Exercises Optical Spectroscopy

1) Name three kinds of electronic transitions and give an example for each one!

2) Which fundamental interactions of light with matter do you know?

3) How are radiometric and physiological quantities of light differentiated?

4) Which are the fundamental components of an optical spectrometer?

5) Sketch the construction of a fluorescence and an absorption spectrometer!

6) Which quantities are plotted on the x- and y-axis of the following spectra?
   a) Reflection spectrum
   b) Excitation spectrum
   c) Emission spectrum
   d) Thermo luminescence spectrum
   e) Mößbauer spectrum

7) Name the reason for a real and an apparent deviation from Lambert-Beer law!

8) What is meant by “melting of DNA” and how may this process be screened spectroscopically?

9) Define the term photoluminescence quantum yield!

10) Which information does a thermoluminescence spectrum provide?

11) Sketch the decay curve of a first and a second order process (choose a logarithmic y-axis)!

12) Explain with the help of the Kubelka-Munk function why there are no ideal black substances!

13) Define the law of conservation of energy for radiation?

14) You measured an optical spectrum. The intensity is plotted against wavelength. How could you convert this spectrum to get one where intensity is plotted against a quantity that is proportional to energy?

15) The absorption of a photon by a solid will lead to which kinds of physical processes?

16) How can you determine if the reason for the coloration of a SiO_2 or Al_2O_3 single crystal is caused by crystal defects or contaminations (impurities/dopants)?

17) Determination of the lumen equivalent of the spectrum of a light source or phosphor

Calculation of the lumen equivalent is done with the help of the normalized V(λ) curve:

$$\Phi_v = K_{max} \int_{380}^{780} V(\lambda)\Phi_e(\lambda)d\lambda$$

With K_{MAX} = 683 lm/W und Φ_e = Integral normalized emission spectrum

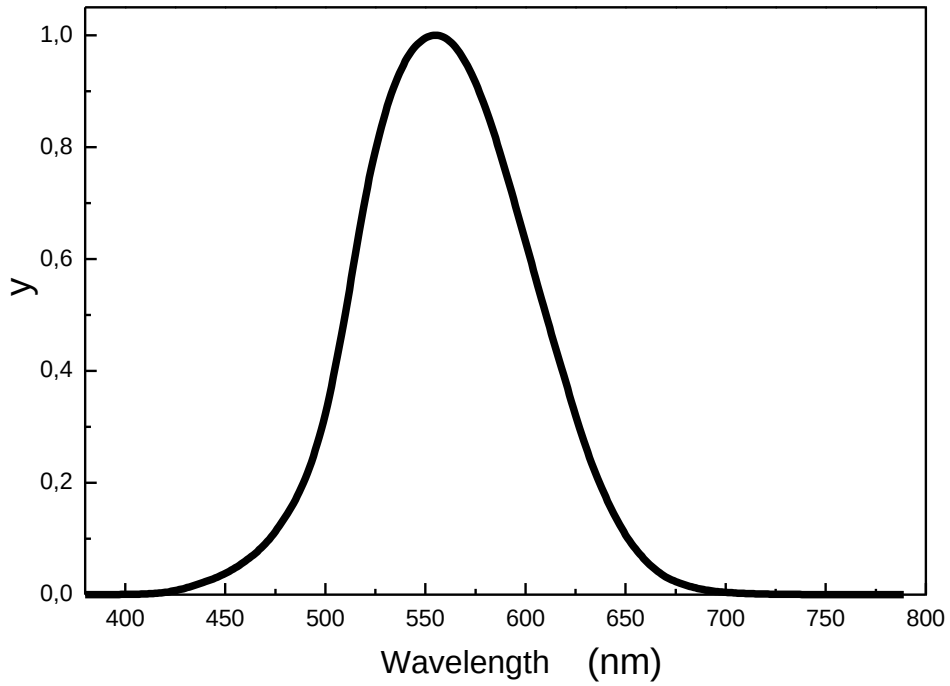
λ [nm]	V(λ)	λ [nm]	V(λ)	λ [nm]	V(λ)
380	3.90044E-5	520	0.71	660	0.061
385	6.39971E-5	525	0.7932	665	0.04458
390	1.2E-4	530	0.862	670	0.032
395	2.16999E-4	535	0.91485	675	0.0232
400	3.96003E-4	540	0.954	680	0.017
405	6.4E-4	545	0.9803	685	0.01192
410	0.00121	550	0.99495	690	0.00821
415	0.00218	555	1	695	0.00572
420	0.004	560	0.995	700	0.0041
425	0.0073	565	0.9786	705	0.00293
430	0.0116	570	0.952	710	0.00209
435	0.01684	575	0.9154	715	0.00148
440	0.023	580	0.87	720	0.00105
445	0.0298	585	0.8163	725	7.4E-4
450	0.038	590	0.757	730	5.2E-4
455	0.048	595	0.6949	735	3.61098E-4
460	0.06	600	0.631	740	2.49195E-4
465	0.0739	605	0.5668	745	1.71903E-4
470	0.09098	610	0.503	750	1.2E-4
475	0.1126	615	0.4412	755	8.48023E-5
480	0.13902	620	0.381	760	6E-5
485	0.1693	625	0.321	765	4.24012E-5
490	0.20802	630	0.265	770	3E-5
495	0.2586	635	0.217	775	2.12006E-5
500	0.323	640	0.175	780	1.49927E-5
505	0.4073	645	0.1382	785	1.06003E-5
510	0.503	650	0.107	790	7.42313E-6
515	0.6082	655	0.0816		

Calculate the lumen equivalent of the phosphor $LaPO_4$:Ce,Tb (LAP:Ce,Tb)! The simplified line spectrum of LAP:Ce,Tb is given on the following page!

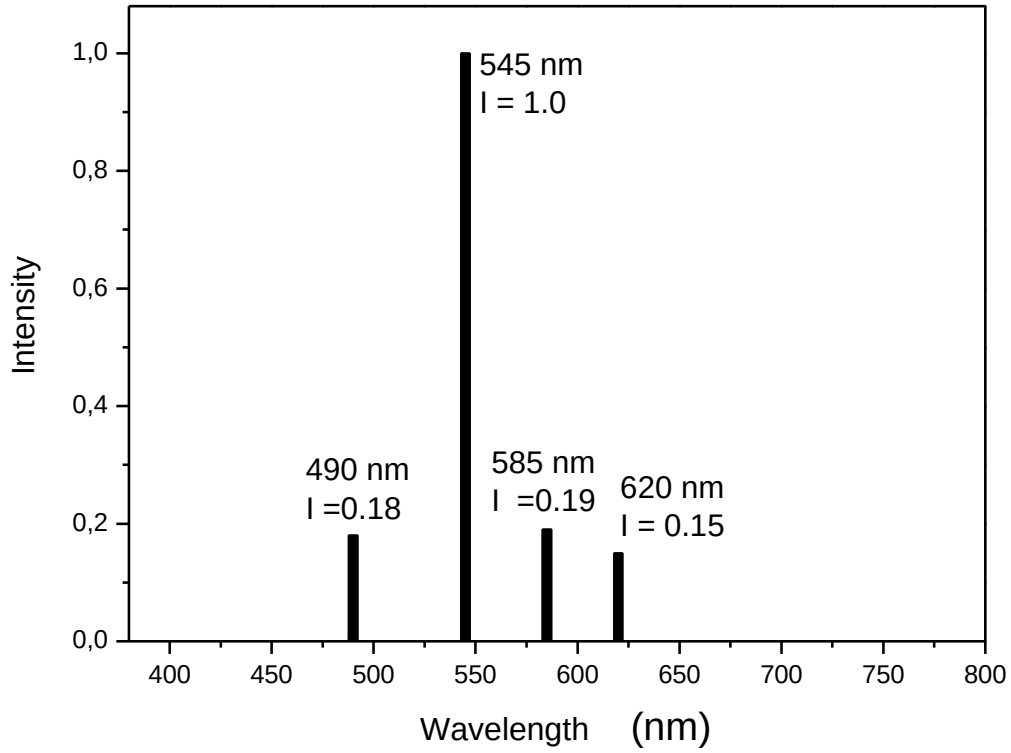
What is the maximum lumen equivalent which a light source can show?

At an excitation wavelength of 254 nm a typical LAP:Ce,Tb sample offers a quantum yield of 90 % and absorption of 85 %. How high is the luminous efficacy at 254 nm?

Eye sensitivity curve



Simplified emission spectrum of $LaPO_4$:Ce,Tb



18) Calculate the quantum yield Φ_{254} of the $BaMgAl_{10}O_{17}$:Eu (BAM) samples given in the following table!!

Sample	$\Phi_{254\ [\%]}$	R_{254} [%]	I_{254} [Counts/s]
Black (Black standard)	-	-	29251
BAM (Reference)	90.0	8.1	1457725
BAM Manufacturer A	?	10.0	1517085
BAM Manufacturer B	?	19.6	1380176

19) Estimate the absorption constant A of the phosphor $LaPO_4$:Ce,Tb at 254 nm with the help of the Kubelka-Munk function the reflection values R_{254} = 0.1, and the average particle size d_{50} = 10 µm!

Kubelka-Munk-function:
$$F(R_\infty) = \frac{A}{S} = \frac{(1-R_\infty)^2}{2 \cdot R_\infty} \sim \frac{\varepsilon \cdot c}{d}$$

20) Which standard materials are used in reflection spectroscopy? Which physical properties limit the range of usable wavelengths?

21) Which spectroscopic methods would you use to determine the position of the absorption bands of a transparent ceramic or of a scattering powder sample?

22) Which color should the following complexes have? The absorption bands have a full width at half maximum (FWHM) of about 50 nm?

Co^{3+}-complex	absorption maximum [nm]
$[Co(CO_3)_3]^{3-}$	640
$[Co(H_2O)_6]^{3+}$	600
$[Co(NH_3)_5Cl]^{2+}$	535
$[Co(NH_3)_5OH]^{2+}$	500
$[Co(NH_3)_6]^{3+}$	475
$[Co(CN)_5Br]^{3-}$	415
$[Co(CN)_6]^{3-}$	310

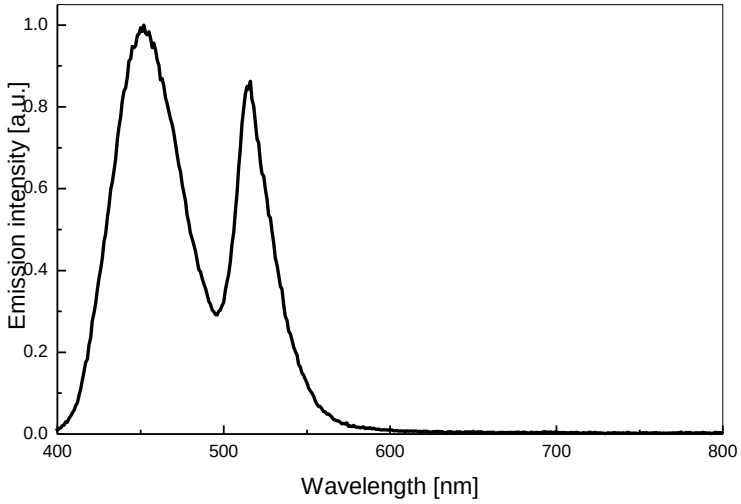
23) Quantum yields are measured mostly relatively to a standard or a reference phosphor. Sketch a procedure with which the quantum yield of a phosphor can be measured directly!

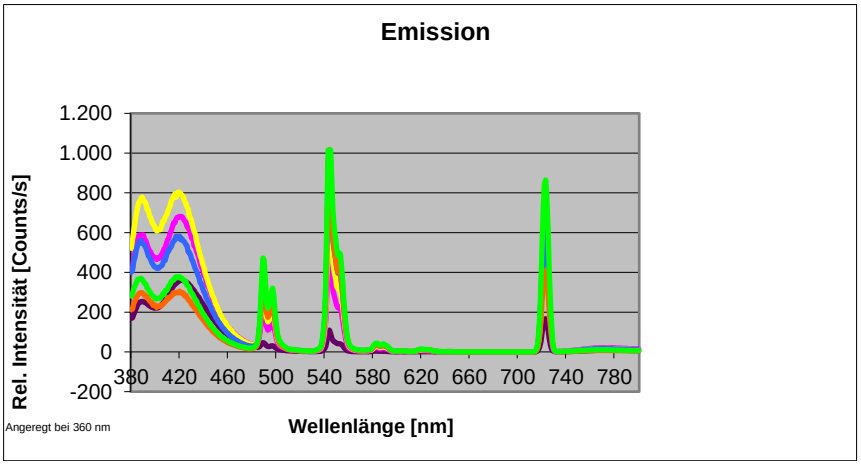
24) What is meant by actinometry? Give a photochemical reaction that is used for actinometry!

25) Which materials for spectroscopic windows would you use for the following spectral ranges?
a) X-ray
b) Vacuum-ultraviolet (VUV)
c) Ultraviolet (UV-A/B/C)
d) Visible (VIS)
e) Infrared (IR)

26) You have acquired the following red emitting phosphors:
$(Y,Gd)BO_3$:Eu
Y_2O_3:Eu
Y_2O_2S:Eu
YVO_4:Eu
$Sr_2Si_5N_8$:Eu
CaS:Eu
Which measurements must be performed to decide which of these materials are suitable for plasma displays (λ_{ex} = 172 nm), fluorescent lamps (λ_{ex} = 254 nm) or blue light emitting diodes (λ_{ex} = 450 nm). How can you determine whether the phosphors are activated by Eu^{2+} or Eu^{3+}?

27) The following emission spectra of $BaMgAl_{10}O_{17}$:Eu,Mn and $(Y,Gd)BO_3$:Ce,Tb were measured with an excitation at 254 nm or 360 nm:





Which measurement method is suitable to determine which emission band belongs to which activator ion?

Which variation of the spectra would you suspect with increasing temperature?