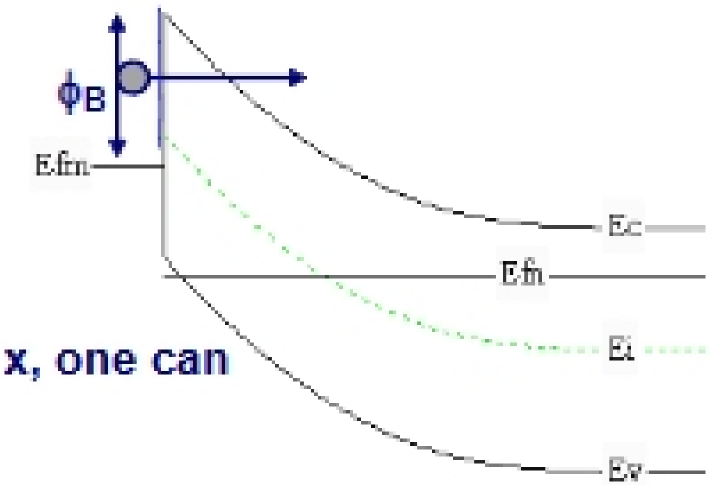
Tunneling

- We derived the thermionic emission over the barrier for electrons having E exceeding the barrier height
- In tunneling, electrons with energy lower than the barrier height can penetrate the barrier and contribute to tunneling current
- Tunnel current is particularly important for a reverse biased M-S junction
- To compute tunneling current we solve Schrodinger's Equation



- Assuming that V(x) is a slowly varying function of x, one can express

$$\psi(L) = \psi(0)e^{-\int_0^L \sqrt{\frac{2m^*(V(x)-E)}{\hbar^2}}dx}$$

- **The tunneling or transmission probability can be solved for a triangular potential barrier**

$$J_{tunnel} = q v_x n \Theta$$

Here $E = \phi_B/L$ is the average built-in electric field

$$\Theta = e^{\left(-\frac{4}{3}\frac{\sqrt{2qm^*}}{\hbar}\frac{\phi_B^{3/2}}{E}\right)}$$

Thermionic Emission

- A metal-semiconductor junction is an obvious component of any semiconductor device. Typically, most M-S junctions form a Schottky contact or rectifying contact due to the mismatch between the Fermi energies of the metal and the semiconductor
- Work-function engineering of the metal can lead to a low resistance ohmic contact or non-rectifying contact, but hard to realize in practice
  - WF requirement for n-type ohmic metal contact < semi. Electron affinity
  - WF requirement for p-type metal > semi electron affinity + energy bang-gap
  - Most metals have work-function between 4eV and 5eV
- Thus, we make tunnel contact by heavily doping the semiconductor layer through which the carriers can readily tunnel

$$\Theta = e^{\left(-\frac{4}{3}\frac{\sqrt{2qm^*}}{\hbar}\frac{\phi_B^{3/2}}{E}\right)}$$

✓Higher doping leads to higher E

✓Lower barrier height favors tunneling

✓Lower mass favors tunneling