ENGINEERING PHYSICS

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Demerits of quantum free electron theory

Class # 46

- Quantum free electron theory was able to provide answers to the drawbacks of classical free electron theory
- However, it was unable to explain some phenomena of which two are relevant to this lesson

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Demerits of quantum free electron theory

HALL COEFFICIENT

The Hall effect refers to the transverse potential difference, V_H, that appears across a current carrying metallic strip placed in a magnetic field which is perpendicular to the surface of the strip

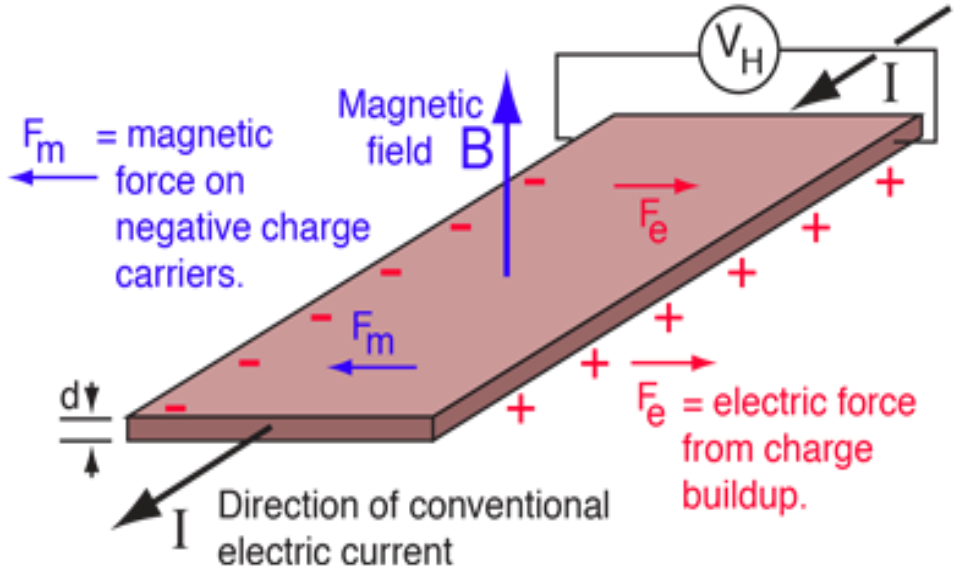

Image Courtsey: Hyperphysics Concepts

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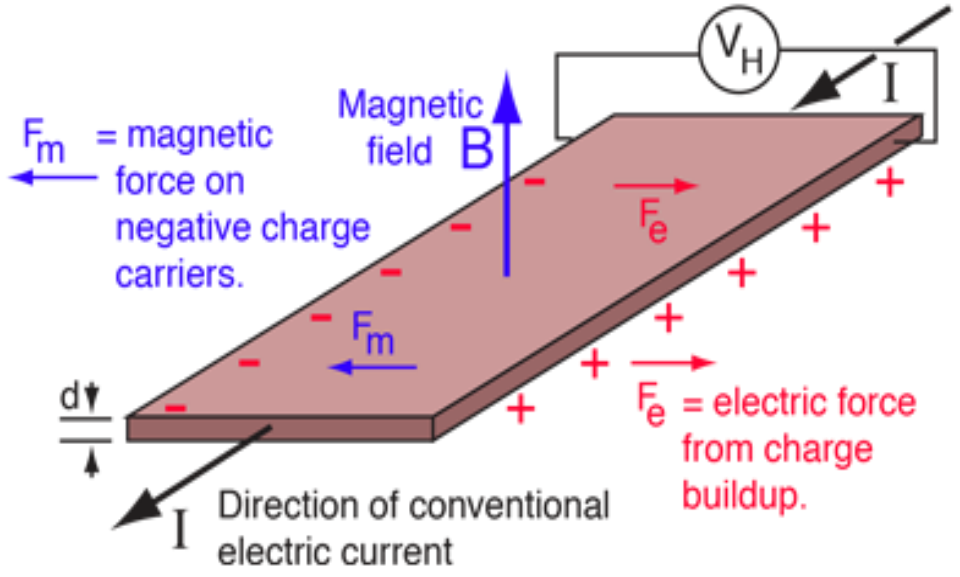
HALL COEFFICIENT

If the transverse electric field is E_H, current density j_x and magnetic field B, then we define the Hall coefficient as $R_H = \frac{E_H}{j_x B}$.

This turns out to be $R_H = -\frac{1}{ne}$



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HALL COEFFICIENT

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then we define the Hall coefficient as $R_H = \frac{E_H}{j_x B}$.

This turns out to be $R_H = -\frac{1}{ne}$. Metals therefore must show negative Hall coefficients.

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The table shows that in general metals report negative values. However, we see some metals show positive Hall coefficients.

QUANTUM FREE ELECTRON THEORY COULD NOT EXPLAIN THIS FEATURE

Metal	Valency	R_H ($m^3 A^{-1} s^{-1}$) (Experiment) $\times 10^{-11}$	R_H ($m^3 A^{-1} s^{-1}$) (Theory) $\times 10^{-11}$	$\mu_H = \lvert\sigma R_H\rvert$ ($cm^2 V^{-1} s^{-1}$)
Na	1	−24.8	−24.6	50.8
K	1	−42.8	−47.0	57.9
Ag	1	−9.0	−10.7	53.9
Cu	1	−5.4	−7.4	31.6
Au	1	−7.2	−10.6	31.9
Mg	2	−8.3	−7.2	18.5
Al	3	−3.4	−3.5	12.6
Co	2	+36		
Be	2	+24		
Zn	2	+3.3		

Image courtesy: Chegg.com

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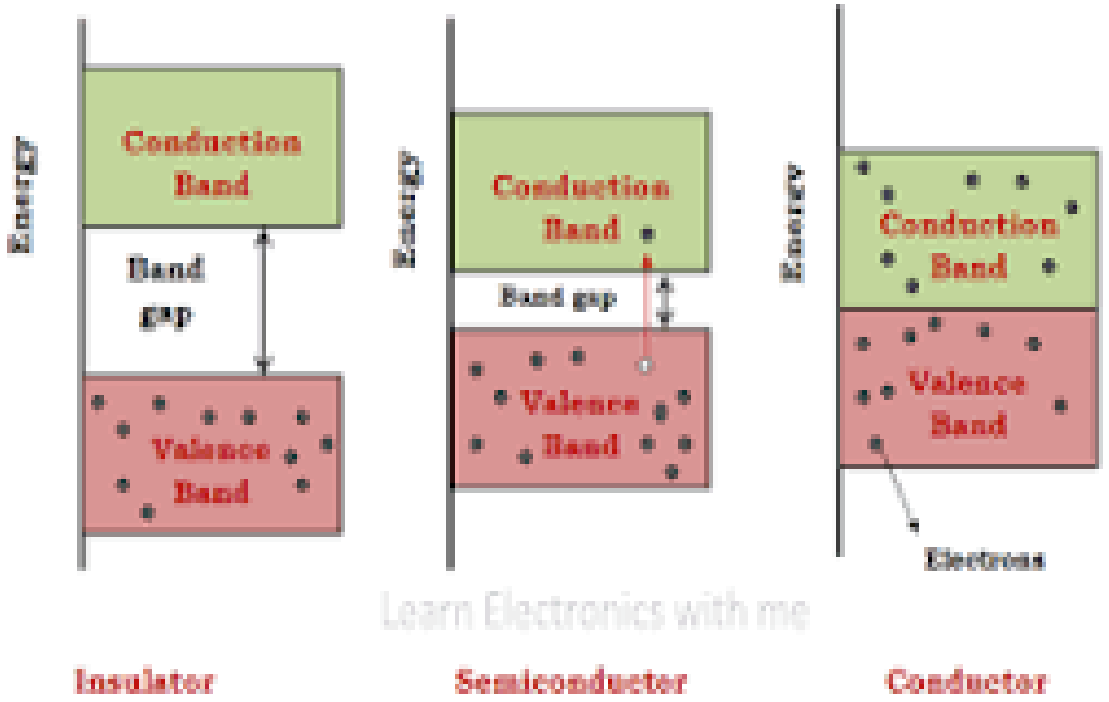
The diagram shows the schematic band diagram for metals, semiconductors and insulators. QUANTUM FREE ELECTRON THEORY COULD NOT EXPLAIN THIS FEATURE ALSO



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Thus, QUANTUM FREE ELECTRON THEORY COULD NOT

- **EXPLAIN WHY CERTAIN METALS REPORT POSITIVE HALL COEFFICIENTS**
- **EXPLAIN WHY SEMICONDUCTORS AND INSULATORS HAVE BANDS WITH GAPS IN BETWEEN**