thermal conduction: Only free electrons close to the Fermi energy are responsible for conduction.

So it is possible to find a relation between these two different physical phenomena

Thermal conductivity of the metal is $K = \frac{1}{3}.\frac{C}{V}.v.L$

V *the volume,* v *is the velocity of electrons and* **L** *the mean free path*

C is the electronic specific heat $C_{el} = \frac{\pi^2}{2}N.\frac{{k_B}^2T}{E_f}$

Relation between electrical conductivity &thermal conductivity

The mean free path of electrons is $L = v\,\tau$ *taking* $v = v_F$

We get expression for the thermal conductivity as

$$K = \frac{1}{3}\cdot\frac{1}{V}\cdot\frac{\pi^2}{2}N.\frac{{k_B}^2 T}{E_f}.v_F.v_F\tau$$

$$= \frac{\pi^2}{6}.n.\frac{{k_B}^2 T}{E_f}.v_F^2.\tau$$

Where $n = N/V$ *is the concentration of free electrons*

Relation between electrical conductivity &thermal conductivity

$$K = \frac{\pi^2}{3}.n.\frac{k_B{}^2 T}{E_f}.\frac{mv_F^2}{2m}.\tau$$

$$= \frac{\pi^2}{3}.n.\frac{k_B{}^2 T}{m}.\tau$$

The electrical conductivity of the metal is then given by

$$\sigma = \frac{ne^2\tau}{m}$$

Relation between electrical conductivity &thermal conductivity

The ratio of thermal conductivity to electrical conductivity can be calculated as

$$\frac{K}{\sigma} = \frac{\frac{\pi^2}{3}\,.\,n.\,\frac{{k_B}^2 T}{m}\,.\,\tau}{\frac{ne^2\tau}{m}}$$

$$= \frac{\pi^2}{3e^2}\,{k_B}^2 T$$

This relation is called Wiedemann-Franz law

Relation between electrical conductivity &thermal conductivity

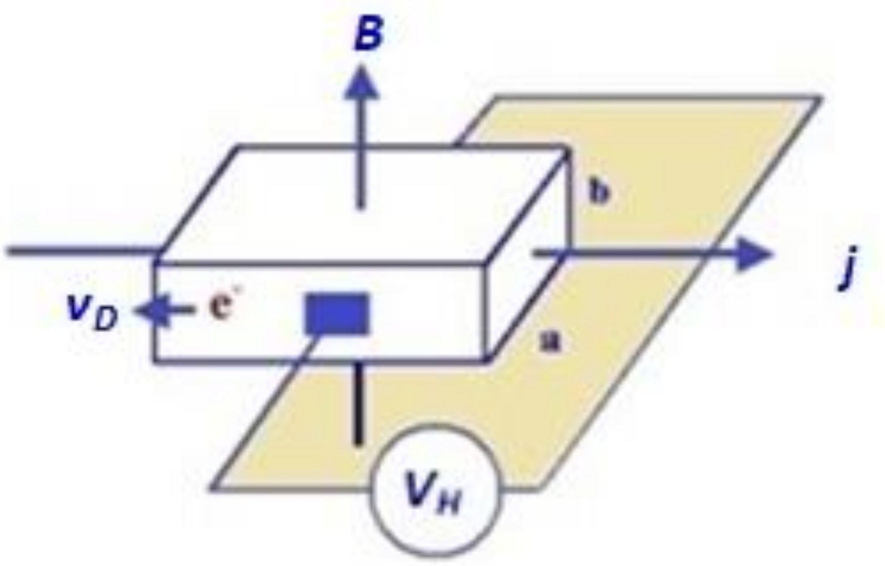
$\frac{K}{\sigma T} = L$ *is a constant irrespective of the metal*

Where $L = \frac{\pi^2}{3e^2} {k_B}^2$ *is the Lorenz number*

The value of Lorenz number is = 2.4 x10^{-8} WΩK^{-2}

Drawbacks of quantum free electron theory

- ***QFET fails explain the experimentally observed positive Hall co-efficient observed in some metals like Zinc.***



Drawbacks of quantum free electron theory

- ***Doesn't differentiate electrical conduction in metals, semiconductors and insulators.***

- ***fails to explain origin of band gap in semiconductors and insulators.***

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Class 29 . Quiz …

The concepts which are correct are….

1. ***The electrons close to the Fermi level are responsible only for the electrical conduction but not thermal conduction.***

2. ***At a given temperature irrespective of any metal, the ratio of the thermal conductivity to electrical conductivity is a constant.***

3. ***QFET explained the origin of band gaps in semiconductors and insulators.***

4. ***Experimentally observed positive Hall co-efficient observed in some metals could not be explained by QFET.***

THANK YOU

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