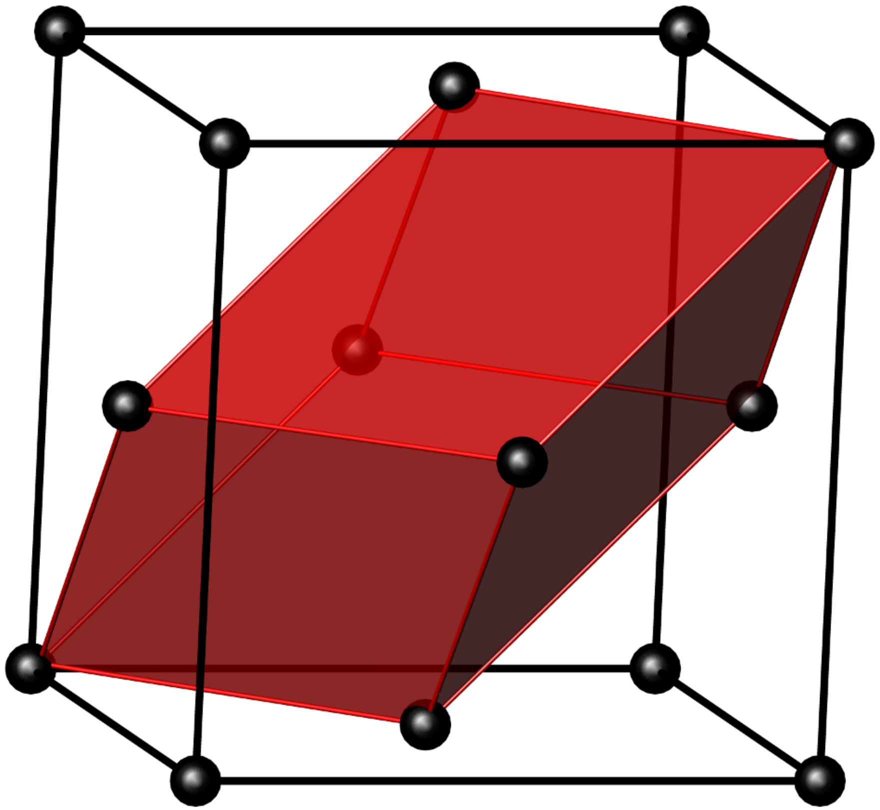
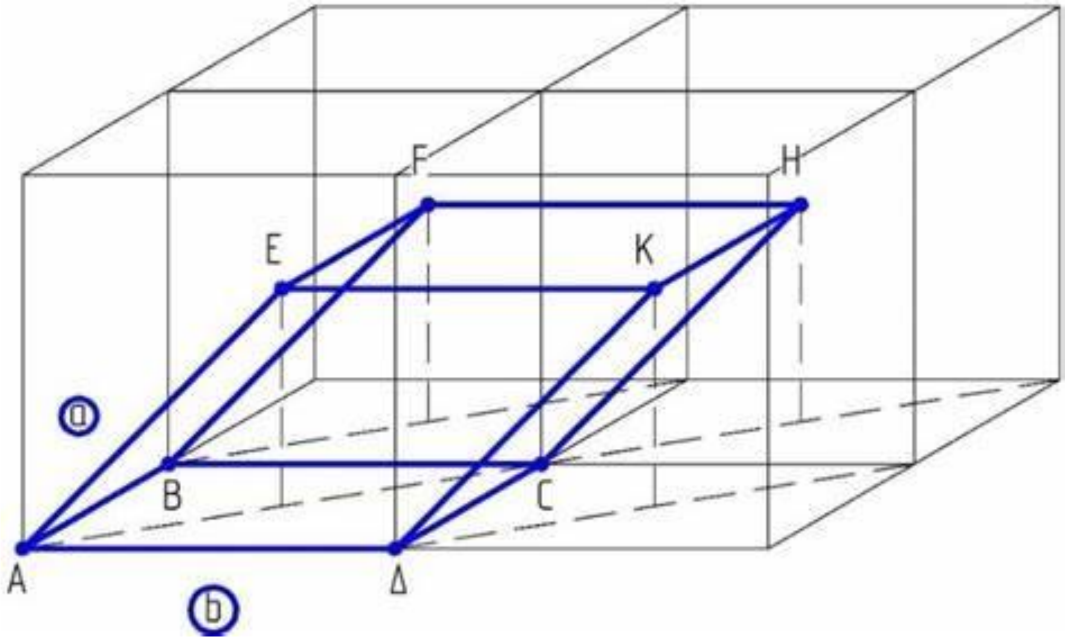
Mid I RC

Mid term I

- Don’t bring any electronic devices like computer, iPad
- Bring calculator

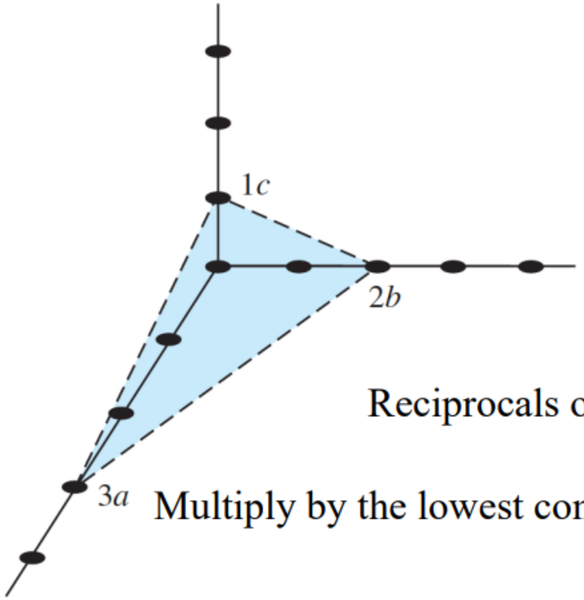
Solid-primitive cell and unit cell





Solid-how to describe a plane-miller index

Crystalline Plane and Miller Index

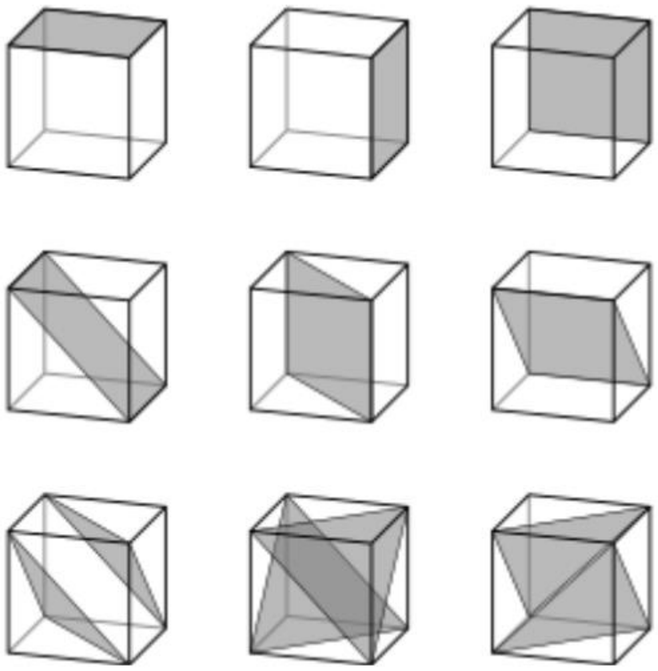


Reciprocals of the intercepts: (1/3, ½, 1)

Multiply by the lowest common denominator: (2,3,6)

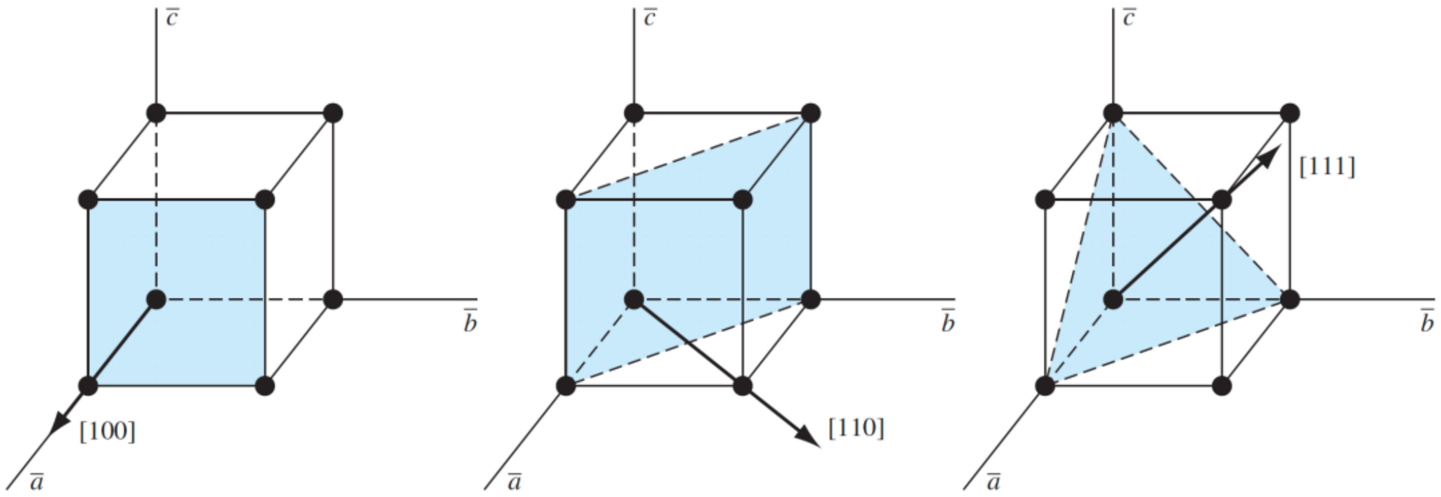
Solid-how to describe a plane-miller index

Identify crystalline plane



Solid-how to describe a direction

<u>Directions in Crystals</u>

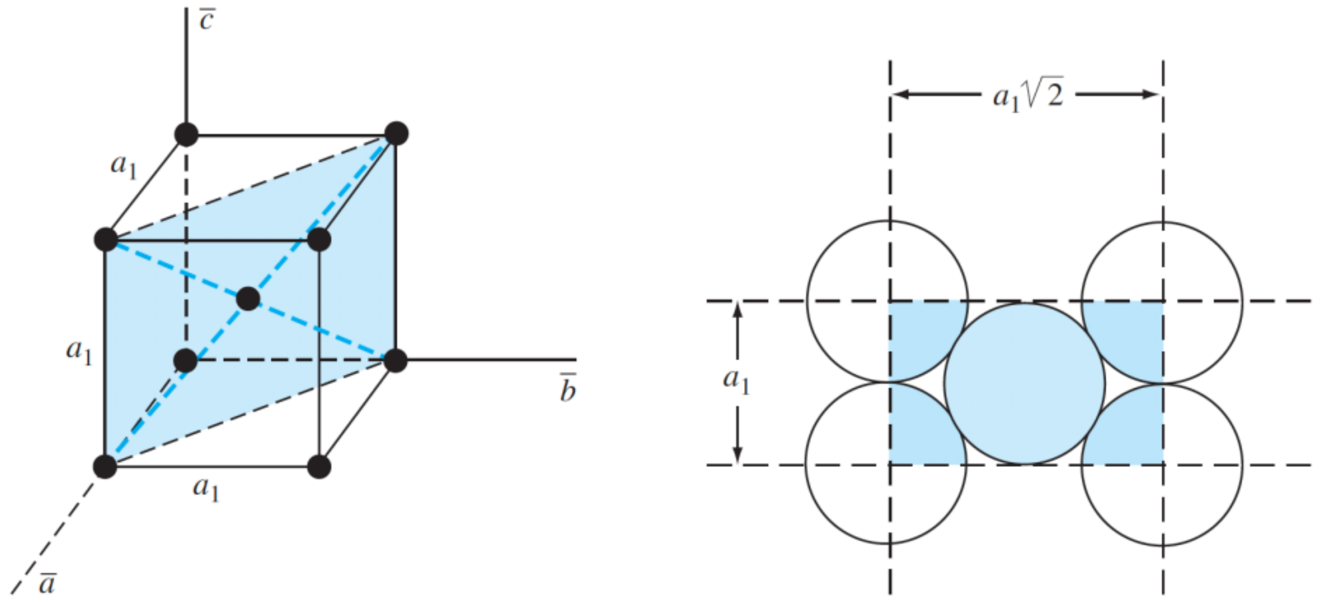


(a) (b) (c)

In cubic lattice: [hkl] direction is perpendicular to the (hkl) plane

Surface density of atoms

Crystalline Plane and Miller Index: surface density of atoms



(a) (b)

Second-order differential equation

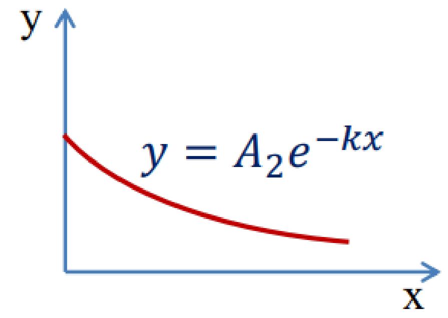
$$\frac{\partial^2 y}{\partial x^2} = k^2 y$$

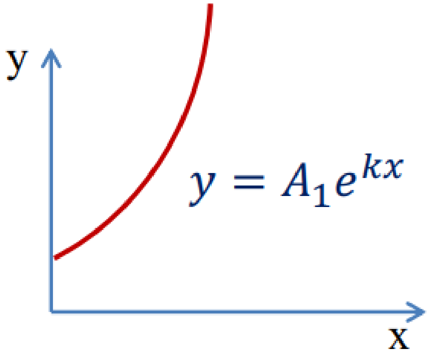
General solution: $y = Ae^{bx}$

Plug into the equation: $b^2 Ae^{bx} = k^2 Ae^{bx}$

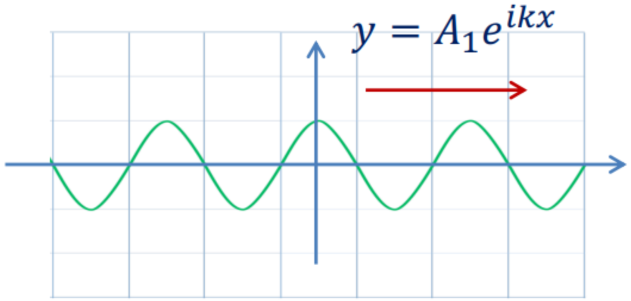
$$\Rightarrow b = \pm k$$

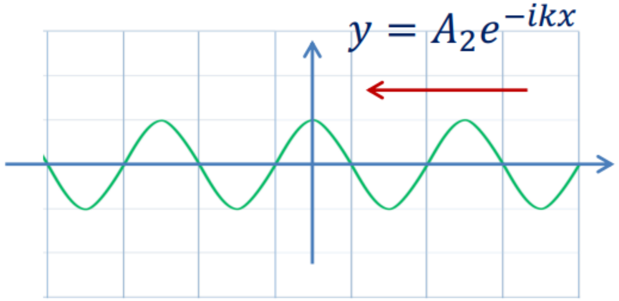
$$\Rightarrow y = A_1 e^{kx} + A_2 e^{-kx}$$





Second-order differential equation





$$\frac{\partial^2 y}{\partial x^2} = -k^2 y$$

General solution: $y = Ae^{bx}$

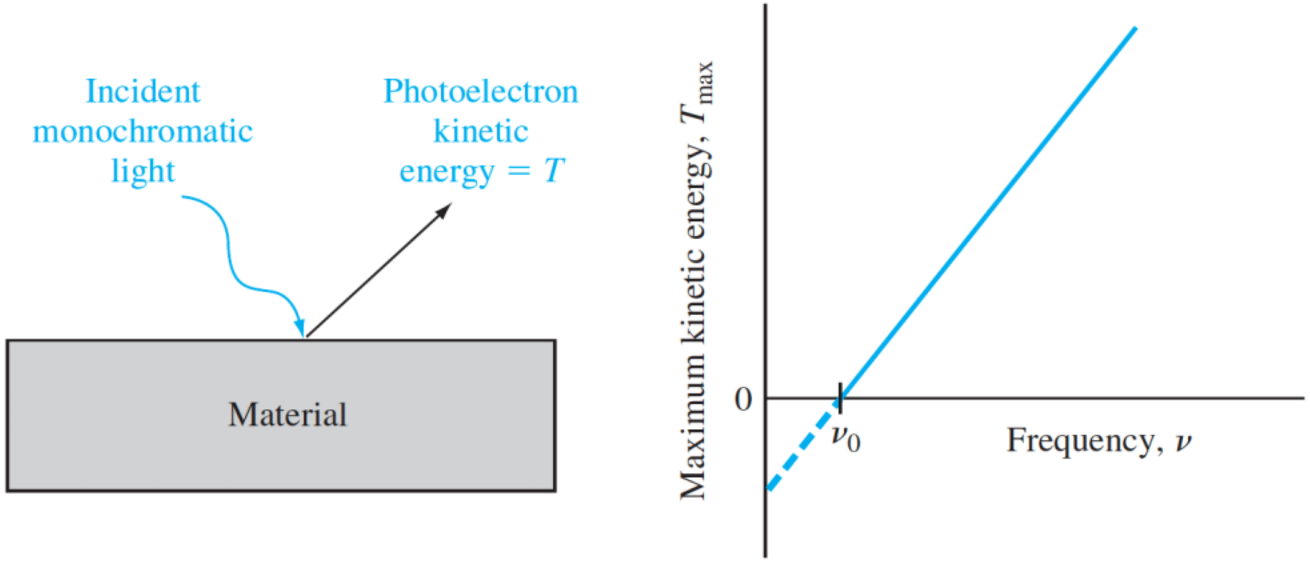
Plug into the equation: $b^2 A e^{bx} = -k^2 A e^{bx}$

$$\Rightarrow b = \pm ki$$

$$\Rightarrow y = A_1 e^{ikx} + A_2 e^{-ikx}$$

Particle-wave duality-photo-electric experiment

③ Light wave-particle duality in 1905



(a) (b)

- ❑ Light wave is a particle: $hv = K_{max} + W_c$

Particle-wave duality-De Broglie relationship

In 1924, Louis de Broglie hypothesized in his Ph.D. thesis that matter also has wave properties. He postulated that matter particles, like photons, have a wavelength called the de Broglie wavelength, is given by:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$$

where the momentum, p, is determined by the kinetic energy ($E = p^2/2m$).

So electron can be both described by classical matter and probability wave.

General procedures in solving Schrödinger equation

- Solve Schrödinger equation

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi(x)}{\partial x^2} + V(x)\psi(x) = E\psi(x)$$

- Apply boundary condition

1. Wave function should be continuous
2. Derivative of wave function should be continuous except for the place where potential energy is infinite

- Normalize the wave function

$$\int_{-\infty}^{\infty} P(x,t)dx = \int_{-\infty}^{\infty} |\Psi(x,t)|^2 \, dx = 1$$

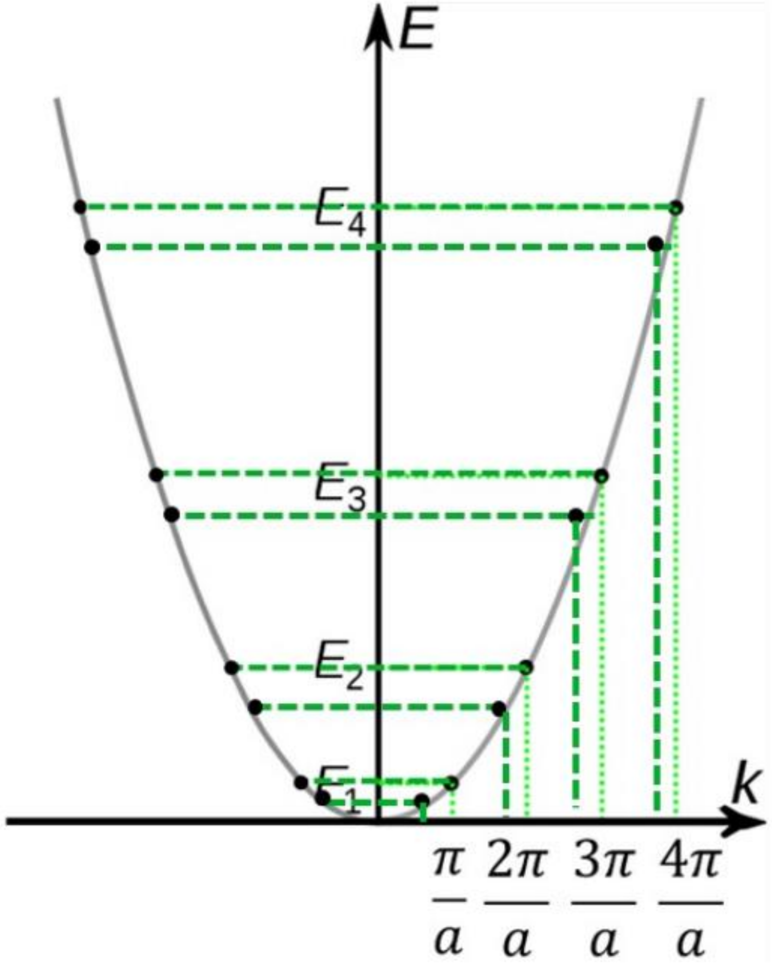
Infinite potential well

- Go to look the solution of HW1 p1
- Be careful when solving the boundary condition

Finite potential well

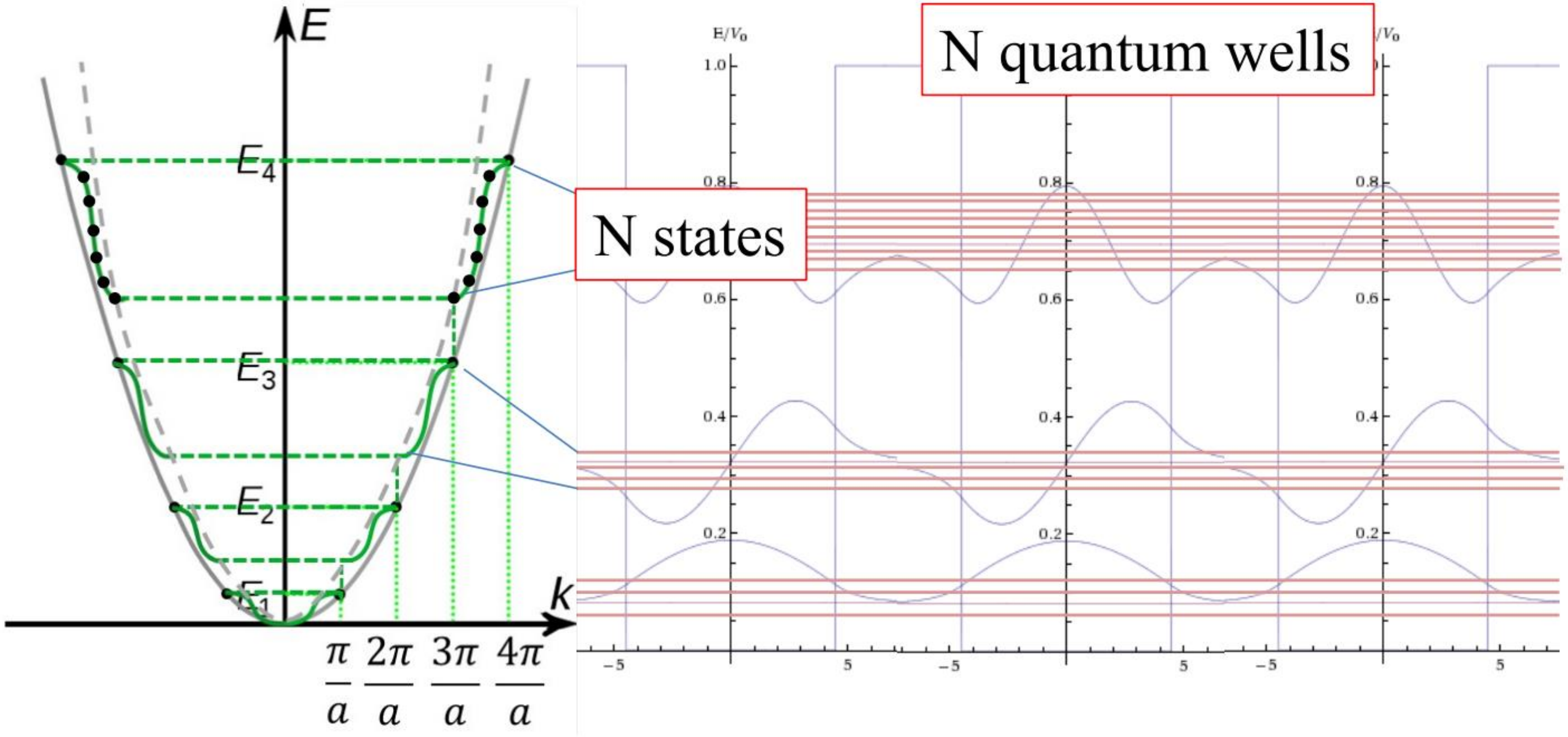
- Go to look the solution of HW1 p2
- Note that derivative of wave function should be continuous **except for the place where potential energy is infinite**
- Note that the general solution is different when E>V and E<V
- Note that typically one solution will be abandoned when E<V due to the normalization condition

Two finite quantum well

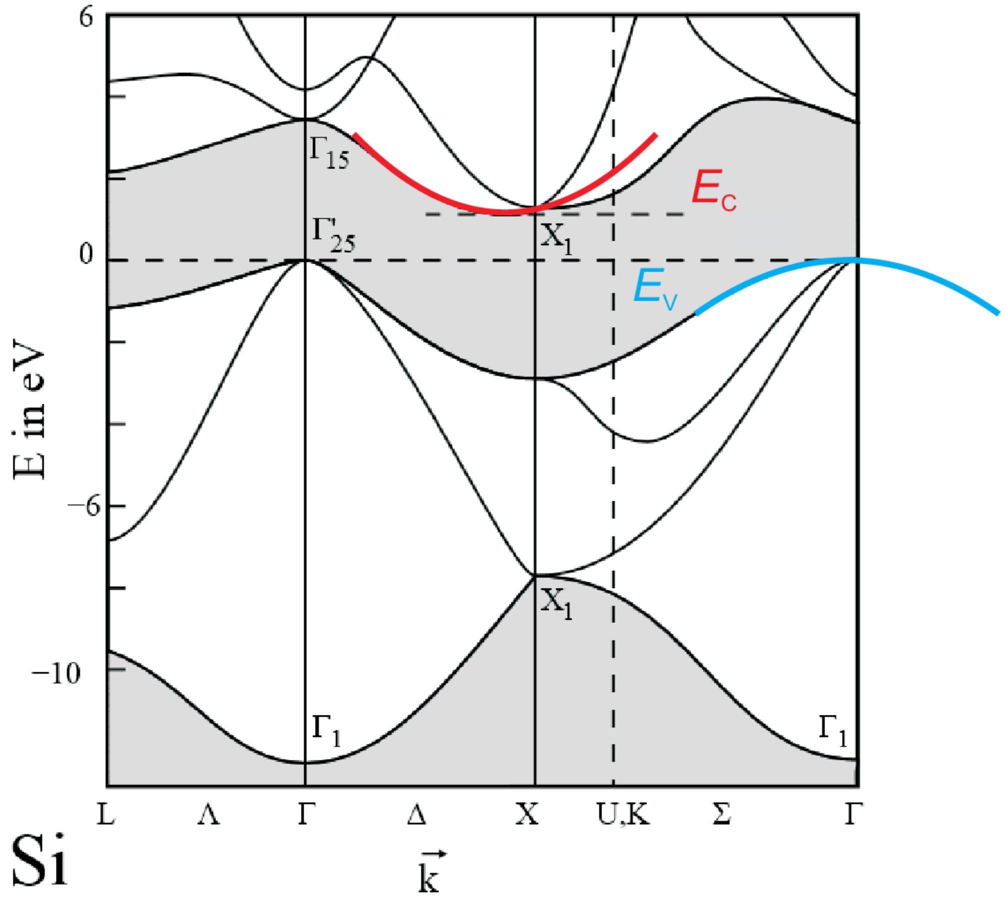


N quantum well-energy band

Forming energy bands: analytical

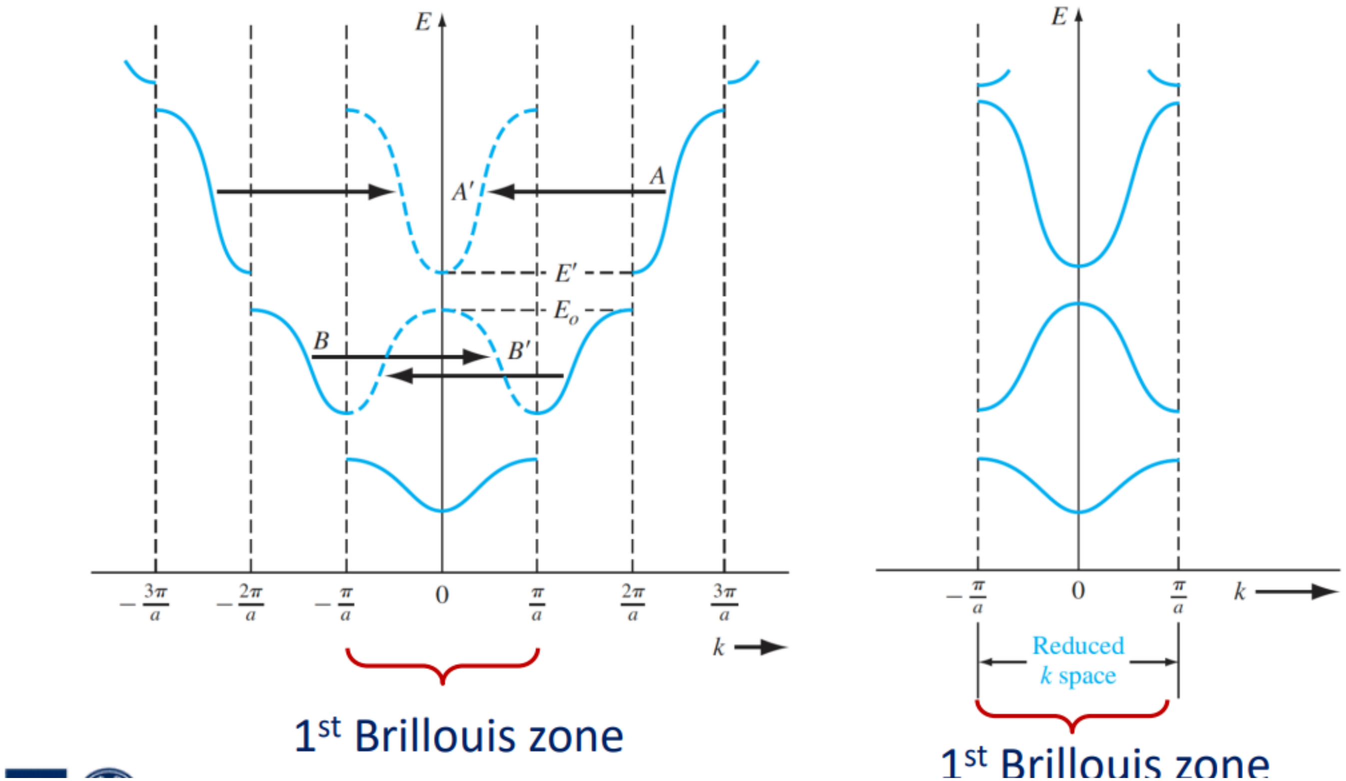


Silicon band structure example



1st Brillouis zone

Band structure in physical and k space for 1D periodic quantum wells



Metal, semiconductor, insulator

- The importance of bandgap
- Conductivity at 0K?
- Direct band gap semiconductor v.s. indirect band gap semiconductor?
- Why glass is transparent?
- Change of conductivity v.s. temperature?