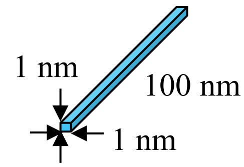
ELEC 315 - Assignment 2 **Due Oct. 29, 2025**
Winter 2025-26 Term 1

1. A three-dimensional (3D) infinite potential well can be used as a model for a nanowire, a wire with a nanoscale cross section.



(a) Using the separation of variable method in a 3D infinite potential well

$$V(x,y,z)=\begin{cases} 0 & (0<x<L_x)\&(0<y<L_y)\&(0<z<L_z) \\ \infty & \text{elsewhere} \end{cases}$$

solve Schrödinger equation and show that electron energy is quantized in form of

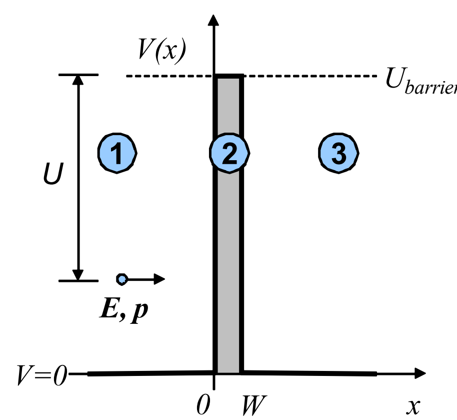
$E=\frac{\hbar^2}{2m_0}\left(k_x{}^2+k_y{}^2+k_z{}^2\right)$, where $k_x=\frac{n_x\pi}{L_x}$, $k_y=\frac{n_y\pi}{L_y}$ and $k_z=\frac{n_z\pi}{L_z}$.

(b) A semiconductor nanowire with a square cross section (L_x=L_y=1 nm) and a length of 100 nm (L_z) can be modeled as an infinite potential well. Calculate the six lowest energy levels of an electron in this nanowire? Write the wave function $\psi_{1,1,1}(x,y,z,t)$ for the lowest energy level (ground state).

(d) Find the wavelengths of the photons emitted if an electron makes the following transitions: $\psi_{1,1,2}\rightarrow\psi_{1,1,1}$ and $\psi_{1,2,1}\rightarrow\psi_{1,1,1}$ ($m_0=9.1\times10^{-31}$ kg and $\hbar=\frac{h}{2\pi}=1.05\times10^{-34}\,Js$).

(e) How many states are there with E < 1.885 eV?.

2. Assume an electron is traveling in positive *x* direction toward a barrier with the height of $U_{barrier}$ and width of *W*. The electron has an energy $E < U_{barrier}$ and its wave function has an amplitude A_1.



(a) Write the solutions for the Schrodinger equations in regions 1 to 3, and write the boundary conditions at $x = 0$ and *W*. What are the *k* values (wave numbers) in the three regions?

(b) After solving the above boundary conditions (no need to go through the math), one finds that the probability for electron tunneling through the barrier *T* is given by

$T=\frac{A_3^2}{A_1^2}=\left[1+D\sinh^2(k_2W)\right]^{-1}$, where $D=\frac{U_{barrier}{}^2}{4E(U_{barrier}-E)}$,

$k_2^2=\frac{2m(U_{barrier}-E)}{\hbar^2}$, and A_3 the amplitude of wave function for tunneled electron in region 3 moving in positive *x* direction. Assume two aluminum wires (regions 1 and 3) are separated by an oxide layer (region 2) with a thickness of 2 nm. The oxide layer acts as a potential barrier with a height of 7 eV for free electrons (E = 2 eV) in Aluminum. Find the tunneling probability for electron from one wire to the other. Find the tunneling probability for when the oxide thickness is 0.8 nm and compare with previous results. If 10^9 electrons hit the barrier each second, what is the expected tunneling current between the two metals in the two cases for barrier thickness?

3. Explain how increasing or decreasing temperature should change the value of the bandgap of silicon?