# ELECTRONICS DEVICES AND CIRCUITS

## OBJECTIVE

# MOBILTY AND VARIATION OF MOBILITY WITH TEMPERATURE,

# ❖ Carrier Mobility

Macroscopic understanding

$$\mu = \frac{V_d}{E}$$

<u>In a  perfect Crystal</u>

$$\rho = 0$$

$$\sigma \rightarrow \infty$$

It is a superconductor

Microscopic understanding? (what the carriers themselves are doing?)

$$\mu = \frac{q\tau}{m^*}$$

$$m_e^* \langle\, m_h^* \quad in\ general$$

$$m_e^*;\ n - type$$

$$m_h^*;\ p - type$$

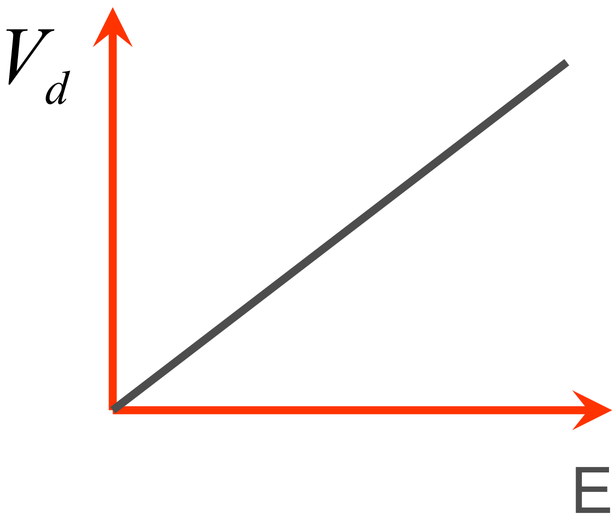
# $\mu$

- A *perfect crystal has a perfect periodicity* and therefore the potential seen by a carrier in a perfect crystal is completely periodic.
- So the *crystal has no resistance to current flow* and behaves as a *superconductor*. The perfect periodic potential does not *impede the movement of the charge carriers*. However, in a real device or specimen, the presence of impurities, interstitials, subtitionals, temperature , etc. creates a resistance to current flow.
- The presence of all these *upsets the periodicity of the potential* seen by a charge carrier.

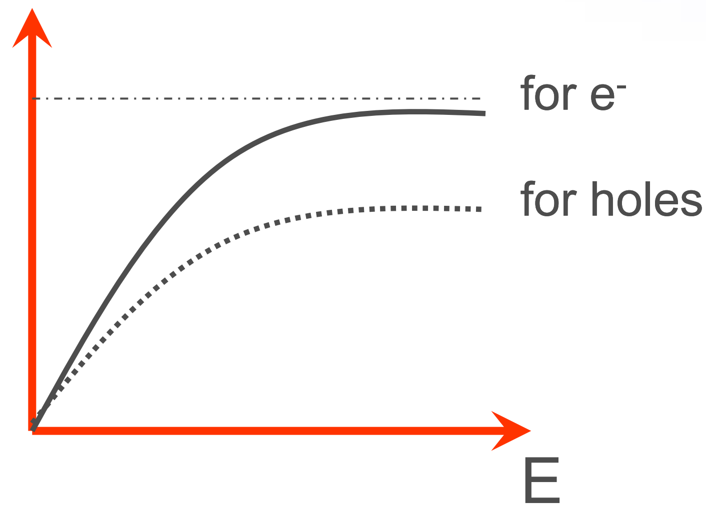
# ❖ Saturated Drift Velocities

$$V_d = \mu E$$

So one can make a carrier go as fast as we like just by increasing the electric field!!!




(a) Implication of above eqn.

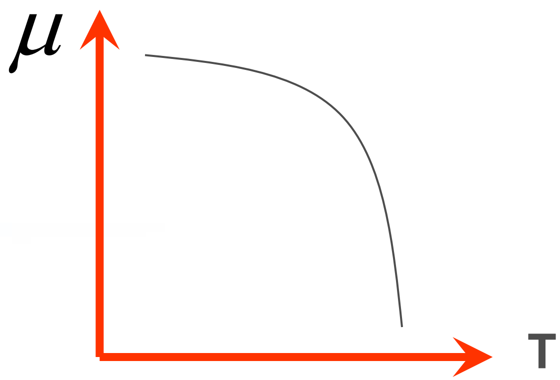



(b) Saturation drift velocity

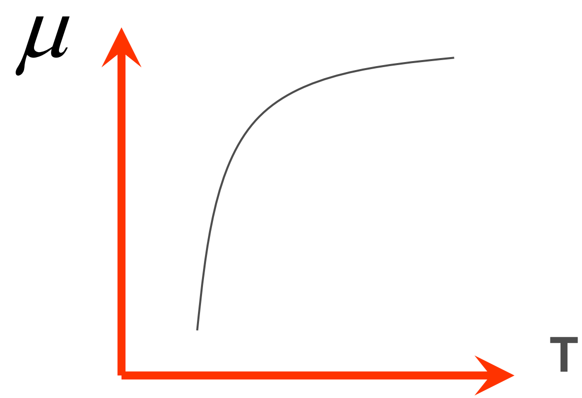
## ❖ Saturated Drift Velocities

- The equation of $V_d = \mu . E$ does not imply that **$V_d$** increases linearly with applied field **E.**
- **$V_d$** increases linearly for low values of **E** and then it saturates at some value of **$V_d$** which is close **$V_{th}$** at higher values of **E**.
- Any further increase in **E** after saturation point does not increase **$V_d$** instead warms up the crystal.

# ❖ Mobility variation with temperature



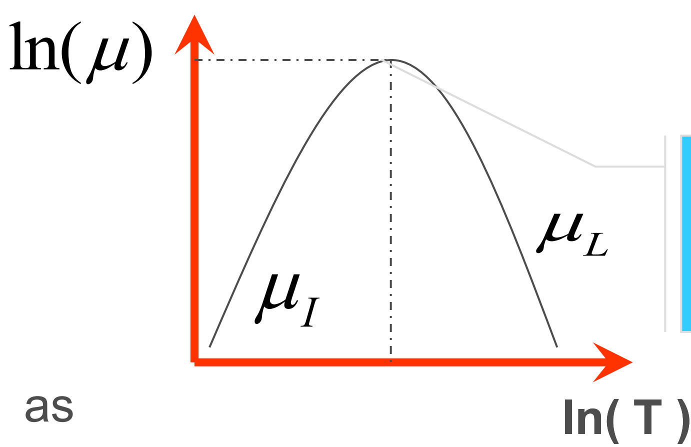

High temperature




Low temperature

$$\frac{1}{\mu_T} = \frac{1}{\mu_L} + \frac{1}{\mu_I}$$

This equation is called as Mattheisen's rule.




Peak depends on the density of impurities