HALL EFFECT

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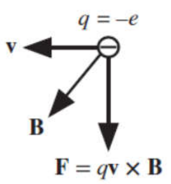
Hall Effect

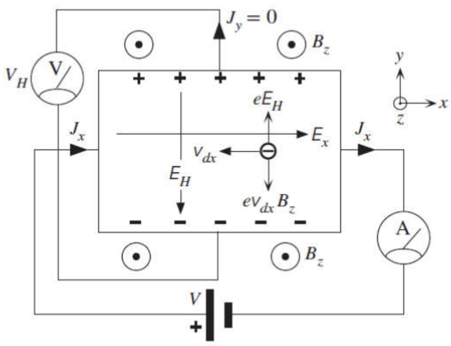
- Voltmeter gives a reading V_H when a transverse magnetic field B_z is applied.
- Lorentz force is applied on the electrons in the downward direction.
- Hall Field in the $-y$ direction.
- In steady-state:

$$eE_H = ev_{dx}B_z$$

$$J_x = env_{dx}$$

$$E_H = \left(\frac{1}{en}\right)J_xB_z$$





Hall Coefficient

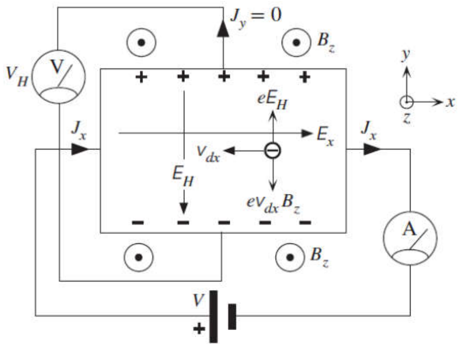
- Hall coefficient (R_H) measures the Hall field, along y, per unit transverse applied current and magnetic field.

$$R_H = \frac{E_y}{J_x B_z}$$

- For metals:

$$E_y = -\left(\frac{1}{en}\right) J_x B_z$$

$$R_H = -\frac{1}{en}$$



Metal	R_H ($m^3 A^{-1} s^{-1}$) (Experiment) $\times 10^{-11}$
Na	−24.8
K	−42.8
Ag	−9.0
Cu	−5.4
Au	−7.2

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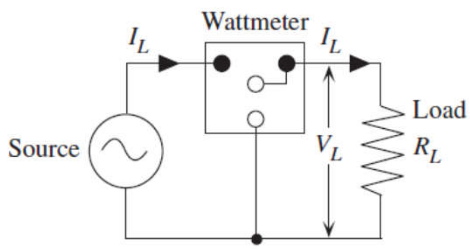
Hall Effect Wattmeter

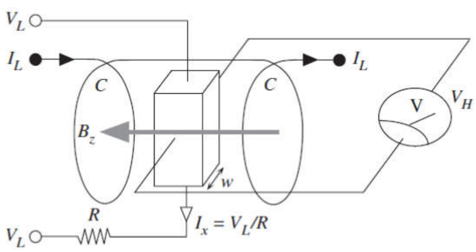
$$B_z \propto I_L$$

$$V_H = wE_H = wR_H J_x B_z$$

$$\propto I_x B_z \propto V_L I_L$$

- The voltmeter can be calibrated to read directly the power dissipated in the load.





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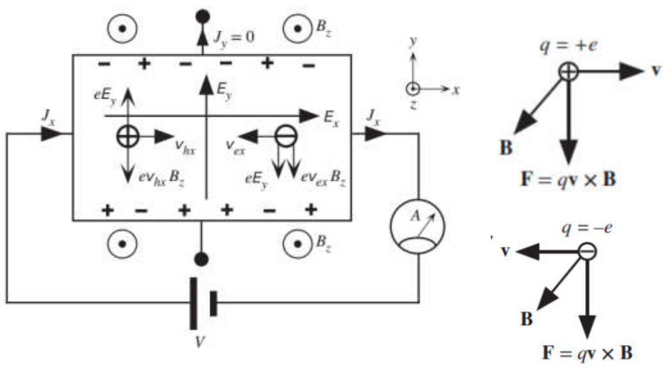
Hall Effect in Semiconductors

- Both positive and negative charge carriers → holes and electrons.
- Remember relationships between drift velocity, mobility and force.

$$v_e = \mu_e E = \frac{\mu_e}{e} F$$

- Both electrons and holes experience a Lorentz force in the same direction.

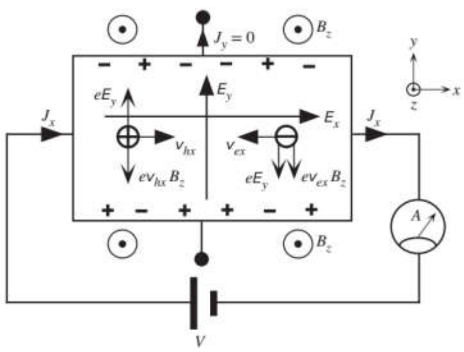


Open-Circuit

$$J_y = J_h + J_e = epv_{hy} + env_{ey} = 0$$

$$pv_{hy} = -nv_{ey}$$

- Either the electron or hole drift velocity must be reversed from its usual direction → holes drifting in the opposite direction.



Force Equations

- **Holes:**

$$F_{hy} = eE_y - ev_{hx}B_z$$

$$\frac{ev_{hy}}{\mu_h} = eE_y - ev_{hx}B_z$$

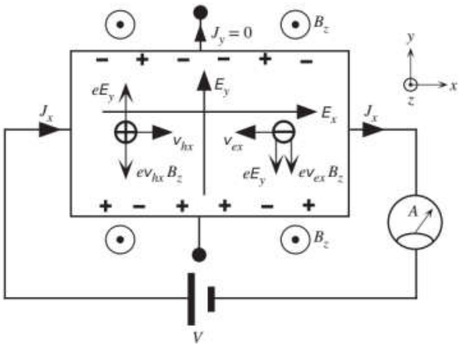
$$\frac{v_{hy}}{\mu_h} = E_y - \mu_h E_x B_z$$

- **Electrons:**

$$-F_{ey} = eE_y + ev_{ex}B_z$$

$$\frac{ev_{ey}}{\mu_e} = eE_y + ev_{ex}B_z$$

$$\frac{v_{ey}}{\mu_e} = E_y + \mu_e E_x B_z$$



R_H

$$p\mu_h E_y - p\mu_h^2 E_x B_z = -n\mu_e E_y - n\mu_e^2 E_x B_z, \qquad E_y = \frac{B_z E_x (p\mu_h^2 - n\mu_e^2)}{(p\mu_h + n\mu_e)}$$

$$J_x = epv_{hx} + env_{ex} = (p\mu_h + n\mu_e)eE_x$$

$$R_H = \frac{E_y}{J_x B_z} = \frac{p\mu_h^2 - n\mu_e^2}{e(p\mu_h + n\mu_e)^2}$$