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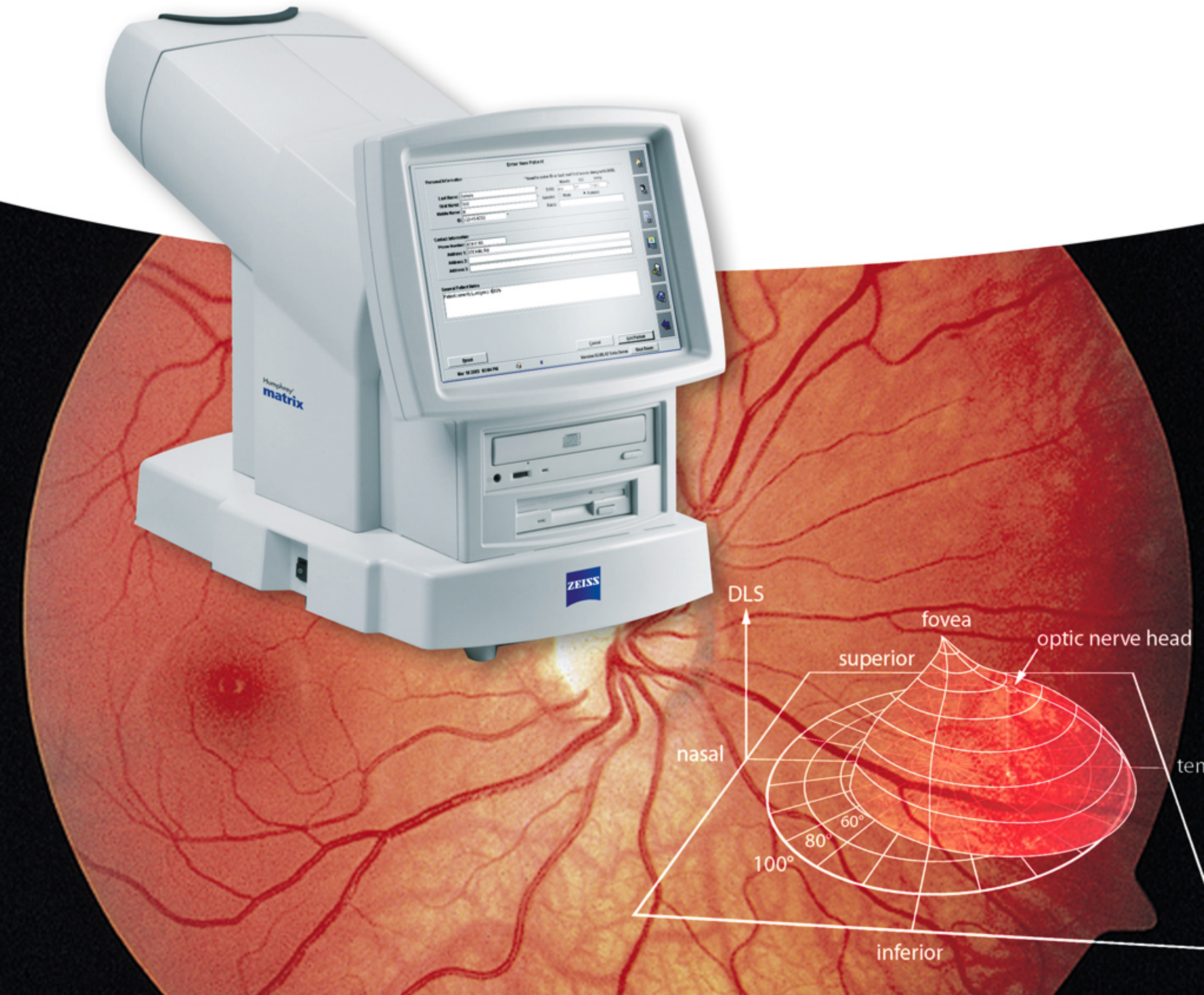
Functional Diagnostics



Solutions to Problems in „Optical Devices in Ophthalmology and Optometry“

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P8.1
Differential light sensitivity

> In the ZEISS Humphrey® Field Analyzer HFA II-i, the maximum luminance of the light stimulus is $\mathcal{L}_{\max} = 10,000$ asb. For the Haag–Streit Octopus®, we have $\mathcal{L}_{\max} = 1,000$ asb. In both devices a luminance $\mathcal{L}_b = 10\ \mathrm{cd/m^2}$ is used for background illumination. With the HFA II-i, the examiner measures a DLS value of 30 dB. What would be the corresponding DLS value of the Octopus® perimeter?

Solution:

Using Eq. (8.2), we find for the threshold differential luminance $\Delta\mathcal{L}_{\mathrm{th}}$

$$\mathrm{DLS\ (in\ dB)} = 10\ \log \frac{\Delta\mathcal{L}_{\max}\ (\mathrm{in\ cd\ m^{-2}})}{\Delta\mathcal{L}_{\mathrm{th}}\ (\mathrm{in\ cd\ m^{-2}})} \tag{S8.1}$$

with $\Delta\mathcal{L}_{\max} = \mathcal{L}_{\max}$. From Eq. (S8.1), we obtain

$$\Delta\mathcal{L}_{\mathrm{th}} = \Delta\mathcal{L}_{\max} \cdot 10^{-\mathrm{DLS}/10} \quad .$$

Inserting the given values, we get

$$\Delta\mathcal{L}_{\mathrm{th}} = 10^4 \mathrm{asb} \cdot 10^{-30/10} = 10\ \mathrm{asb} \quad .$$

For the Octopus device, we calculate the DLS value for $\Delta\mathcal{L}_{\mathrm{th}} = 10$ asb again using Eq. (S8.1). It follows that

$$\mathrm{DLS\ (in\ dB)} = 10\ \log\left(\frac{1000\ \mathrm{asb}}{10\ \mathrm{asb}}\right) = 20\ \mathrm{dB} \quad .$$

P8.2
Luminance

> Consider a hot tungsten platelet with a luminating area of $1\,\mathrm{mm}^2$. The platelet has a temperature of 3500 K. Under the assumption that the platelet can be considered a black body, what is its luminance? Compare this result with the maximum luminance of $\mathcal{L}_{\max} = 10,000$ asb for the ZEISS Humphrey® Field Analyzer HFA II-i.

Solution:

According to the Stefan–Boltzmann law about the radiant emittance (intensity) emitted by a black body, we know that

$$I(\mathrm{T}) = \sigma_{\mathrm{b}}\, T^4 \tag{S8.2}$$

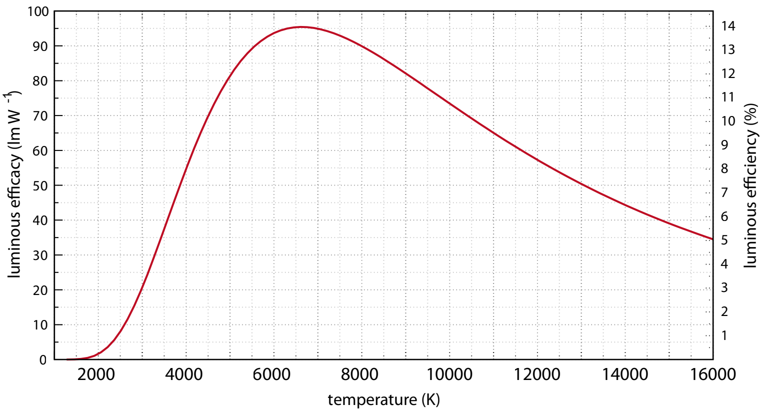

Figure S8.1 Luminous efficacy versus temperature for a black body radiator. Taken from http://en.wikipedia.org/wiki/Luminous_efficacy

with the Stefan–Boltzmann constant $\sigma_b = 5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$. The radiance of a black body platelet at 3500 K thus becomes

$$L_e = I\,(3500K) \cdot \mathrm{sr}^{-1} = 8.51 \times 10^6\ \mathrm{Wm^{-2}sr^{-1}}\ .$$

According to Table A4, we know that a monochromatic light source at a wavelength of 555 nm with an emitted power of $\mathrm{K_m} = \frac{1}{683}$ W (watts) into a solid angle of 1 sr (steradian) has a luminous intensity of 1 cd (candela) or a luminous power of 1 lumen.

For polychromatic light, such as black body radiation, the conversion between radiometric and photometric quantities (Section A.2.1.5) is given by the luminous efficacy in units of lumens per watt lm/W. Photopic luminous efficacy of radiation has a maximum possible value of 683 lm/W for the case of monochromatic light at a wavelength of 555 nm (green). Scotopic luminous efficacy of radiation reaches a maximum of 1700 lm/W for narrow-band light of wavelength 507 nm. In the table below, we find calculated and measured luminous efficacies. It is clear that light energy outside the visible wavelength range (~380 nm – 750 nm) reduces the luminous efficacies. For the black body radiator, we can find in the internet the dependency shown in Figure S8.1.

Type	Luminous efficacy of radiation (lm/W)
Typical tungsten light bulb at 2800 K	15
Ideal black body radiator at 3500 K	37
Ideal black body radiator at 7000 K	95
Ideal monochromatic 555 nm source	683

We thus find with the relation 1 W = 37 lumen = 37 cd sr, the luminance of the tungsten platelet at 3500 K to be

$$\begin{aligned}\mathcal{L} &= L_\mathrm{e} \cdot 37\,\mathrm{cd\,sr} = 8.51 \times 10^6\,\mathrm{W\,m^{-2}\,sr^{-1}} \cdot 37\,\mathrm{cd\,sr\,W^{-1}} \\ &= 3.149 \times 10^8\,\mathrm{cd/m^2} = 3.149 \times 10^4\,\mathrm{sb} \\ &= \frac{3.149}{\pi} \times 10^8\ \mathrm{asb} \approx 10^8\,\mathrm{asb}\ .\end{aligned}$$

Compared to the maximum luminance of the ZEISS Humphrey® Field Analyzer HFA II-i with a maximum luminance of 10,000 asb, the tungsten platelet is about $10000\times$ higher. For information, we give here a couple of useful relations (see also Table A4):

Radiometry:			
Radiant flux	P	W	sometimes also called "power"
Radiant intensity	I_e	$\mathrm{W \cdot sr^{-1}}$	sometimes inadequately called "intensity"
Radiance	L_e	$\mathrm{W \cdot sr^{-1} \cdot m^{-2}}$	sometimes inadequately called "intensity"
(Radiant) Emittance	W_e, I	$\mathrm{W \cdot m^{-2}}$	emitted power surface area, often called "intensity"
(Radiant) Irradiance	E_e, I	$\mathrm{W \cdot m^{-2}}$	incident power per surface area, often called "intensity"

Photometry:			
Luminous power	ϕ_v	$\mathrm{lm = cd \cdot sr}$	also called luminous flux
Luminous intensity	$\mathcal{I}_\mathrm{v}$	$\mathrm{cd = lm \cdot sr^{-1}}$	an SI base unit
Luminance	$\mathcal{L}, \mathcal{L}_\mathrm{v}$	$\mathrm{cd \cdot m^{-2} = lm \cdot sr^{-1} \cdot m^{-2}}$	other units are sb, asb
Illuminance	$\mathcal{E}_\mathrm{v}$	$\mathrm{lx = lm \cdot m^{-2}}$	light incident on a surface

The apostilb (asb) is an older unit of luminance defined by $1\ \mathrm{asb} = 1/\pi \times 10^{-4}\,\mathrm{sb} = 1/\pi \cdot \mathrm{cd/m^2}$.