Grading Note: Numerical answers within 20% will receive full credit.

1. The nanowire has a "core-shell" structure, where the core is the active gain region, and the shell is the passive cladding region. Assume the confinement factor of the core region is 10%, effective refractive index is 3, and the intrinsic loss is 10 cm^{-1}. The maximum gain available from the active core is 10^4 cm^{-1}.
   a) If the maximum mirror reflectivity is $e^{-1} = 36.8\%$ for both top and bottom mirrors, what is the minimum cavity length that the nanowire laser can reach threshold?
2. In a microdisk laser, light propagates along the periphery of the disk through near total internal reflection at the disk edge. Assume the effective refractive index is 3, and the lasing wavelength is 1 μm. The quality factor corresponding to radiation loss can be approximated by $Q_{rad} = 10^{\frac{D}{1\mu m}}$. The intrinsic loss due to residue absorption of the semiconductor is 10 cm^{-1}. The confinement factor of the active region is 50%.
   a) Consider a microdisk laser with a diameter of 4 μm,
      i) Is the total loss dominated by radiation or absorption?
      ii) What is the photon lifetime?
      iii) What is the threshold gain?
      iv) What is the external quantum efficiency (assume all radiation can be collected as useful output)?
   b) The radiation loss is a function of the diameter of the microdisk. Find the diameter at which the radiation loss is equal to the intrinsic loss.
3. A quantum well has an effective electron mass of 0.1 m_0 and a hole effective mass of 0.5 m_0. The well width is 5 nm. Under high level excitation (e.g., forward-biased p-n junction), there are equally high electron and hole concentrations. Fermi levels split into two quasi-Fermi levels, electron and hole. The hole quasi-Fermi level just reached the second sub-band (second quantized level).
   a) What is the hole concentration?
   b) Use $n = p$, find the position of the quasi-Fermi level (in reference to the bottom of the first quantization state, E_{n1}.