NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 283 – Modern Physics — Fall 2025

Problem Set #5

Problem Set Due: Thurs., Oct. 9, 2025
Read Krane: Chapter 5.6, Lecture Notes #1, #2

1. **OpenStax University Physics Vol. 3: Section 1.1:** Problem 27
2. **OpenStax University Physics Vol. 3: Section 1.2:** Problem 34
3. **OpenStax University Physics Vol. 3: Section 1.2:** Problem 35

4. Krane: **Problem 33** page 175

(a) For Part (a) of this problem: *also* sketch the potential energy barrier and where the energy of the electron is relative to the barrier.
Note: *there is an error in the textbook:* The energy barrier is shown in **Figure 5.26** (not 5.25)

(b) Do Part (b)

(c) Do Part (c)

(d) Sketch the wavefunction representing a possible solution to the Schrodinger equation in each of the regions of this problem.

5. Krane: **Problem 36** page 175

in addition to each sketch, explain:
(a) how the wavelength changes in the well?
(i.e., does it increase or decrease as x increases?)—explain why.
(b) how the amplitude of the wave changes in the well?
(i.e., does it increase or decrease as x increases?)—explain why.
(c) how does the wavefunction behave outside the box?
(i.e., is it zero or can the particle exist in the classically forbidden region?)—explain why.

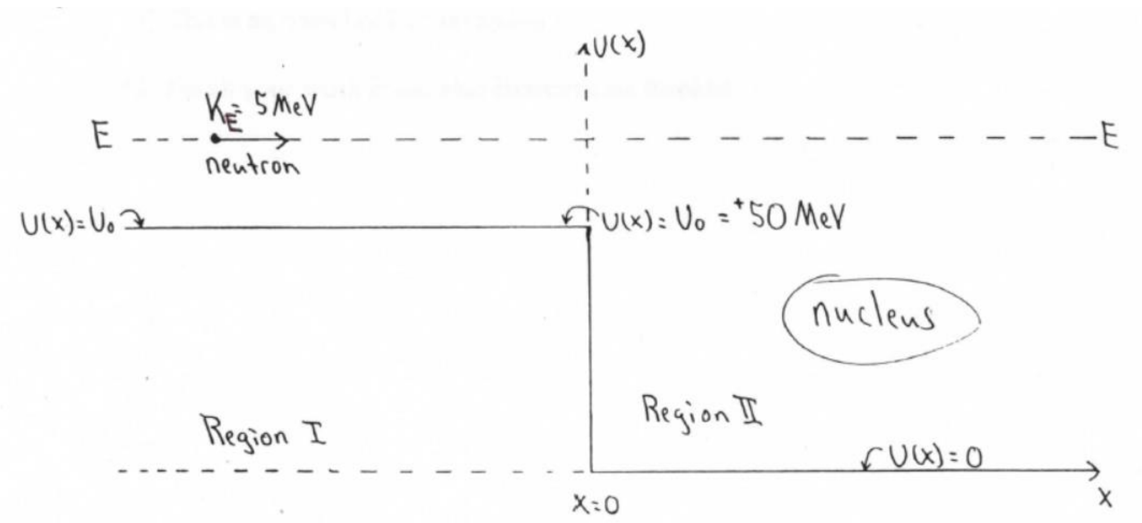
6. Krane: **Problem 37** page 175 (just show calculation)

use integral by parts (or any other method you learned in calculus) to solve the integral (do not just look up the integral in the integral tables).

7. Krane: **Problem 38** page 176 (just show calculation)

8. When a neutron enters a nucleus, it experiences a potential energy which drops at the nuclear surface very rapidly from a constant external value $U = 0$ to a constant internal value of about $U = -50$ MeV. The decrease in the potential is what makes it possible for a neutron to be bound in a nucleus. Consider a neutron incident upon a nucleus with an external kinetic energy $K_E = 5$ MeV, which is typical for a neutron that has just been emitted from a nuclear fission. In this problem we will estimate the probability that the neutron will be reflected at the nuclear surface, thereby failing to enter and have its chance at inducing another nuclear fission.

The model for the neutron-nucleus interaction is shown below as a one-dimensional step potential.



For this problem: ***Use only complex exponentials for wavefunctions (like was done in class)***

(a) Write down the wave function, $\psi_I(x)$, for region I. Let A be the amplitude of the *incident wave* and B be the amplitude of the *reflected wave*.

(b) Write down the wave function, $\psi_{II}(x)$, for region II.

(c) What are the expressions for k_I and k_{II} in terms of E and U_0?

(d) Which coefficient(s) in Part (a) & (b) should be set to zero? Why?

(e) Use the continuity boundary conditions for $\psi(x)$ and its slope at $x = 0$ to find two relationships among the coefficients.

(f) Evaluate the reflection coefficient:

$$R = \frac{\text{reflected probabilility flux}}{\text{incident probability flux}} = \frac{k_I \left|B\right|^2}{k_I \left|A\right|^2}$$

(g) For the values of K_E and U_0 given above, numerically evaluate the reflection coefficient for these low energy neutrons, thereby showing the percentage of neutrons that do not contribute to nuclear fission.

($\hbar = 6.582 \times 10^{-16}$ eV sec, $m_{neutron} = 939.6$ MeV/c^2)