The University of Georgia

Department of Physics and Astronomy

Graduate Qualifying Exam ─ Part II

11 August 2017

Instructions:

- Attempt all problems. You *must* show your work and/or clearly explain your answers in order to be able to earn a passing grade for a problem.
- Start each problem on a new sheet of paper. Write the problem number on the top left of each page, and your pre-arranged prelim **ID number** (but *not* your name) on the top right of each page. Leave margins for stapling and photocopying.
- This is a closed-book exam. You are permitted to bring one page of notes (equations, definitions, physical constants, etc.) per exam day. You must hand in this page of notes with the exam each day.
- You may use a calculator, but *only* for arithmetic functions (i.e., not for referring to notes stored in memory, doing symbolic algebra, etc.).

Part I has five problems, numbered 6 — 10.

Problem 6: (two parts)

Consider a single quantum mechanical particle of mass *m* in a one-dimensional potential well shown to the left. For $-L \leq x \leq +L$, the potential $V(x) = 0$; otherwise, $V(x) = V_o$.

(a) Write down the Schrödinger equation for the particle.

(b) Suppose $V_o = \infty$:

  i. What are the boundary conditions on the wave functions for the particle?

  ii. What are the possible normalized wave functions for the particle?

  iii. What are the possible energies of the particle?

  iv. Draw the wave functions for the lowest three energy levels.

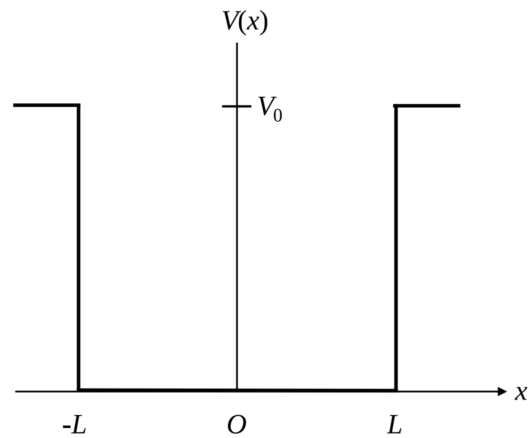

Figure 6

Problem 7: (one part)

Gasoline engines use the heat produced in the combustion of the carbon and hydrogen in gasoline. One of the important sources of energy in this process is the oxidation of carbon to form carbon dioxide,

$$C + O_2 \longrightarrow CO_2 + 11.4\ \text{eV}.$$

Find the total energy released when 1 kg of carbon is oxidized. If this energy was used with 10% efficiency to drive a 1500-kg car up a hill, what elevation gain would it produce? (We assume the car moves sufficiently slowly and thus friction effects are small compared to the work needed to lift the car.)

Problem 8: (four parts)

Consider a refrigerator to be a thermodynamic system operating between T_{hot} and T_{cold}. Let Q_{hot} be the heat that enters the system from the hot reservoir and Q_{cold} be the heat that enters the system from the cold reservoir. ΔW is the work done by the system and ΔU is the change in the internal energy of the system.

(a) What is ΔU for one closed cycle?

(b) State the first law of thermodynamics to relate ΔW, Q_{hot}, Q_{cold} for one cycle.

(c) For this to be a refrigerator, what are the signs of ΔW, Q_{hot}, Q_{cold} for one closed cycle? State your reasoning.

(d) Define the coefficient of performance for a refrigerator as the ratio of $\frac{Q_{cold}}{-\Delta W}$. Find this ratio in terms of Q_{hot}, Q_{cold}. Show your reasoning and calculation.

Problem 9: (three parts)

Given three particles, one in state $\psi_a(x)$, one in state $\psi_b(x)$, and one in state $\psi_c(x)$. Assuming that $\psi_a(x)$, $\psi_b(x)$, $\psi_c(x)$ are orthonormal, construct the three-particle states representing

(a) distinguishable particles,

(b) identical bosons,

(c) identical fermions.

Problem 10: (three parts)

A beam of X-rays of 17.0 keV is incident on a thin foil. Compton-scattered X-rays are observed at 90^{o} with respect to the direction of the incident X-rays.

(a) What energy does one of these Compton-scattered X-rays have?

(b) What is the kinetic energy of the corresponding electron?

(c) What is the component of the electron's momentum along the direction of the incident X-rays?