Physics 237, Midterm Exam #1

Tuesday February 10, 2022
8.00 am – 9.30 am

Do not turn the pages of the exam until you are instructed to do so.

Exam rules: You may use *only* a writing instrument while taking this test. You may *not* consult any calculators, computers, books, nor each other.

Problems 1 and 2 must be answered in exam booklet 1. Problems 3 and 4 must be answered in exam booklet 2. The answers need to be well motivated and expressed in terms of the variables used in the problem. You will receive partial credit where appropriate, but only when we can read your solution. Answers that are not motivated will not receive any credit, even if correct.

At the end of the exam, you need to hand in your exam, the blue exam booklets, and the equation sheet. All items must be clearly labeled with your name, your student ID number, and the day/time of your recitation. **If any of these items are missing, we will not grade your exam, and you will receive a score of 0 points.**

You are required to complete the following *Honor Pledge for Exams*. Copy and sign the pledge before starting your exam.

"I affirm that I will not give or receive any unauthorized help on this exam, and that all work will be my own."

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Name: ____

Signature: ____

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Good Luck !

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Problem 1 (25 points) **ANSWER IN BOOKLET 1**

The correspondence principle can be used to justify the selection rules observed in experimental studies of the atom. In this problem, we will consider the Bohr model of the hydrogen atom.

a) **(2 points)** What is the correspondence principle, enunciated by Bohr in 1923?

b) **(10 points)** In the Bohr model of the hydrogen atom, we assume that the electron of mass m is moving in a circular orbit. Classically, we expect that the electron will radiate electromagnetic waves with a frequency equal to the frequency of the orbital motion of the electron. Determine the frequency of the orbital motion of the electron after applying the Bohr quantization condition of the orbital angular momentum.

c) **(10 points)** Bohr assumed that radiation could only be emitted when transitions occur between the quantized energy levels of the atom. Assuming that the electron undergoes a transition from an energy level characterized by the quantum number $n + \Delta n$ to an energy level characterized by the quantum number n, what is the frequency of the emitted radiation?

d) **(3 points)** Comparing the results obtained in part b) and part c) when n becomes large, what do these two results tell you about the selection rules that govern the transitions that can be observed in the hydrogen atom?

Your answers need to be well motivated and expressed in terms of the variables provided.

Problem 2 (25 points) **ANSWER IN BOOKLET 1**

Consider an electron with a speed given by $\beta = v/c$. Assume the mass of the electron is m.

a) **(15 points)** What is smallest possible uncertainty in the position of this electron?

b) **(5 points)** What is does the equation you derived in part a) tell us about the measurements we carry out when $\beta = 0$?

c) **(5 points)** What is does the equation you derived in part a) tell us about measurements we carry out when $\beta = 1$?

Your answers need to be well motivated and expressed in terms of the variables provided.

Problem 3 (25 points) **ANSWER IN BOOKLET 2**

Consider x-rays with wavelength λ_x and γ-rays with wavelength λ_γ, incident on a region of free electrons. The scattered x-rays and γ-rays are observed at 90° with respect to the direction of the incident beam. You can treat the electrons non relativistically. Note: you can use the fact that $\lambda_x > \lambda_\gamma$.

a) **(5 points)** By how much is the wavelength of the incident x-rays shifted? By how much is the wavelength of the incident γ-rays shifted?

b) **(10 points)** What is the energy of a recoiling electron after it interacted with an x-ray? What is the energy of a recoiling electron after it interacted with a γ-ray? Assume the electron is initially at rest.

c) **(10 points)** Which photon, the x-ray or the γ-ray, will have the largest percentage of energy loss after it has interacted with a free electron?

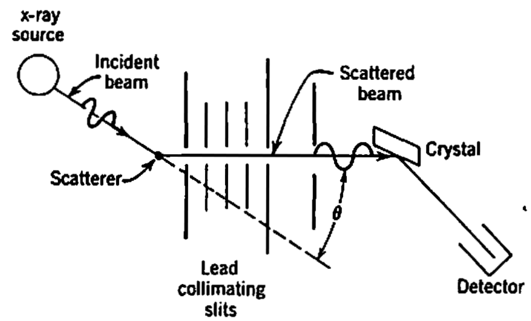
Your answers need to be well motivated and expressed in terms of the variables provided.

Problem 4 (25 points) **ANSWER IN BOOKLET 2**

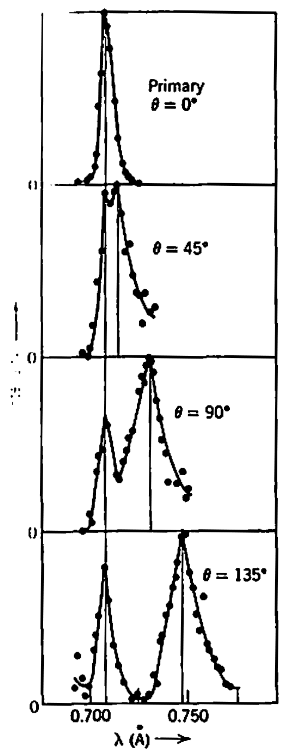
Short answer questions. No derivations are needed

a) **(5 points)** What is the color of the top front of this KLM plane? What is the significance of this color? Yes, I know the image is in gray scale, but you have seen the color version in class (on January 20, 2022).

b) **(5 points)** Consider the experiment shown in the following Figure where monochromatic X rays fall on a graphite scatterer. The distribution of scattered wavelengths as function of the scattering angle is measured using Bragg reflection from the crystal shown on the right-hand side.

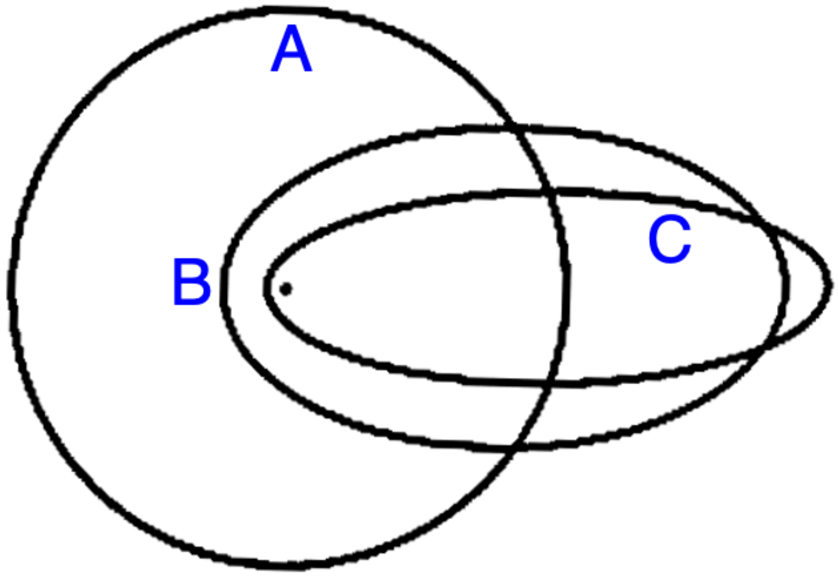


The measured wavelength distributions at various scattering angles are shown in the following Figure.



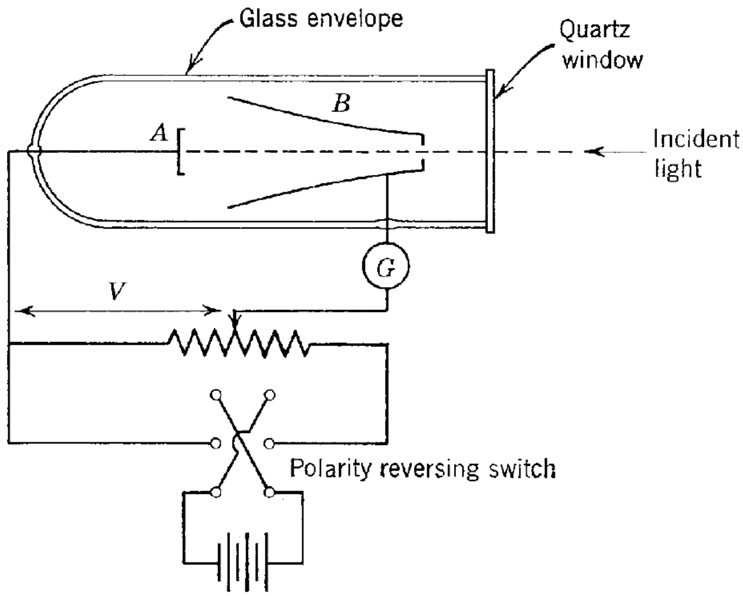
Explain the two components visible in each of the wavelength distributions.

c) **(5 points)** Consider the following Bohr-Sommerfeld orbits that form the complete set of orbits for a specific principal quantum number. The nucleus is located at the common focus of the orbits, indicated by the dot.

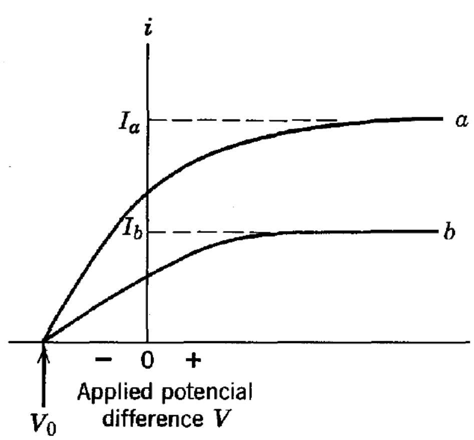


What is the principal quantum number of this set of orbits? What are the azimuthal quantum number for orbits A, B, and C?

d) **(5 points)** The apparatus shown in the following Figure was used to study the photoelectic effect.



The measured current as function of the applied voltage V is shown in the following Figure for a specific wavelength λ. Curves a and b in this Figure were obtained at two different intensities of the incident light; curve b was obtained with an intensity that was ½ of the intensity used to obtain curve a.



Sketch the current versus V graphs that you expect if instead of reducing the intensity by a factor of 2, measurement b is made when you reduce the wavelength by a factor of 2 while keeping the intensity the same. Include curve a for reference in your sketch.

e) **(5 points)** What is a black body?

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