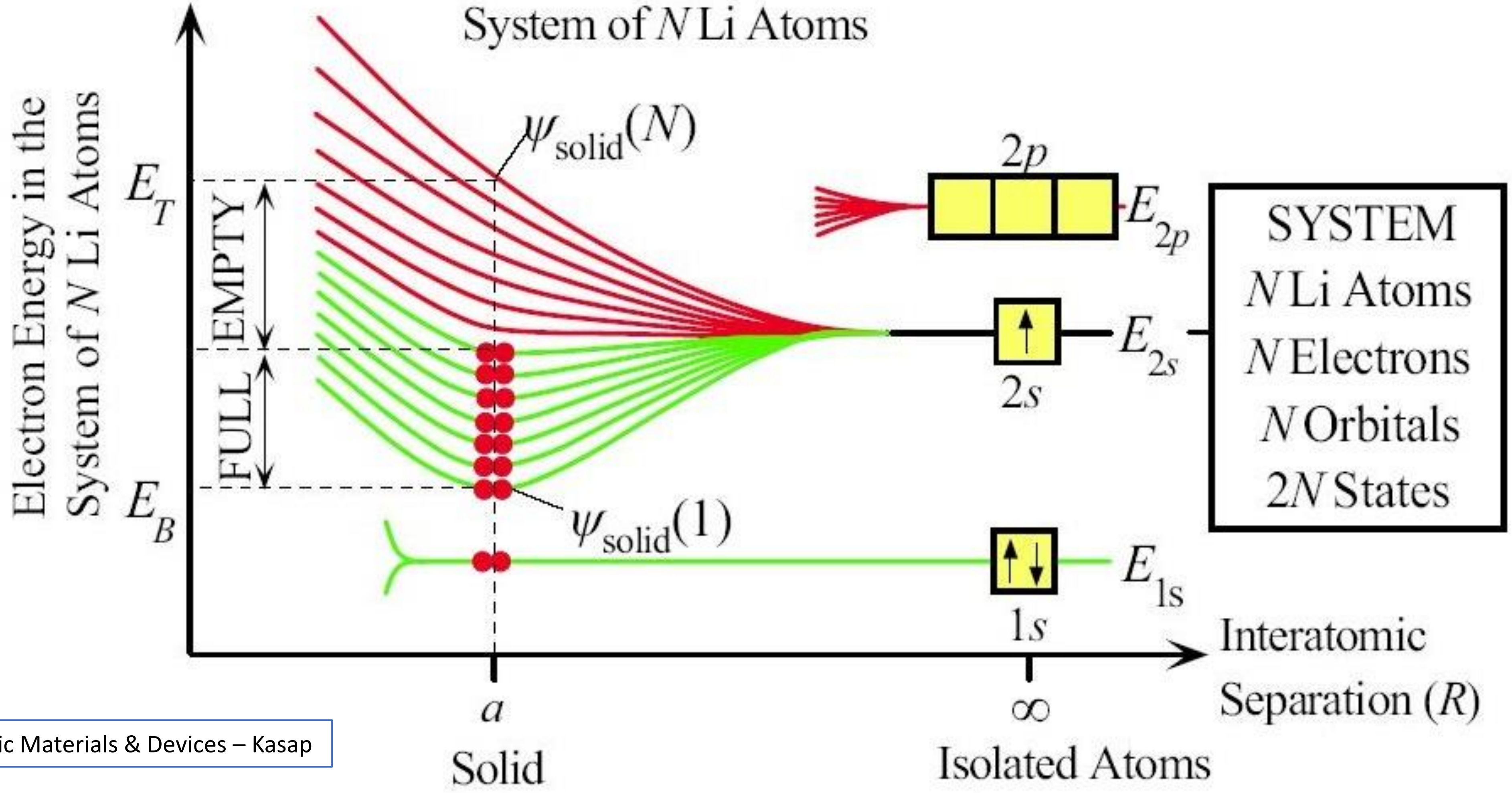
Density of states

$$g(E) = \frac{1}{2\pi^2} \left(\frac{2m^*}{\hbar^2} \right)^{3/2} E^{1/2}$$

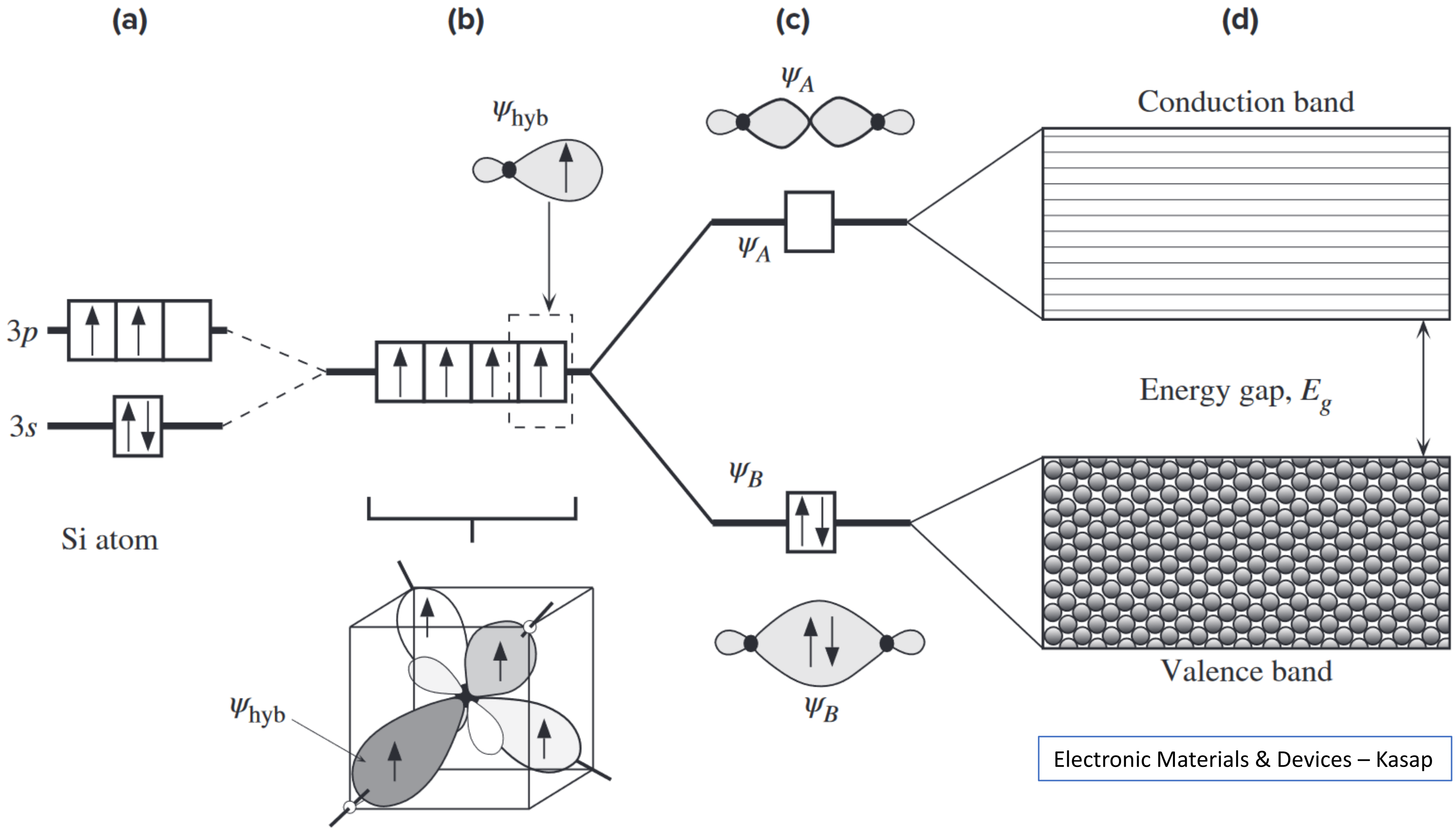
Dr Mohammad Abdur Rashid

Formation of solid - Lithium



Electronic Materials & Devices – Kasap

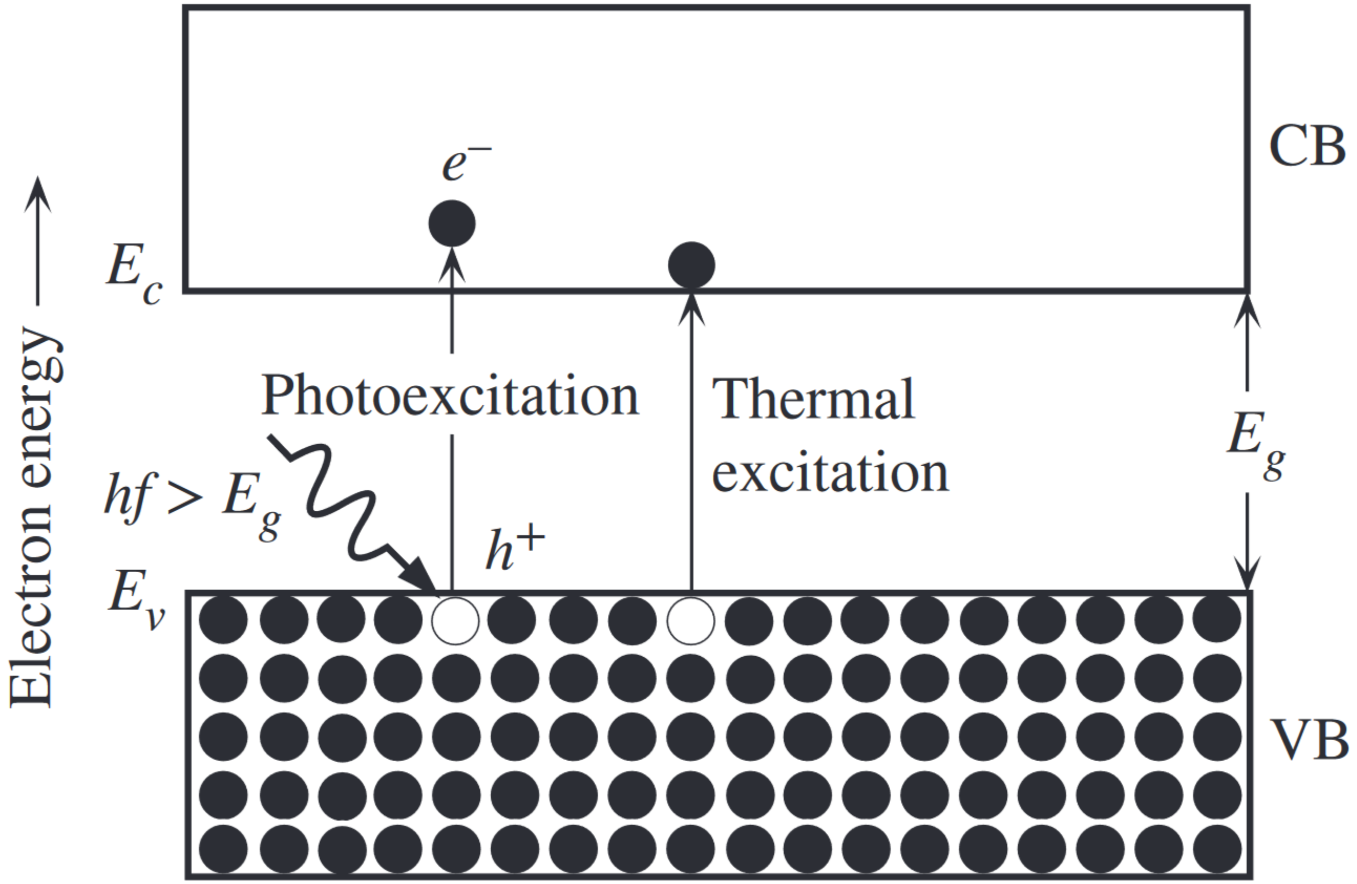
Formation of energy band in silicon crystal



Electronic Materials & Devices – Kasap

Excitation of electrons from VB to CB

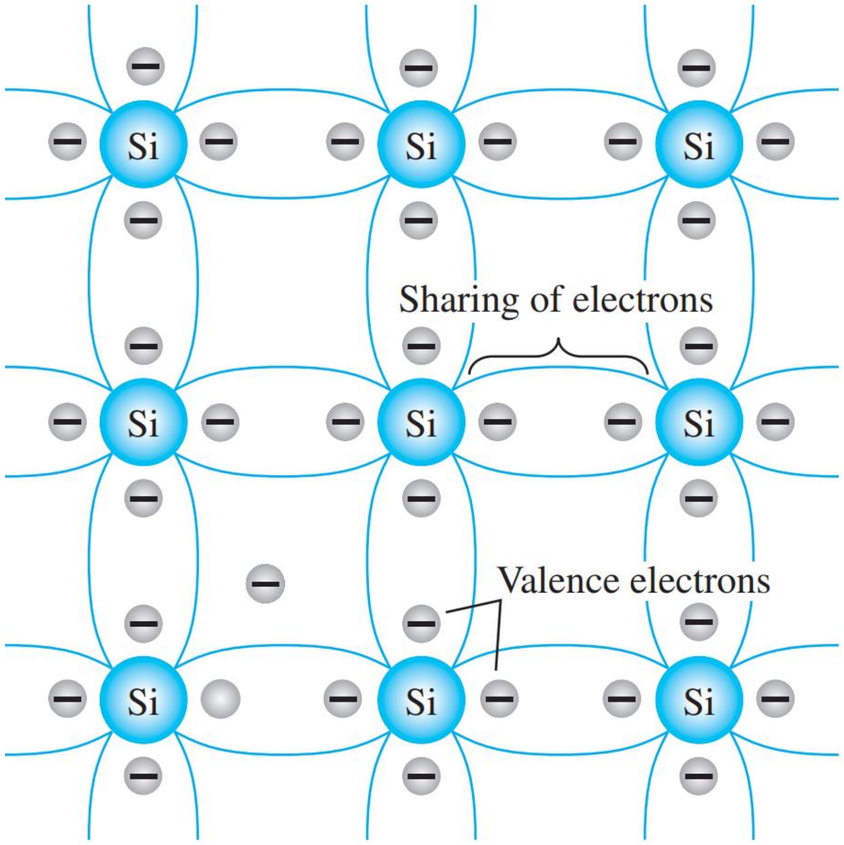
At room temperature



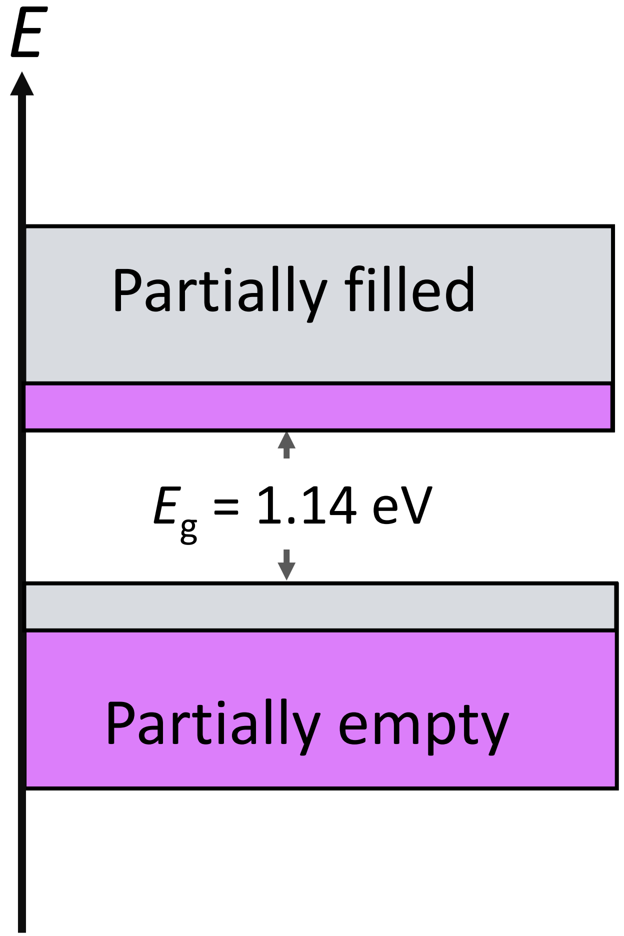
Electronic Materials & Devices – Kasap

Electron and Hole in intrinsic silicon

At room temperature there are approximately 1.5×10^{10} free carriers in 1 cm^3 of *intrinsic* silicon.



Electronic Devices and Circuit Theory – Boylestad, Nashelsky



Density of states

- Energy bands: A number of closely-spaced energy levels/states

- Density of states, $g(E)$:

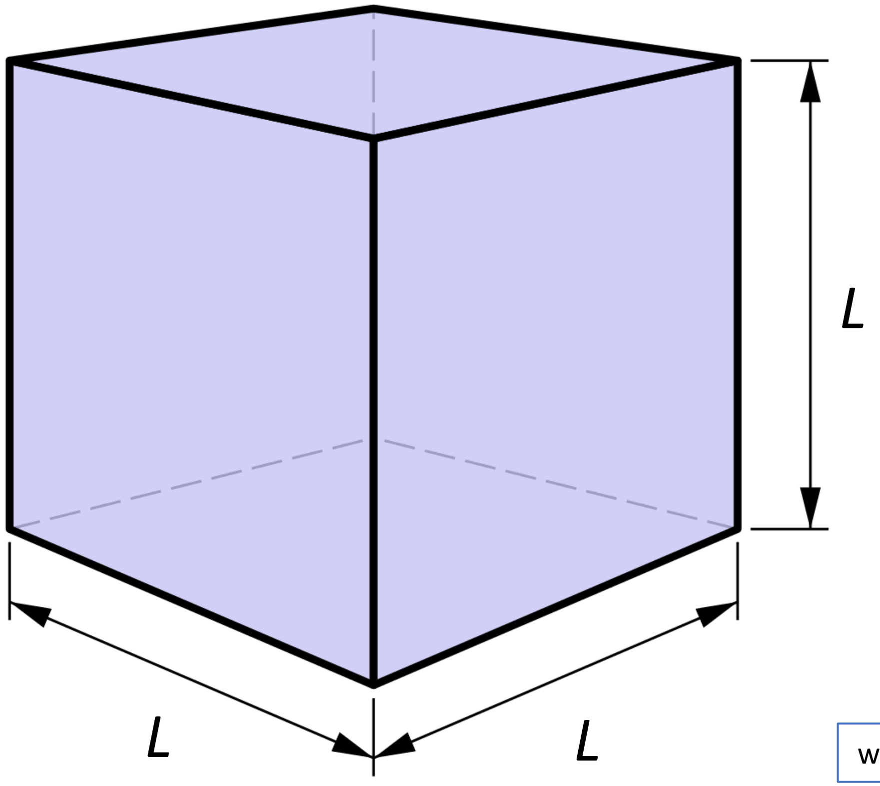
  - $g(E)$ is the number of states per unit volume per unit energy range

  - $g(E)\,\mathrm{d}E$ is the number of states per unit volume in the energy range $(E, E + \mathrm{d}E)$

$$g(E) \equiv \frac{\text{number of states in } \Delta E}{\Delta E \times \text{volume}}$$

Density of states

Consider a cube of semiconductor crystal with length *L* on each side



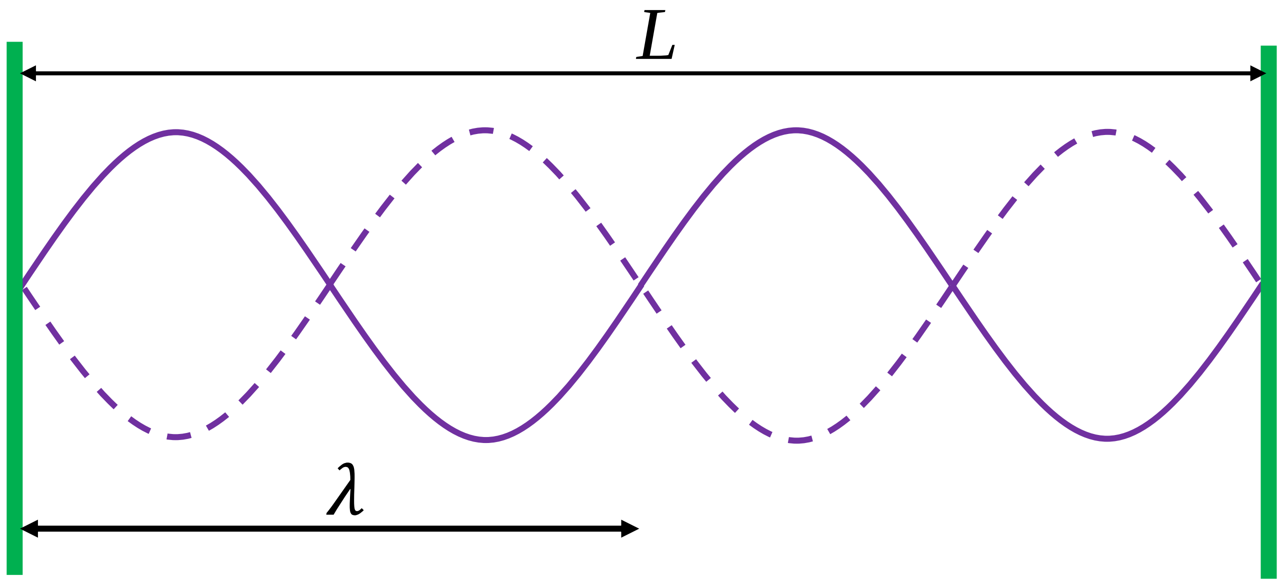
wikipedia

Density of states

Consider a cube of semiconductor crystal with length L on each side

The electron waves in the crystal are standing waves

$$\lambda_x = \frac{L}{n_x}$$



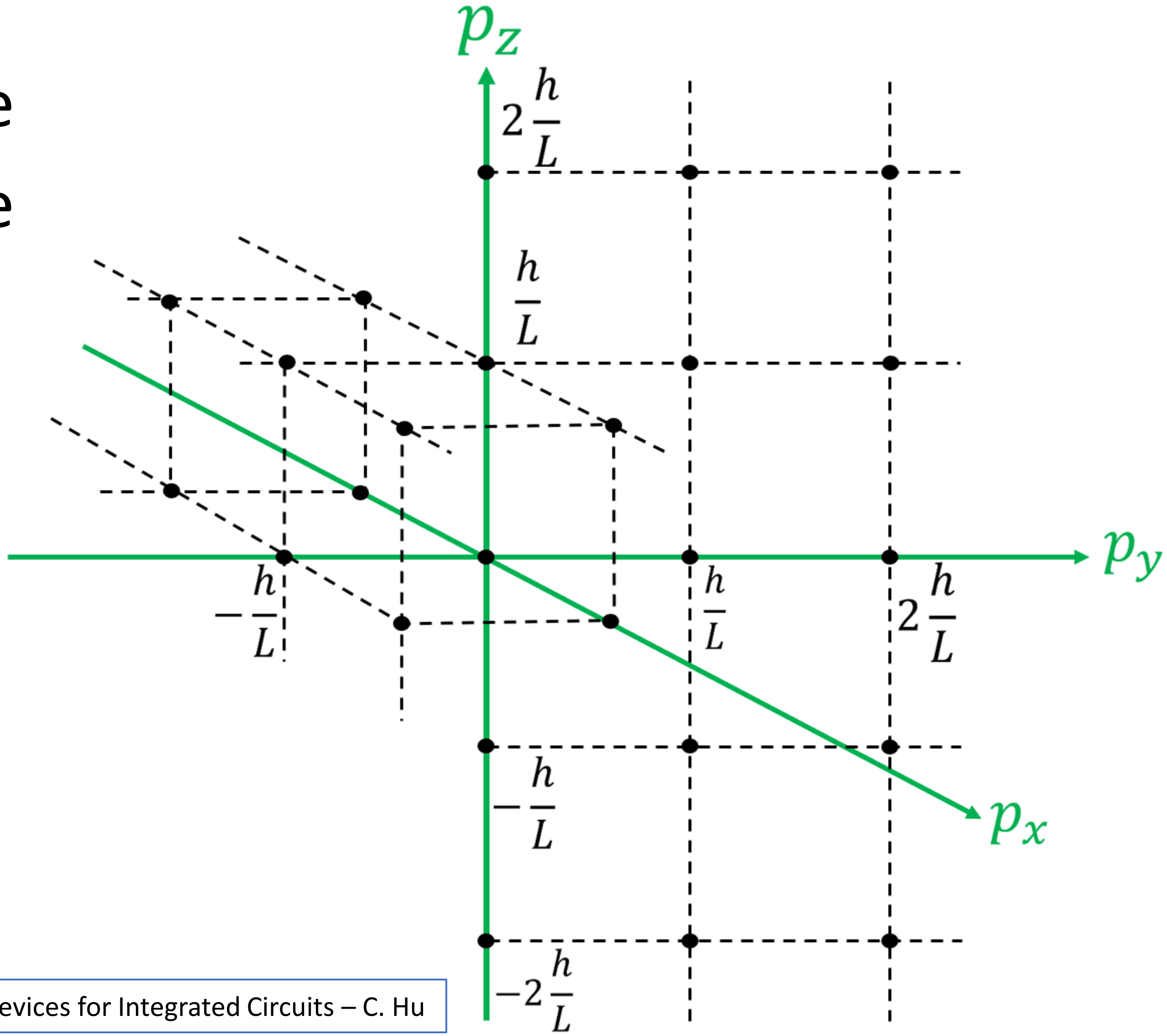
n_x is equal to 1, 2, 3 . . . .

Density of states

The wavelength is related to the electron momentum through the de Broglie relationship

$$p_x = \pm\frac{h}{\lambda_x} = \pm\frac{n_x h}{L}$$

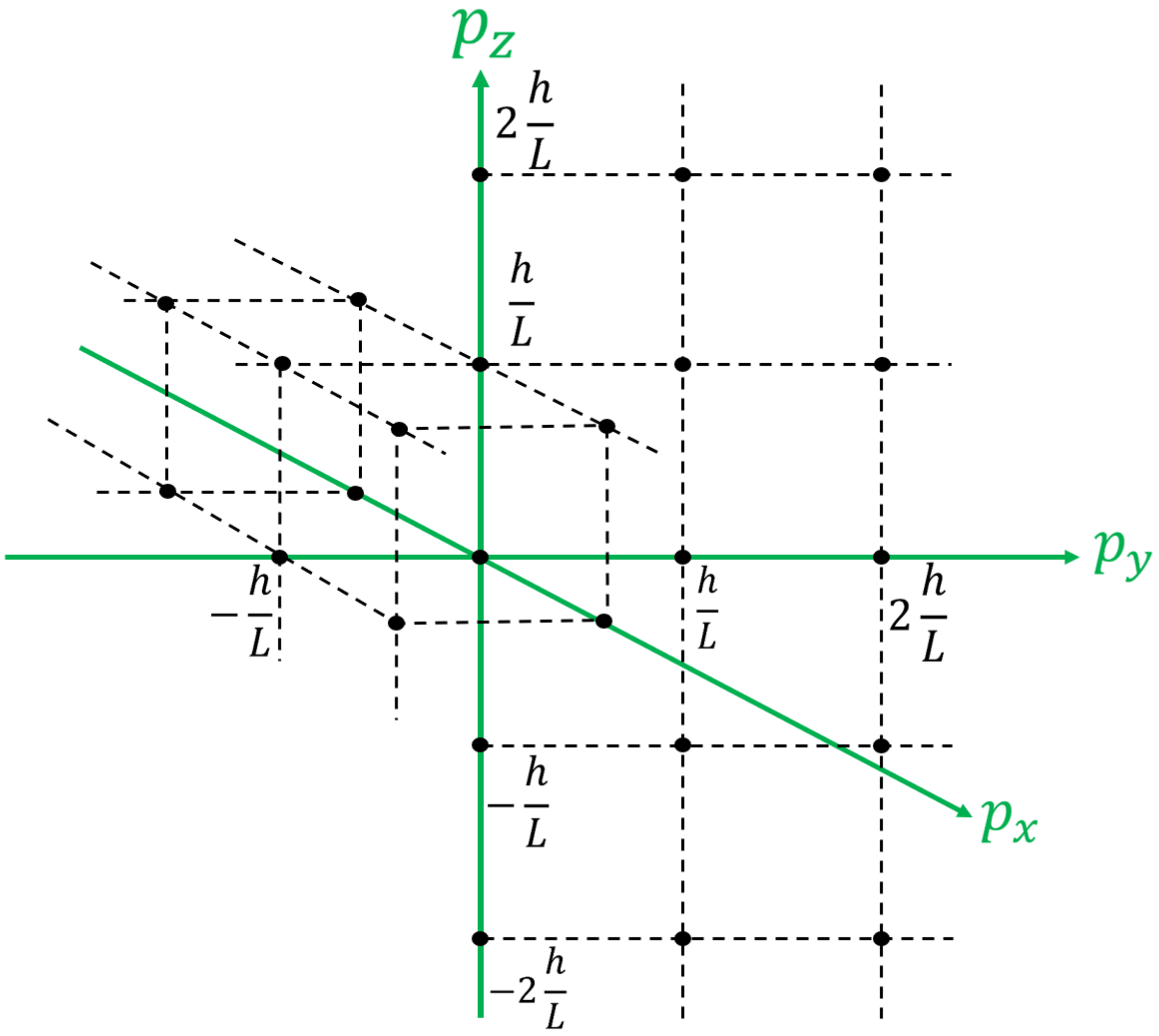
n_x is equal to 1, 2, 3 . . . .



Modern Semiconductor Devices for Integrated Circuits – C. Hu

Density of states

Allowed energy states occupy points separated from one another by h/L in p_x, p_y, and p_z. There are two allowed states (the factor of 2 accounting for the two spin directions) for every cube of h^3/L^3 volume in the momentum space. Each state therefore occupies a volume of $h^3/2L^3$.



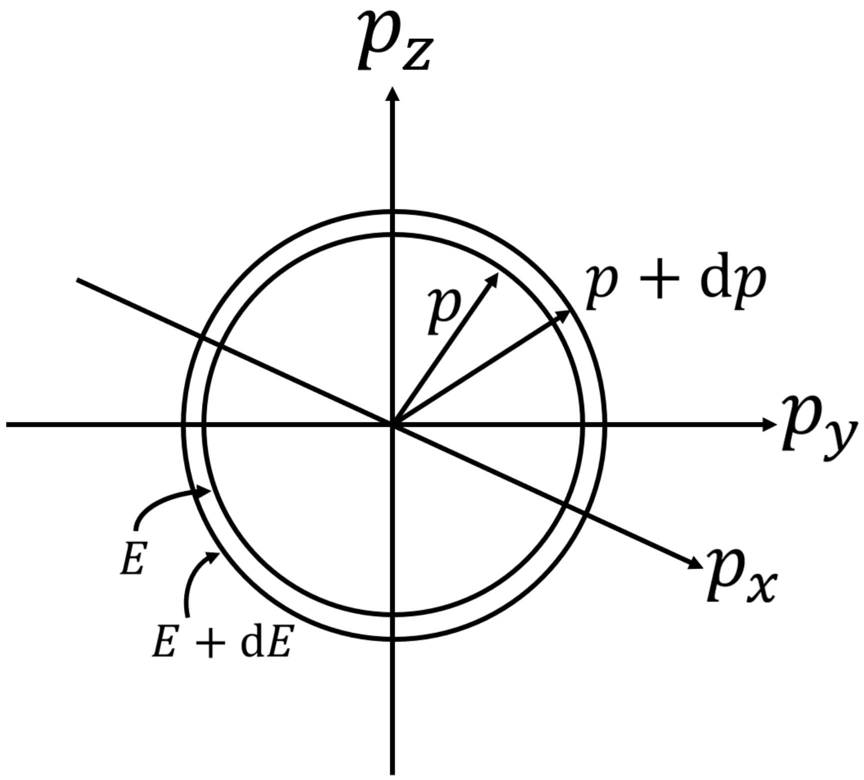
Modern Semiconductor Devices for Integrated Circuits – C. Hu

Density of states

A sphere in the momentum space represents a constant total momentum, *p*, and therefore a constant kinetic energy, *E*.

$$E = \frac{p^2}{2m^*}$$

m^* is the effective mass



Modern Semiconductor Devices for Integrated Circuits – C. Hu

Density of states

Kinetic energy: $$E = \frac{p^2}{2m^*}$$

Derivative of *E* w.r.t. *p*: $$\frac{\mathrm{d}E}{\mathrm{d}p} = \frac{p}{m^*} = \frac{\sqrt{2m^*E}}{m^*} = \sqrt{\frac{2E}{m^*}}$$

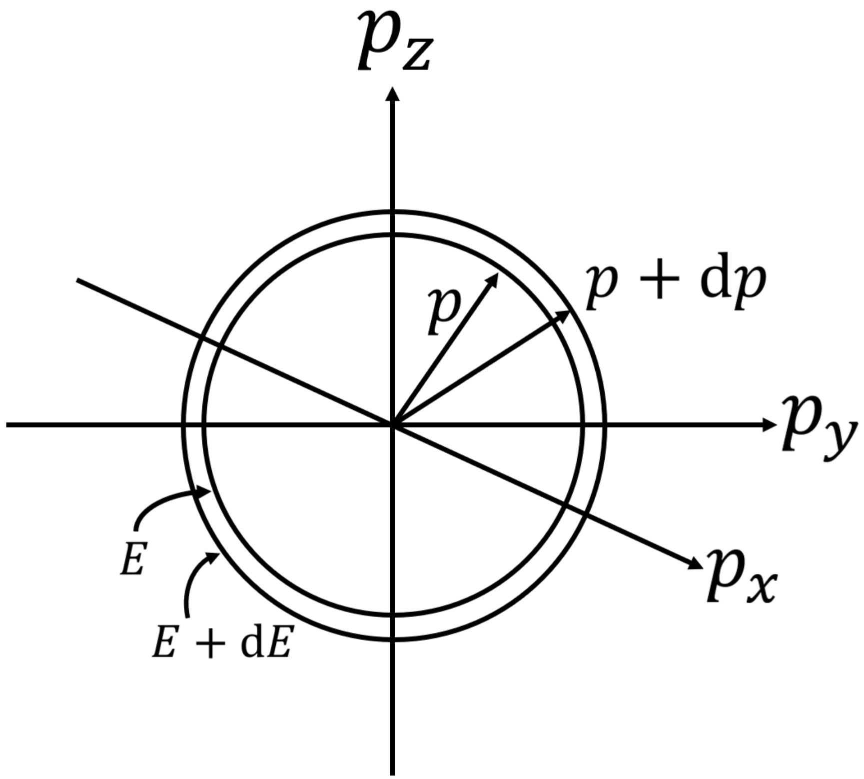
Rearranging: $$\mathrm{d}p = \sqrt{\frac{m^*}{2E}}\mathrm{d}E$$

Density of states

Two spheres that differ in energy dE have two radii that differ by dp:

$$\mathrm{d}p = \sqrt{\frac{m^*}{2E}}\mathrm{d}E$$

$$\text{Volume} = 4\pi p^2 \mathrm{d}p = 4\pi(2m^* E)\mathrm{d}p$$
$$= 8\pi m^* \sqrt{\frac{m^* E}{2}}\mathrm{d}E$$



Modern Semiconductor Devices for Integrated Circuits – C. Hu

Density of states

The number of states contained in this shell between *E* and *E* + d*E* is

$$8\pi m^* \sqrt{\frac{m^* E}{2}} \times \frac{2L^3}{h^3} \mathrm{d}E$$

The number of states per unit volume per unit energy is

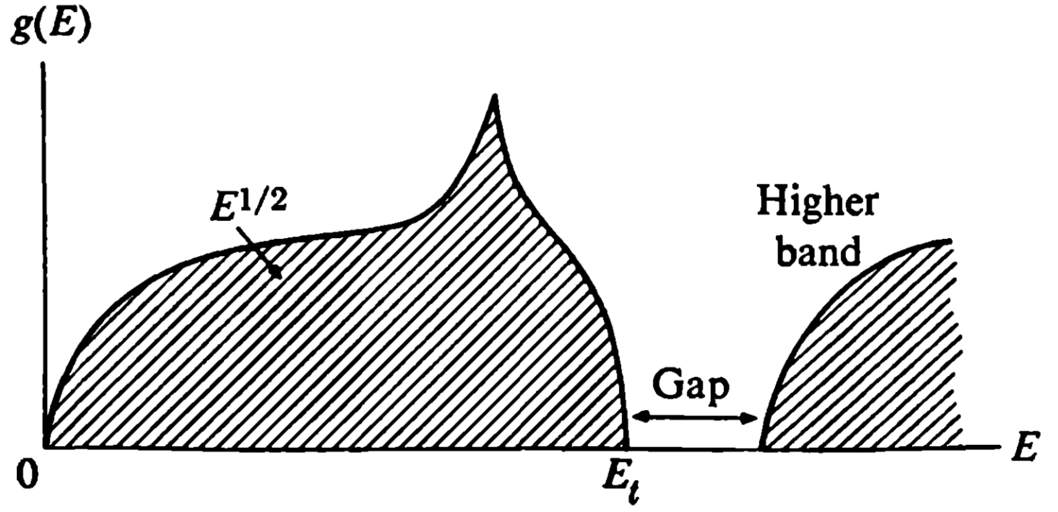
$$g(E) = \frac{8\pi m^* \sqrt{2m^* E}}{h^3}$$

Density of states

Using $\hbar = h/2\pi$, reduced Planck's constant, we have

$$g(E) = \frac{1}{2\pi^2}\left(\frac{2m^*}{\hbar^2}\right)^{3/2} E^{1/2}$$

m^* is the effective mass



Elementary Solid State Physics – Ali Omar