Homework #4

Due Wednesday September 21, 2022 by 11:59 PM

Reading

- Chapter 3.1-3.3

Problems

Note:

Problem 1 will be used for the School's ABET accreditation process, so please show your best effort!

Please submit problem 1 as a separate PDF file.

1. **Photoelectric Effect**

You are working in the analytical lab of a company that manufactures semiconductor processing equipment. Your company's equipment is manufactured from a variety of metals. One of your important clients refuses to accept a piece of equipment claiming that it exhibits unacceptable levels of contamination. Your manager asks you to determine the contaminant and the base metal material used for the equipment. You decide to employ ultraviolet photoelectron spectroscopy with sputter depth profiling. Using this approach, you obtain the attached data set, which contains measurements of the maximum kinetic energy of photo-emitted electrons versus the incident photon frequency. There are two data sets: one scan of the initial contaminated surface and a second scan of the surface after sputtering the sample with argon for 30 minutes, which should show only the base metal.

Analyze the data and write a professional report to your manager that includes

i. A restatement of the key question to be answered.
ii. A brief discussion of the experimental design and motivation for using ultraviolet photoelectron spectroscopy.
iii. An analysis of the data with the relevant physical model.
iv. Be sure to include clear, descriptive captions for the figures included in your report.
v. Error analysis: A discussion of the statistical significance of the results, the reliability of the analysis and/or validity of the model in representing the data.
vi. A concise conclusion, based on your judgement of the data, of the metal and contaminant. You may speculate on the source of the contamination.
vii. References to any sources used in preparing your report. (Hint: Table 4.1 pg. 323 of Kasap 4th edition may be helpful.)

2. **Planck's law and photon energy distribution of radiation**

Planck's law, stated in Equation 3.9, provides the spectral distribution of the black body radiation intensity in terms of wavelength through I_λ, intensity per unit wavelength:

$$I_\lambda = \frac{2\pi hc^2}{\lambda^5\left[\exp\left(\frac{hc}{\lambda kT}\right) - 1\right]}$$

a. Plot Planck's radiation law as a function of wavelength for a blackbody at 2700 K and 6000 K.

b. At what wavelength does the peak intensity occur for the above two temperatures?

c. Compare the peak wavelengths from part (b) to those computed using Wien's displacement law, $\lambda_{\max} \approx (2.89\times10^{-3}$ m K$)/T$(in K).

3. **Wave Functions**

Consider an electron in a 1-dimensional box of length a. The wave function for an electron in this box is given by:

$$\psi(x) = AiSin\left[\frac{n\pi}{a}x\right]$$

a. Normalize the wave function. Show all work in a step-by-step manner

4. **Operators**

The momentum operator in quantum mechanics, $\hat{p}_x$, in one dimension is given by:

$$\hat{p}_x = -i\hbar\nabla_x = -i\hbar\frac{d}{dx}.$$

a. Show that the momentum operator can be written as: $\hat{p}_x = \frac{\hbar}{i}\nabla_x$

b. Given the wave function:

$$\Psi(x,t) = Ae^{-ikx}e^{iwt},$$

find the eigenvalue for momentum. Show all work in a step-by-step manner.