ENGINEERING PHYSICS

Sunitha V R

Department of Science & Humanities

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. ***Concepts of Modern Physics, Arthur Beiser, Chapter 9***
  3. ***Learning material prepared by the department- Unit III***

- ***Reference Videos***

  1. ***Physics Of Materials-IIT-Madras/lecture-16.html***

ENGINEERING PHYSICS

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

Class# 24

Concepts of Quantum free electron gas

- *Quantum model of valence electrons in a metal - Fermi energy*
- *Fermi Dirac statistics, Fermi factor*

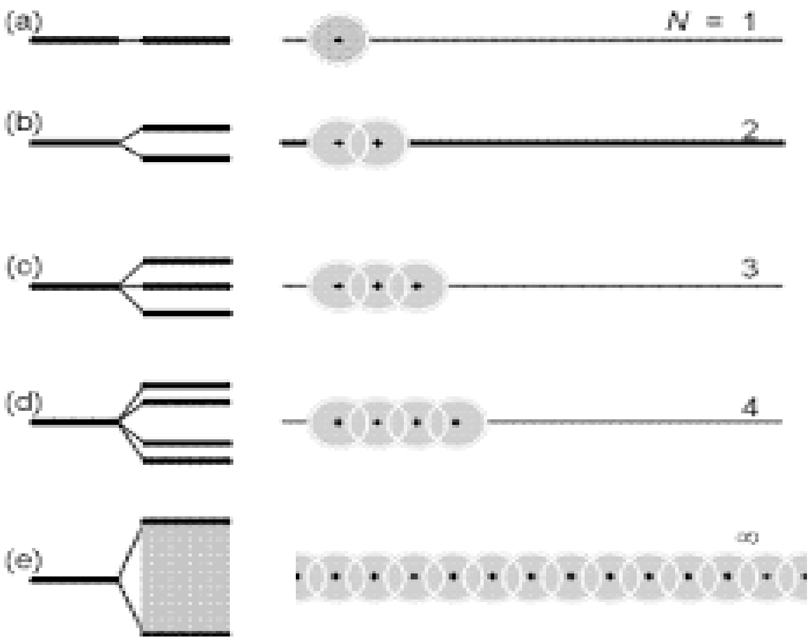
Features of Quantum free electron model

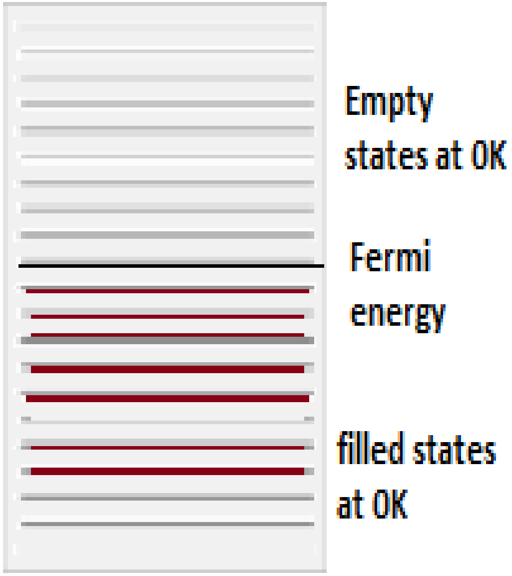
Sommerfeld proposed the Quantum free electron theory of electrical conductivity of metals in 1928

- *Free electron model*
- *Quantum mechanical principles to the Drude model*
- *Pauli's exclusion principle*
- *Fermions and Fermi-Dirac distribution function*

ENGINEERING PHYSICS

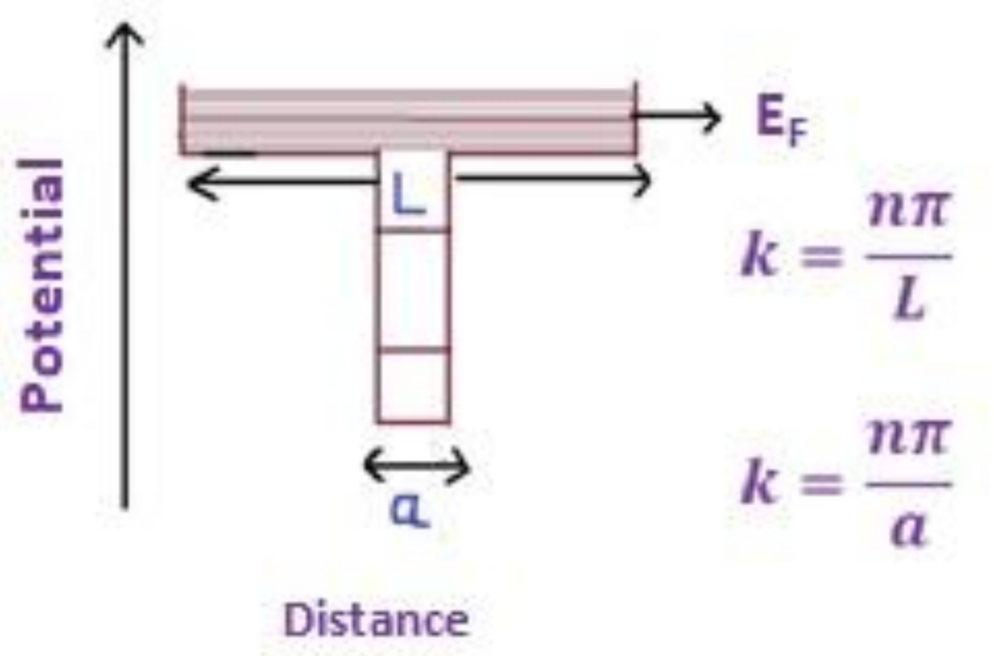
Quantum model of valence electrons in metals – Fermi Energy

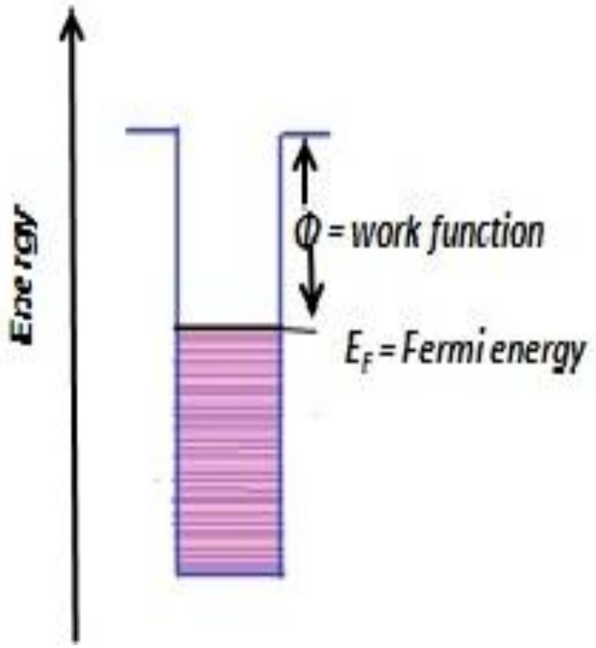




ENGINEERING PHYSICS

Quantum model of valence electrons in metals – Fermi Energy





$$F(E) = \frac{1}{\left(e^{\left(\frac{E-E_f}{k_B T}\right)} + 1\right)}$$

Estimation of the Fermi factor at T=0K

Case 1: If $E<E_F$ then $E-E_F$ is negative, hence

$$F(E) = \frac{1}{\left(e^{-\left(\frac{\Delta E}{k_B T}\right)} + 1\right)}$$

$$F(E) = \frac{1}{(e^{-(\infty)} + 1)} = 1$$

This implies that at 0K all electron states below the Fermi level are filled states.

PES UNIVERSITY ONLINE

Case 3: For T > 0 and E = E_F

$$F(E) = \frac{1}{\left(e^{\left(\frac{E-E_f}{k_B T}\right)} + 1\right)}$$

$$= \frac{1}{e^0 + 1} = \frac{1}{2} = 0.5$$

This imply that probability of occupancy of Fermi level at any temperature other than 0K is 0.5.

PES UNIVERSITY ONLINE

<u>Case 2</u>: If $E>E_f$ then for $E-E_f$ is positive, then

$$F(E) = \frac{1}{\left(e^{\left(\frac{\Delta E}{k_B T}\right)} + 1\right)}$$

$$F(E) = \frac{1}{\left(e^{(\infty)} + 1\right)} = 0$$

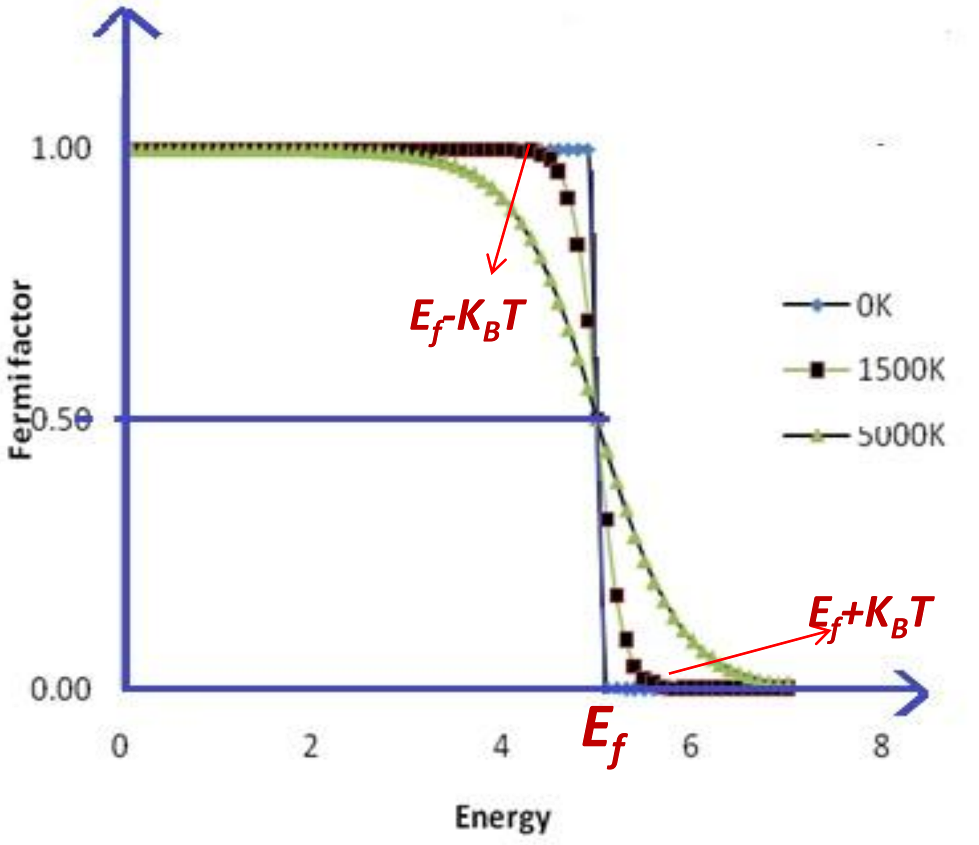
This implies that at 0K all electron states above the Fermi level are empty states.

ENGINEERING PHYSICS

Variation of Fermi factor with temperature

If $E_f >> K_BT$

Fermi energy of copper is 7 eV and at T= 300K , the value of KT is 0.026 eV



Variation of Fermi factor with temperature

The effective number of electrons above the Fermi level is approximated as $n_{eff} = n\frac{kT}{E_f}$

The effective number of electrons above the Fermi level for copper (E_f = 7eV) at 300K

$$n_{eff} = n\frac{kT}{E_f} = n * 0.0036 = n * 0.36\%$$

ENGINEERING PHYSICS

Class 24 .   Quiz …

The concepts which are correct are….

1. ***Sommerfeld model treats the free electrons as Fermi particles.***
2. ***According to QFET all free electrons participate in the conduction process.***
3. ***The electrons energies in quantum free electron theory follow Fermi-Dirac statistics.***
4. ***The value of Fermi distribution function at absolute zero is 1 under the condition $E>E_F$***
5. ***The quantum free electron theory explains the temperature dependence of conductivity in metals.***

THANK YOU

Sunitha VR, Ph.D.

Assistant Professor, Department of Science and Humanities

sunithavr@pes.edu

+91 80 21722683 Extn 716