Rendering
Worksheet 4

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Part 1

25W bulb with 20% efficiency has actual output of 25W $\times$ 20% $=$ 5W. With energy per photon being:

$$E_\gamma = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \cdot 2.998 \times 10^{8}}{5 \times 10^{-7}} = 3.973 \times 10^{-19}\,\mathrm{J}$$

So photons per second is:

$$\frac{5}{3.973 \times 10^{-19}} = 1.26 \times 10^{19}$$

Part 2

Radiant flux

$$VI = 2.4 \times 0.7 = 1.68\,\mathrm{W}$$

Radiant intensity

$$\frac{1.68}{4\pi} = .0.1337\,\mathrm{W/sr}$$

Radiant exitance

Sphere radius $r = 5 \times 10^{-3}\,\mathrm{m}$
Area $A = 4\pi r^2 = 3.1415 \times 10^{-4}\,\mathrm{m}^2$

$$M_e = \frac{1.68}{3.1416 \times 10^{-4}} = 5.35 \times 10^{3}\,\mathrm{W/m}^2$$

Emited energy in 5 minutes

$$1.68 \times 60 \times 5 = 504\,\mathrm{J}$$

Part 3

Area of light at 1m is: $4\pi \cdot 1^2$ with pupil area of $(0.003)^2 \cdot \pi$ so pupil receives: $\frac{0.003^2 \cdot \pi}{4\pi \cdot 1^2}$ of total light. So $\frac{0.003^2 \cdot \pi}{4\pi \cdot 1^2} \times 1.68\,\mathrm{W} = 3.78 \times 10^{-6}\,\mathrm{W}$

Part 4

Given a 200 W bulb with 20 % efficiency, the radiant flux is

$$\Phi_e \;=\; 0.20 \times 200\,\mathrm{W} \;=\; 40\,\mathrm{W}$$

Assuming isotropic emission, the irradiance at distance $r = 2\,\mathrm{m}$ is

$$E_e \;=\; \frac{\Phi_e}{4\pi r^2} \;=\; \frac{40\,\mathrm{W}}{4\pi(2\,\mathrm{m})^2} \;=\; \frac{40}{16\pi}\,\mathrm{W/m^2} \;=\; 0.7958\,\mathrm{W/m^2}$$

Photometric quantities follow

$$\text{Photometric} \;=\; \text{Radiometric} \cdot 685 \cdot V(\lambda),$$

and for $\lambda = 650\,\mathrm{nm}$ we have $V(\lambda) = 0.1$. Thus the illuminance is

$$E_v \;=\; E_e \cdot 685 \cdot 0.1 \;=\; 0.7958\,\mathrm{W/m^2} \times 68.5 \;=\; 54.51\,\mathrm{lx}$$

Part 5

At the match position, the illuminances from the two point sources on each side of the screen are equal:

$$E = \frac{I_s}{r_s^2} = \frac{I_x}{r_x^2},$$

with $I_s = 40\,\mathrm{cd}$, $r_s = 0.35\,\mathrm{m}$, and $r_x = 0.65\,\mathrm{m}$ Hence

$$I_x \;=\; I_s\left(\frac{r_x}{r_s}\right)^2 \;=\; 40\,\mathrm{cd}\left(\frac{0.65}{0.35}\right)^2 \;=\; 40\,\mathrm{cd}\left(\frac{13}{7}\right)^2 \;=\; 40\,\mathrm{cd}\cdot\frac{169}{49} \;=\; 138.16\,\mathrm{cd}$$

$$I_x \approx 138\,\mathrm{cd}$$

Part 6

For a diffuse emitter, the *radiosity* (radiant exitance) is related to the radiance by

$$M = \pi L$$

Given $L = 5000\,\mathrm{W/(sr\,m^2)}$, we get

$$M = \pi \times 5000\,\mathrm{W/(sr\,m^2)} = 15\,708\,\mathrm{W/m^2}.$$

The emitting area is $A = (0.10\,\mathrm{m})^2 = 0.01\,\mathrm{m}^2$, so the total emitted power is

$$\Phi_e = M \times A = 15\,708\,\mathrm{W/m^2} \times 0.01\,\mathrm{m^2} = 157.08\,\mathrm{W}$$

$$M = 1.57 \times 10^4\,\mathrm{W/m^2}, \quad \Phi_e = 157\,\mathrm{W}$$

Part 7

For a non-diffuse emitter, the radiance varies as $L(\theta) = L_0 \cos\theta$. The radiant exitance is obtained by integrating over the hemisphere:

$$M = \int_\Omega L(\theta)\cos\theta\,d\omega = 2\pi\int_0^{\pi/2} L_0\cos^2\theta\,\sin\theta\,d\theta = \frac{2\pi L_0}{3}$$

With $L_0 = 6000\,\mathrm{W}/(\mathrm{m}^2\,\mathrm{sr})$,

$$M = \frac{2\pi}{3} \times 6000\,\mathrm{W}/(\mathrm{m}^2\,\mathrm{sr}) = 12\,566\,\mathrm{W}/\mathrm{m}^2$$

The emitting area is $A = (0.10\,\mathrm{m})^2 = 0.01\,\mathrm{m}^2$, so the total emitted power is

$$\Phi_e = M \times A = 12\,566\,\mathrm{W}/\mathrm{m}^2 \times 0.01\,\mathrm{m}^2 = 125.66\,\mathrm{W}$$

$$M = 1.26 \times 10^4\,\mathrm{W}/\mathrm{m}^2, \quad \Phi_e = 126\,\mathrm{W}$$