Assignment 11
Physics/ECE 176

Made available: Friday, April 22, 2011
Due: 5pm, Thursday, April 28, 2011.

1. **Problem 7.45** on page 297 of Schroeder.

   - You need to find $U = U(S, V)$ as a function of S and V to calculate the derivative $P = -(\partial U/\partial V)_S$ so look at Eqs. (7.86) and (7.89).

2. **Problem 7.48** on pages 297-298, but do only parts (b), (c), and (d). Just assume the result of part (a), that $\mu = 0$ for all the neutrino and antineutrino species.

   - For part (b), you should find that your answer for the energy density U/V for neutrinos and antineutrinos is 21/8 times the photon energy density for the same temperature.

   - For part (c), you should get $U/V \approx 3 \times 10^8 \, \mathrm{m}^{-3}$ but you should give your answer to two significant digits.

   - For part (d), use the fact that the mass density of the universe corresponds to about one proton per cubic meter.

3. **Problem 7.51 but skip (f)** on pages 303-304.

   - For (a), translate your answer into a memorable number by giving it in terms of the length L of a square whose area L^2 is the surface area of the filament. You should find $L \approx 1 \, \mathrm{cm}$ but your answer should have two significant digits.

   - For (b), you should get a wavelength $\lambda \approx 2 \, \mu m$ to one digit, but give your answer to two digits.

   - For (d), use Mathematica's `NIntegrate` function to get an approximate numerical value.

   - For (e), "efficiency" means the fraction of light energy emitted that is in the visible range that is useful to humans.

4. **Problem 7.54** on pages 306-307.

   The luminosity $\mathcal{L}$ of some light-emitting object like a star is defined to be the total power (in watts) emitted by the object[1]. If the surface of the glowing object is a spherical blackbody emitter of radius R and surface temperature T, then Stefan's law, Eq. (7.98) on page 302, implies $\mathcal{L} = (4\pi R^2)\, \sigma T^4$. Now write down this equation for the Sun and write this equation for the star of interest and take the ratio of these two equations to obtain an equation involving just ratios of quantities between the Sun and the star. Finally, use Wien's law, that the peak energy $\epsilon_{\max}$ in the Planck spectrum is related to the surface temperature of the object by $\epsilon_{\max} = 2.72 \, kT$

   To check your answers, the numerical answers are (a) 2, (b) 7×10^{-3}, and (c) 3×10^2 to one significant digit, although you should give your answer to two significant digits to demonstrate success.

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[1]The luminosity of a remote object can be measured by a device like a charge-coupled device (CCD), that counts (electrically, via the photo-electric effect) how many photons strike the device. If d is the distance of the glowing object to the measuring device, the flux of energy (energy per unit time per unit area, also called the intensity or apparent brightness) striking the device is given by $I = \mathcal{L}/(4\pi d^2)$. Thus a measurement of I (easy) and a determination of d (usually hard) yields the luminosity $\mathcal{L}$.

5. **Problem 7.55** on page 307.

   This problem, together with Problem 7.56, helps to explain the dangerous implications of global warming. The answer you should get is about $340\,\mathrm{K} \approx 60°\,\mathrm{C}$, which would be a disaster for life.

   As a hint, you want to generalize Figure 7.25 by adding a second thin horizontal gray line above the existing gray line. Starting from the outermost layer, then work your way toward the surface of the Earth, figuring out how much energy each layer must emit outward and inward.

6. **Problem 5.28** on page 171.

   This problem is similar to the discussion in the text of the relative stability of graphite versus diamond so is straightforward if you read and understand Schroeder's discussion.

7. **Problem 5.30** on page 172.

8. **Problem 5.32** on page 174.

   - The answer to (b) is about 100 bars to one digit, but you should give two digits.
   - For part (c), use the fact (which you should know from freshman physics) that the difference in pressure between the top and bottom of a column of material whose mass density is ρ and whose height is z is given by $\rho g z$. To one digit, you should get a depth of about a kilometer (!), but you should give two digits.
   - For part (d), if you use the Internet to get information about figure skates, please include the URL of your source.

9. **Problem 5.48** on page 185.

10. **Problem 5.51** on page 185. You should get the expression

$$p = \frac{8t}{3v - 1} - \frac{3}{v^2}. \tag{1}$$

   The fact that the constants a and b have disappeared mans that one has an equation whose mathematical structure applies to all van der Waals fluids.

11. **Problem 5.52** on page 185.

   The purpose of this problem is to encourage you to think through the details of the discussion in the text, in particular to understand where Fig. 5.21 on page 183 comes form. To plot the Gibbs free energy G as a function of pressure, write G as given by Eq. (5.56) on page 182 in terms of the van der Waals reduced variables, $g = g(t, p, v)$, and you can ignore the terms that involve the temperature t when plotting since those terms are constant when varying the volume V at fixed temperature.

   Finally, use the Mathematica command `ParametricPlot` to plot the parameterized curve $(p(v), g(v))$ as a function of the reduced volume v, where $p(v)$ is given by Eq. (1) above.

Problem 1: Time to Finish This Homework Assignment

Please tell me the approximate time in hours that it took you to complete this homework assignment.