ECE 447/547 (Semiconductor Devices)
Southern Illinois University at Carbondale

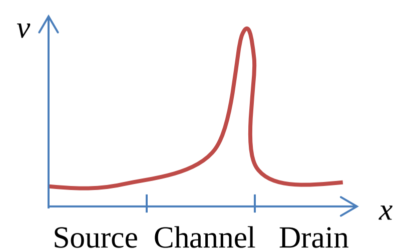
Homework 02

Q1. What is the de Broglie wavelength (in Å) of an electron at 100 eV? What is the wavelength for electrons at 12 keV, which is typical of electron microscopes? Comparing this to visible light, comment on the advantages of electron microscopes.

Q2. A particle is trapped in the ground state (lowest energy level) of a potential well of width *L*. To understand how the particle is localized, a common measure is the standard deviation Δx defined by $\Delta x = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$, where $\langle x^2 \rangle$ and Δx are the expectation values of x^2 and x, respectively. Find the uncertainty Δx in the position of the particle in terms of length *L* and estimate the minimum uncertainty in the momentum of the particle, using the Heisenberg uncertainty principle in terms of *L* and the Planck's constant *h*. (Hint: To do the integrations, you may find integration tables useful).

Q3. (Textbook Problem 2.27) A particle with a mass of 15 mg is bound in a one-dimensional infinite potential well that is 1.2 cm wide. (*a*) If the energy of the particle is 15 mJ, determine the value of *n* for that state. (*b*) What is the energy of the (*n*+1) state? (*c*) Would significant quantum effects be observable for this particle? Why or why not?

Q4.
In a MOSFET, the variation of electron velocity (*v*) as a function of position (*x*) from the source to the drain end is depicted in the figure. De Broglie hypothesized that particles (e.g. electrons) can be modeled via waves and the wavelength is given by: $\lambda = h/mv$.
According to this hypothesis (and referring to the *v*-*x* profile), comment on how we should treat an electron (classically or quantum mechanically) as it moves from the source to the drain end of a MOSFET? Explain why.



Q5. (For ECE 547 students): A time-independent wave function has the normalized form: $\psi(x) = \frac{1}{\sqrt{L\sqrt{\pi}}} exp\left(-x^2/2L^2\right)$. Calculate the expectation value $\langle x \rangle$ for this wave function. Give a physical interpretation.