Physics 202H - Introductory Quantum Physics I Homework #02

Fall 2004 Due 5:01 PM, Monday 2004/09/27

[65 points total]

"Journal" questions. Briefly share your thoughts on the following questions:
– What is your major/minor/etc.? What are you planning on doing after you finish your degree?
– Any comments about this week's activities? Course content? Assignment? Lab?

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1. (From Eisberg & Resnick, Q 1-8, pg 22) In your own words give a brief (not more than 50 words) explanation of the "ultraviolet catastrophe". [10]

2. A pendulum of length $l = 0.1\,\mathrm{m}$ and mass $m = 0.01\,\mathrm{kg}$ swings up to a maximum angle of $\theta = 0.1\,\mathrm{rad}$. If its energy is quantized, the discontinuous jumps in energy are very small.
   (a) For this angle of swing, what is the quantum number n that corresponds with the total kinetic energy of the system? What does this mean? [5]
   (b) From a relativistic point of view, how much larger would the measured mass of the swinging system be than the rest mass of the stationary system? What does this mean? [5]

3. The peak of the radiation curve for a certain blackbody occurs at a wavelength of $\lambda_a = 1\,\mu\mathrm{m}$. If the temperature is raised so that the total radiated power is increased 16–fold, at what wavelength λ_b will the new intensity maximum be found? [10]

4. (From Eisberg & Resnick, P 1-20, pg 24) Show that, at the wavelength $\lambda_{\max}$, where $\rho_T(\lambda)$ has its maximum, $\rho_T(\lambda_{\max}) \approx 170\pi\,(kT)^5/(hc)^4$. [10]

5. Think of the Sun as a blackbody radiator at temperature $T = 5777\,\mathrm{K}$.
   (a) How much power is radiated by each square metre of the Sun's surface? [5]
   (b) Given that the Sun is a sphere of radius $R_\odot = 6.95508 \times 10^8\,\mathrm{m}$, what is its total power output? [5]
   (c) How much solar energy per second passes through an area of one square metre at a distance $r_\oplus = 1.496 \times 10^{11}\,\mathrm{m}$ from the Sun's centre (this is the average Earth-Sun distance)? [5]
   (d) Suppose that Earth (radius $R_\oplus = 6.37814 \times 10^6\,\mathrm{m}$) absorbs all incident sunlight (100%), and reradiates as a blackbody. What would be its temperature T_{100}? [5]
   (e) Suppose that Earth absorbs 65% of incident sunlight, and reradiates as a blackbody. What would be its temperature T_{65}? Where is the contradiction in this last argument? [5]

Headstart for next week, Week 03, starting Monday 2004/09/27:
– Read Chapter 2.2 "Light as a Particle" in "Simple Nature" by Crowellk
– Read Chapter 2 "Photons – Particlelike Properties of Radiation" in Eisberg & Resnick
– – Section 2.1 "Introduction"
– – Section 2.2 "The Photoelectric Effect"
– – Section 2.3 "Einstein's Quantum Theory of the Photoelectric Effect"
– – Section 2.4 "The Compton Effect"
– – Section 2.5 "The Dual Nature of Electromagnetic Radiation"
– – Section 2.6 "Photons and X-Ray Production"