3.2 At what distance from a 100-W light bulb is the radiant flux equal to the solar irradiance?

3.3 The parallax angle for Sirius is 0.379″.

(a) Find the distance to Sirius in units of (i) parsecs; (ii) light-years; (iii) AU; (iv) m.

(b) Determine the distance modulus for Sirius.

3.4 Using the information in Example 3.6.1 and Problem 3.3, determine the absolute bolometric magnitude of Sirius and compare it with that of the Sun. What is the ratio of Sirius's luminosity to that of the Sun?

3.5 **(a)** The Hipparcos Space Astrometry Mission was able to measure parallax angles down to nearly 0.001″. To get a sense of that level of resolution, how far from a dime would you need to be to observe it subtending an angle of 0.001″? (The diameter of a dime is approximately 1.9 cm.)

(b) Assume that grass grows at the rate of 5 cm per week.

i. How much does grass grow in one second?

ii. How far from the grass would you need to be to see it grow at an angular rate of 0.000004″ (4 microarcseconds) per second? Four microarcseconds is the estimated angular resolution of SIM, NASA's planned astrometric mission; see page 59.

3.6 Derive the relation

$$m = M_{\mathrm{Sun}} - 2.5 \log_{10}\left(\frac{F}{F_{10,\odot}}\right).$$

3.7 A 1.2×10^4 kg spacecraft is launched from Earth and is to be accelerated radially away from the Sun using a circular solar sail. The initial acceleration of the spacecraft is to be $1g$. Assuming a flat sail, determine the radius of the sail if it is

(a) black, so it absorbs the Sun's light.

(b) shiny, so it reflects the Sun's light.

Hint: The spacecraft, like Earth, is orbiting the Sun. Should you include the Sun's gravity in your calculation?

3.8 The average person has 1.4 m^2 of skin at a skin temperature of roughly 306 K (92°F). Consider the average person to be an ideal radiator standing in a room at a temperature of 293 K (68°F).

(a) Calculate the energy per second radiated by the average person in the form of blackbody radiation. Express your answer in watts.

(b) Determine the peak wavelength $\lambda_{\max}$ of the blackbody radiation emitted by the average person. In what region of the electromagnetic spectrum is this wavelength found?

(c) A blackbody also absorbs energy from its environment, in this case from the 293-K room. The equation describing the absorption is the same as the equation describing the emission of blackbody radiation, Eq. (3.16). Calculate the energy per second absorbed by the average person, expressed in watts.

(d) Calculate the net energy per second lost by the average person via blackbody radiation.

3.9 Consider a model of the star Dschubba (δ Sco), the center star in the head of the constellation Scorpius. Assume that Dschubba is a spherical blackbody with a surface temperature of 28,000 K and a radius of 5.16×10^9 m. Let this model star be located at a distance of 123 pc from Earth. Determine the following for the star:

(a) Luminosity.

(b) Absolute bolometric magnitude.

(c) Apparent bolometric magnitude.

(d) Distance modulus.

(e) Radiant flux at the star's surface.

(f) Radiant flux at Earth's surface (compare this with the solar irradiance).

(g) Peak wavelength $\lambda_{\max}$.

3.10 **(a)** Show that the Rayleigh–Jeans law (Eq. 3.20) is an approximation of the Planck function B_λ in the limit of $\lambda \gg hc/kT$. (The first-order expansion $e^x \approx 1 + x$ for $x \ll 1$ will be useful.) Notice that Planck's constant is not present in your answer. The Rayleigh–Jeans law is a *classical* result, so the "ultraviolet catastrophe" at short wavelengths, produced by the λ^4 in the denominator, cannot be avoided.

(b) Plot the Planck function B_λ and the Rayleigh–Jeans law for the Sun ($T_\odot = 5777$ K) on the same graph. At roughly what wavelength is the Rayleigh–Jeans value twice as large as the Planck function?

3.11 Show that Wien's expression for blackbody radiation (Eq. 3.21) follows directly from Planck's function at short wavelengths.

3.12 Derive Wien's displacement law, Eq. (3.15), by setting $dB_\lambda/d\lambda = 0$. *Hint:* You will encounter an equation that must be solved numerically, not algebraically.

3.13 **(a)** Use Eq. (3.24) to find an expression for the frequency $\nu_{\max}$ at which the Planck function B_ν attains its maximum value. (*Warning:* $\nu_{\max} \neq c/\lambda_{\max}$.)

(b) What is the value of $\nu_{\max}$ for the Sun?

(c) Find the wavelength of a light wave having frequency $\nu_{\max}$. In what region of the electromagnetic spectrum is this wavelength found?

3.14 **(a)** Integrate Eq. (3.27) over all wavelengths to obtain an expression for the total luminosity of a blackbody model star. *Hint:*

$$\int_0^\infty \frac{u^3\,du}{e^u - 1} = \frac{\pi^4}{15}.$$

(b) Compare your result with the Stefan–Boltzmann equation (3.17), and show that the Stefan–Boltzmann constant σ is given by

$$\sigma = \frac{2\pi^5 k^4}{15c^2h^3}.$$

(c) Calculate the value of σ from this expression, and compare with the value listed in Appendix A.

3.15 Use the data in Appendix G to answer the following questions.

(a) Calculate the absolute and apparent visual magnitudes, M_V and V, for the Sun.

(b) Determine the magnitudes M_B, B, M_U, and U for the Sun.

(c) Locate the Sun and Sirius on the color–color diagram in Fig. 3.11. Refer to Example 3.6.1 for the data on Sirius.

3.16 Use the filter bandwidths for the UBV system on page 75 and the effective temperature of 9600 K for Vega to determine through which filter Vega would appear brightest to a photometer