PROBLEM 12.21

KNOWN: Visible spectral region 0.47 μm (blue) to 0.65 μm (red). Daylight and incandescent lighting corresponding to blackbody spectral distributions from the solar disk at 5800 K and a lamp bulb at 2900 K, respectively.

FIND: (a) Band emission fractions for the visible region for these two lighting sources, and (b) wavelengths corresponding to the maximum spectral intensity for each of the light sources. Comment on the results of your calculations considering the rendering of true colors under these lighting conditions.

ASSUMPTIONS: Spectral distributions of radiation from the sources approximates those of blackbodies at their respective temperatures.

ANALYSIS: (a) From Eqs. 12.30 and 12.31, the band-emission fraction in the spectral range λ_1 to λ_2 at a blackbody temperature T is

$$F_{(\lambda 1-\lambda 2,\, T)} = F_{(0 \to \lambda 2,\, T)} - F_{(0 \to \lambda 1,\, T)}$$

where the $F_{(0 \to \lambda\, T)}$ values can be read from Table 12.1 (or, more accurately calculated using the *IHT Radiation | Band Emission* tool)

Daylight source (T = 5800 K)

$$F_{(\lambda 1-\lambda 2,\, T)} = 0.4374 - 0.2113 = 0.2261$$ <

where at $\lambda_2 \cdot T = 0.65\ \mu m \times 5800\ K = 3770\ \mu m \cdot K$, find $F_{(0 - \lambda T)} = 0.4374$, and at $\lambda_1 \cdot T = 0.47\ \mu m \times 5800\ K = 2726\ \mu m \cdot K$, find $F_{(0 - \lambda T)} = 0.2113$.

Incandescent source (T = 2900 K)

$$F_{(\lambda 1-\lambda 2,\, T)} = 0.05098 - 0.00674 = 0.0442$$ <

(b) The wavelengths corresponding to the peak spectral intensity of these blackbody sources can be found using Wien's law, Eq. 12.27.

$$\lambda_{max} = C_3 / T = 2898\ \mu m \cdot K$$

For the daylight (d) and incandescent (i) sources, find

$$\lambda_{max,\ d} = 2898\ \mu m \cdot K / 5800\ K = 0.50\ \mu m$$ <

$$\lambda_{max,\ i} = 2898\ \mu m \cdot K / 2800\ K = 1.0\ \mu m$$ <

COMMENTS: (1) From the band-emission fraction calculation, part (a), note the substantial difference between the fractions for the daylight and incandescent sources. The fractions are a measure of the relative amount of total radiant power that is useful for lighting (visual illumination).

(2) For the daylight source, the peak of the spectral distribution is at 0.5 μm within the visible spectral region. In contrast, the peak for the incandescent source at 1 μm is considerably outside the visible region. For the daylight source, the spectral distribution is "flatter" (around the peak) than that for the incandescent source for which the spectral distribution is decreasing markedly with decreasing wavelength (on the short-wavelength side of the blackbody curve). The eye has a bell-shaped relative spectral response within the visible, and will therefore interpret colors differently under illumination by the two sources. In daylight lighting, the colors will be more "true," whereas with incandescent lighting, the shorter wavelength colors (blue) will appear less bright than the longer wavelength colors (red)