PHYS 202 OUTLINE FOR PART IV

QUANTUM & ATOMIC PHYSICS

ATOMS AND QUANTA

A. Blackbody radiation S-42,43

1. spectral response: $\lambda_{max} = b/T$ where $b = 2.9 \times 10^{-3}$ m$*$K

2. power output: $P_{out/in} = \sigma \varepsilon A T_{obj/sur}^4$ where $\sigma = 5.67 \times 10^{-8}$ W/m²K^4 and ε measures whiteness (ε=0) or blackness (ε=1)

3. Classical theory: predicts UV catastrophe: $I_{ntensity}/\lambda \to \infty$ as $\lambda \to 0$.

4. Planck's theory: start with: $\Delta E = hf$ (ΔE does not go to 0)
   where $h = 6.63 \times 10^{-34}$ J sec (energy not continuous)

B. Photoelectric Effect S-44

1. wave theory: wrongly predicts no V_{stop}, time lag, no f_{cutoff}

2. particle theory: start with $E_{one\ photon} = hf$ (same h as Planck)

C. The atom: a nucleus and electrons S-45

1. size
   a) of the atom
   b) of the nucleus
   c) of the electrons

2. charge of electrons & protons

3. planetary model: trouble with radiation

D. Bohr theory S-46

1. assumptions: $L = n\hbar$; circular orbits (where $\hbar \equiv h/2\pi$)

2. get: $E_n = [-mk^2Z^2e^4] / [2\hbar^2n^2]$; and $r = [n^2\hbar^2] / [mke^2Z]$

3. spectra: $\Delta E = -13.6\,\text{eV}\,[(1/n_f)^2 - (1/n_i)^2] = h f = \hbar\omega$

4. weaknesses: a) only works for 1 electron atoms/ions
   b) why assume $L = n\hbar$?

Supplementary Problems (S-):

42. Assume a temperature for the skin surface of yourself and calculate the wavelength where your radiation peaks assuming you radiate as a perfect blackbody.

43. The sun's power output per wavelength vs. wavelength curve peaks at a wavelength of 480 nm. (a) Assuming the sun is a perfect blackbody [a good but not perfect assumption], calculate its surface temperature. (b) What is the total power output of the sun? ($R_{SUN} = 7X10^5$ km.)
(c) What is the total power per area (in Watts/m^2) at the position where the earth orbits the sun (radius of orbit = 93 million miles = 149 million kilometers)? [This answer is for a collector pointed directly at the sun without any atmosphere/clouds and without any day/night.]

44. The work function for Aluminum is 4.08 eV. (a) What is the cut-off frequency? (b) What is the stopping voltage for light of wavelength 250 nm (in the UV) ?

45. What is the approximate size of (a) atoms? (b) nucleons? (c) electrons? (d) How are these sizes determined?

46. (a) What is the ground state energy of the hydrogen atom?
(b) How much energy does it take to ionize the hydrogen atom?
(c) What would be the maximum wavelength of light that would be able to do this?
(d) What kind of photon is this (i.e., ultraviolet, visible, IR, etc.) ?
(e) How much energy would it take to excite a hydrogen atom in the ground state up to the n=3 state?
(f) What would be the possible decay schemes for this excited state, and the energy, wavelength, and color of the photons emitted in each scheme?

Answers to Supplementary Problems (S-):

42. depends on the temperature; if you assume a T of 30 °C, then wavelength of max. power is 9.6×10^{-6} meters (I.R.).

43. a) 6000 K; b) 4.5×10^{26} Watts; c) answer not given here - try to see if your answer is reasonable

44. a) 9.85×10^{14} Hz; b) 0.89 Volts.

45. (a) 1×10^{-10} m; (b) 1×10^{-14} m; (c) less than 1×10^{-17} m;
(d) by scattering high speed charged projectiles from them.

46. a) -13.6 eV; b) 13.6 eV; c) 91.4 nm; d) UV; e) 12.09 eV;
f-1) $3 \rightarrow 1$, E = 12.09 eV, λ = 103 nm, UV;
f-2) $3 \rightarrow 2 \rightarrow 1$, E = 1.89 eV & 10.20 eV, λ = 658 nm & 122 nm, red & UV.

QUANTUM MECHANICS

A. Waves and particles S-47

1. for light: $\Delta E = hf$; $\lambda f = v$

2. for matter: $\lambda = h/p$ (DeBroglie wavelength)

B. Heisenberg's Uncertainty Principle

1. position & momentum: $\Delta x \, \Delta p_x > h/4\pi$ (here, Δ indicates uncertainty, not change)
   (a) if know λ, ($\Delta\lambda \rightarrow 0 \Rightarrow \Delta p \rightarrow 0$), don't know x ($\Delta x \rightarrow \infty$)
   (b) if know x, ($\Delta x \rightarrow 0$), don't know λ ($\Delta\lambda \rightarrow \infty \Rightarrow p \rightarrow \infty$)
2. energy & time: $\Delta E \, \Delta t > h/4\pi$

C. Schrodinger's Equation S-48,49

1. depends on potential energy for situation

2. wave function, Ψ
   (a) Ψ is solution of Schrodinger's Equation
   (b) Ψ is related to probability of finding particle at x,t

3. quantum numbers
   (a) there are three (in 3-D) from applying boundary conditions to Schrodinger's Equation;
   (b) there is a fourth from relativistic considerations (spin)