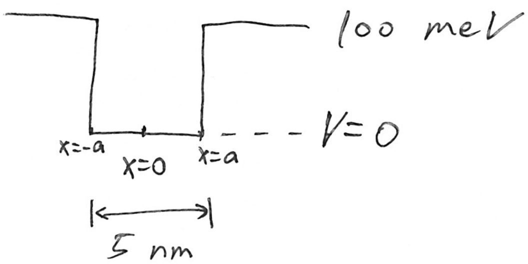
HW #1.

1.



For symmetric 1-Dimensional quantum well, the solution is given by the following equations:

$\cos ka = \pm ka/k_0 a$ (even parity wave function)

$\sin ka = \pm ka/k_0 a$ (odd parity wave function)

where a is half the width of the well (5 nm), k is the wave vector of the wave function $k = \frac{\sqrt{2mE}}{\hbar}$, and

$k_0 = \frac{\sqrt{2mV_0}}{\hbar}$ where $V_0 = 100$ meV.

So, solved by numerical method, we found only one solution, corresponding to one bound state, and

$ka = 0.8476$

So $E_1 = \frac{\hbar^2 k^2}{2m_e^*} = \boxed{43.8 \text{ meV}}$

2. Same calculation as problem 1, use the numbers from Lecture 2, Slide 11.

For electrons, $V_0 = \Delta E_c = 200$ meV, $m_e^* = 0.1\, m_e$,

we have two solutions, $ka = 0.9915$ and $ka = 1.7740$.

So $E_1 = 59.9$ meV, $E_2 = 191.8$ meV

For holes, $V_0 = \Delta E_v = 390$ meV, $m_h^* = 1\, m_e$,

we have six solutions, $ka = 1.3954$, 2.7858, 4.1647, 5.5213, 6.8304 and 7.9565.

So $E_1 = 11.9$ meV, $E_2 = 47.3$ meV, $E_3 = 105.7$ meV,
$E_4 = 185.8$ meV, $E_5 = 284.4$ meV, $E_6 = 385.9$ meV.

lowest energy emission $E = \underset{\uparrow \; E_g \text{ of InGaAs}}{760} + 59.9 + 11.9 = 831.8$ meV

$$\lambda = \frac{hc}{E} = \frac{1.240\ \mu m}{E\ (eV)} = \boxed{1.491\ \mu m}.$$

3. $n = N_c e^{-(E_c - E_{Fn})/k_B T}$

$$N_c = 2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} \approx 8 \times 10^{17}\ cm^{-3} \quad (m_e^* = 0.1 m_e, T = 300K)$$

Assume $E_g = 0.8$ eV and let $E_v = 0$, so $E_c = 0.8$ eV.