Physics 4410
Quantum Mechanics 2

Lecture 2

Review: Free particles

August 26, 2020

1. A quantum particle moving in space is described by a wave function $\psi(x)$.

2. Describe the position x and momentum p as operators.

3. Describe the Heisenberg uncertainty principle.

4. Describe a free quantum particle of mass m, moving in d spatial dimensions.

5. Now suppose the particle is trapped to move in one dimension, in the region $0 \leq x \leq L$ (the infinite square well).

6. Now suppose the particle is trapped to move in one dimension, on a circle of circumference L.

Activity: Electrons in GaAs.

Electrons of (effective) mass m are confined in a thin slab of GaAs. Treat them as free particles in the domain $-\infty < x, y < \infty$, $0 \leq z \leq a$.

(a) Find the eigenstates and eigenvalues of the Hamiltonian.

(b) At temperature T, electrons typically occupy energy levels with

$$E - E_0 \lesssim k_{\mathrm{B}} T$$

with E_0 the ground state energy. Below what temperature T_* are the available energy levels equivalent to a free particle moving in two dimensions?

(c) A high quality thin film might have $a \approx 3 \times 10^{-8}$ m, i.e. be about 60 atomic layers thick. Using effective mass $m \approx 5 \times 10^{-32}$ kg and $k_{\mathrm{B}} \sim 10^{-23}$ J/K, estimate T_*. Is it achievable in experiment?