Physics 202H - Introductory Quantum Physics I
Example Midterm Test

Fall 2004 **Name:** _____

Thursday 2004/11/04 **Student Number:** _____

The following are the types of questions that you can expect to see on the midterm test. The multiple-choice questions would make up about one third of the total points for the test.

Please let me know of any typos or similar errors.

This examination paper includes 2 pages and 12 questions. You are responsible for ensuring that your copy of the paper is complete. Bring any discrepancy to the attention of your invigilator.

Special Instructions:

The only aids allowed are: a one (1) page single-sided hand-written formula sheet, and a calculator. When completed, turn in all exam booklets, the test paper, and the formula sheet.

Write your name and student number on the top of this paper AND on the front of your answer booklet AND on your formula sheet. Be prepared to present your student ID for verification.

Portable communications devices of all types (e.g. pagers, cellular phones, communicating calculators) are prohibited in the examination room. All such devices must be turned off prior to the start of the examination. A penalty of 5% of the exam mark may be assessed to anyone who fails to prevent a call from interrupting the examination.

Giving or receiving aid during an exam is a violation of university rules and may result in a failing grade and/or expulsion from the university.

---

1. The wavelength of the peak in the blackbody spectrum increases by a factor of two when the temperature of the object is increased from 300°K to 600°K. [2]
   (a) True
   (b) False

2. A passenger on a train travelling at 90% of the speed of light takes one hour to eat their dinner in the dining car. From the point of view of someone sitting at rest beside the train track the dinner took: [3]
   (a) less than an hour to complete.
   (b) one hour to complete.
   (c) more than an hour to complete.

3. A passenger on a train travelling at 90% of the speed of light takes one hour to eat their dinner in the dining car. From the point of view of someone sitting at rest beside the train track, during dinner, the train travelled: [3]
   (a) a longer distance than from the passenger's point of view.
   (b) the same distance as from the passenger's point of view.
   (c) a shorter distance than from the passenger's point of view.

4. Planck was forced to quantize the energy of the oscillators in a black body because: [3]
   (a) the photoelectric effect would lead to the "ultraviolet catastrophe".
   (b) a continuous distribution would lead to the "ultraviolet catastrophe".
   (c) photons have zero rest mass.

5. In order to double the *intensity* of an electromagnetic wave of a particular frequency you must: [3]
   (a) increase the wave's amplitude by a factor of two.
   (b) increase each photon's frequency by a factor of two.
   (c) increase the number of photons by a factor of two.

6. If Ba_{56}^{137} emits a gamma-ray photon of energy $6.6 \times 10^5\,\mathrm{eV}$ during a nuclear transition, what is the recoil momentum of the atom? [3]
   (a) $0\,\mathrm{eV}/c$
   (b) $6.6 \times 10^5\,\mathrm{eV}/c$
   (c) $3.3 \times 10^5\,\mathrm{eV}/c$

7. What energy of photon is needed to cause an electron in a Hydrogen atom to make a transition from the $n = 2$ state to the $n = 1$ state? [5]

8. Planck's expression for $R_T(\lambda)$ is

$$R_T(\lambda) = \frac{2\pi\, hc^2}{\lambda^5} \frac{1}{\mathrm{e}^{(hc/\lambda kT)} - 1}.$$

   (a) What does $R_T(\lambda)\, d\lambda$ represent? What are its units (SI)? [5]
   (b) Show that $R_T(0) = 0$. [5]
   (c) For large values of λT, show that the above reduces to the Rayleigh-Jeans formula. [5]

9. A reverse voltage of $V_0 = 2.5\,\mathrm{V}$ reduces the photocurrent to zero when light of wavelength 400 nm strikes a certain metal.
   (a) What is the speed of the fastest photoelectrons? [5]
   (b) What is the work function of the metal? [5]
   (c) Above what wavelength does the photoelectric effect not occur? [5]

10. A photon scatters off a charged particle, initially at rest, transferring in the process the maximum energy possible. If the particle recoils with kinetic energy equal to its rest energy, find the ratio of the wavelength of the incident photon to λ_C, the Compton wavelength of the scatterer. [5]

11. What is the accelerating voltage of an X-Ray tube that produces X-Rays with wavelengths as short as 0.01 nm but no shorter? [5]

12. Show that the attenuation length $\Lambda = 1/\sigma\, n$ is equal to the average distance that a photon will travel before being scattered or absorbed. Here, σ is the total cross-section for absorption or scattering, and n is the number density of absorbers/scatterers. [5]

13. An electron is confined in a region of width $\Delta x = 0.1\,\text{Å}$. What is its minimum kinetic energy? [5]