Chemistry 524--Hour Exam--Keiderling

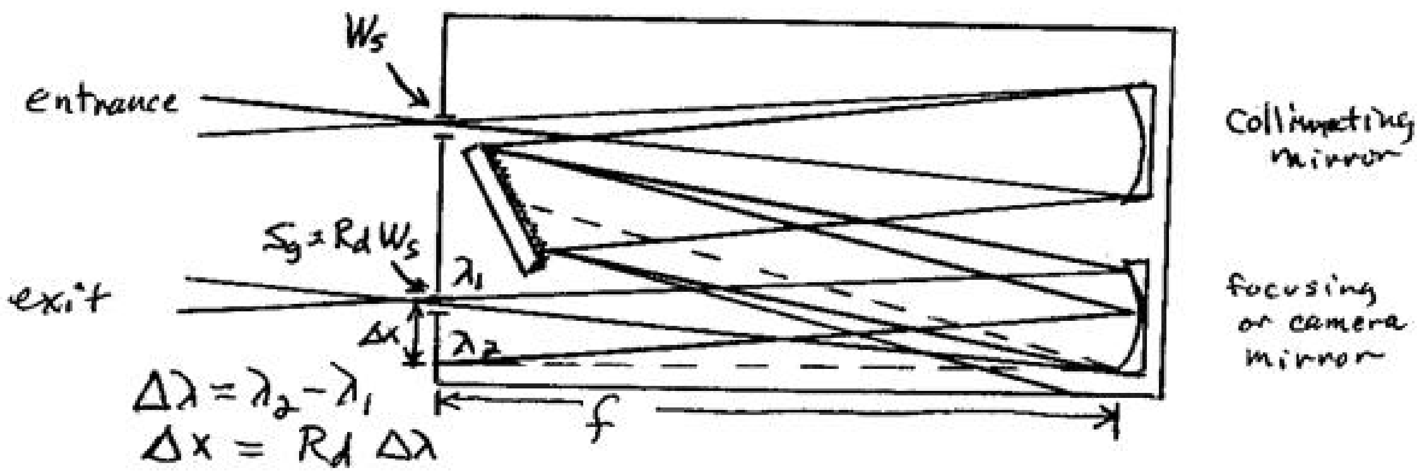
Oct. 14, 2002 -- 2-4 pm -- 174 SES

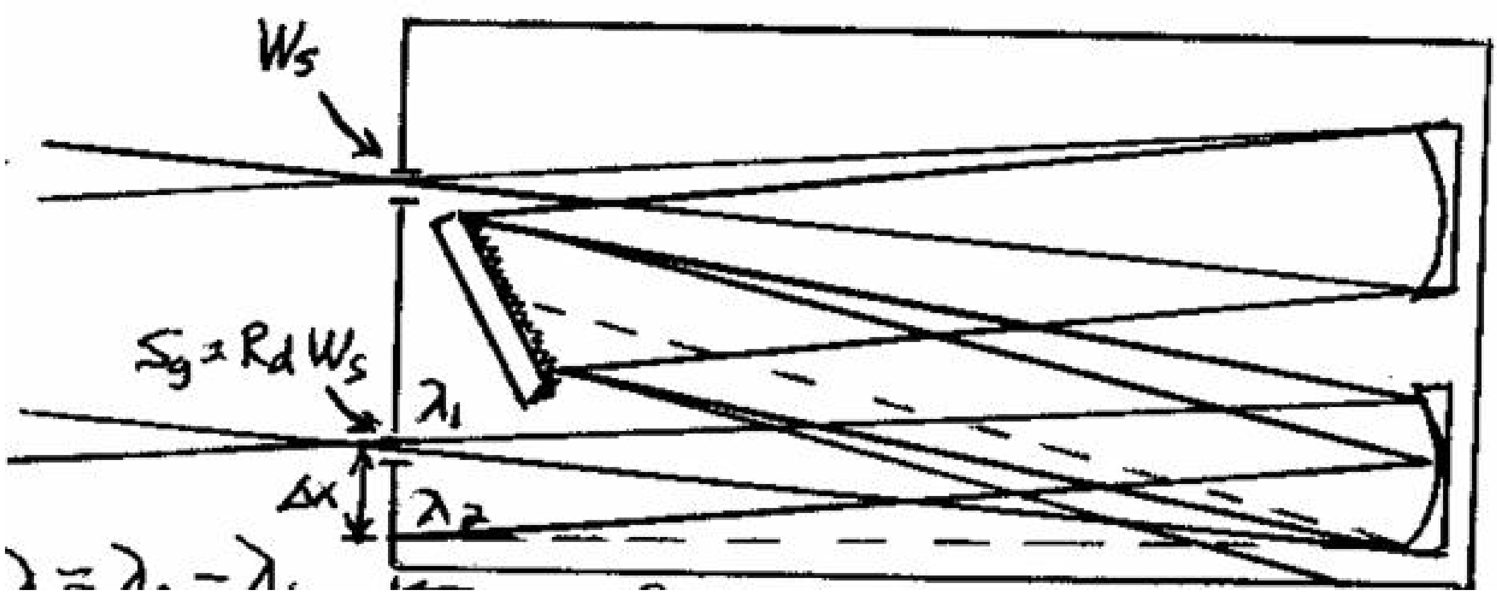
Please answer all questions **in the answer book** provided. Calculators, rulers, pens and pencils permitted. You may also bring in **one** 8.5x11" sheet of paper with anything you wish on it. **No open books allowed.** Everything needed should be in the exam, unless I made an error!

There is some helpful information at the end of the exam.

GOOD LUCK!

(30) 1. I have a Czerny-Turner style monochromator in my lab with approximately the following specifications: focal length 1 m, take-off angle of 9.5° , variable slits (0 - 8 mm). I use this primarily for infrared spectroscopy. We have available several gratings, one with 300 g/mm blazed at 3 μ and one with 150 g/mm blazed at 6 μ, each of which is 140 mm wide and 120 mm tall (parallel to the groves). The grating in this instrument rotates toward the entrance slit and away from the exit slit, see drawing below. Please answer (or calculate) the following:





a. Determine the effective aperture of the monochromator in F/#.

b. To what angle must the grating turn in this instrument to obtain 5 μ wavelength at the exit slit with the 150 g/mm grating?

c. Due to mechanical constraints, the grating in this instrument has a maximum rotation angle of 47° . What will be the maximum wavelengths accessible with each of these gratings in practice?

d. If there were no mechanical limits, what would be the maximum wavelengths of diffraction for each grating?

e. These gratings differ by a factor of 2 in both blaze wavelength and groove density. Explain why there is an advantage to having two gratings rather than using one in second order. (Keep it very brief, not worth many points

f. Determine the angular and linear dispersion at 5 μ, in first order, for the 150 g/mm grating.

g. Determine the resolution at 5 μ, for m=1, with the 150 g/mm grating in this monochromator if both slits are set at 3 mm width.

h. Determine the wavelength of optimal operation, the free spectral range and the resolution if you decided operate at higher resolution with 0.1 mm slits when operating the 300 g/mm grating in this monochromator but in **4th order.**

i. What angle θ would you need to rotate the grating to get the result in part **h**?

j. What is the theoretical resolving power of this set-up in part **h**?

i. Determine the blaze angle (groove slope) for λ_b = 6 μ for this 150 g/mm grating?

(12) 2. Contrast the use of the Nernst glower, Glowbar and tungsten-halogen lamp, i.e. the incoherent, black-body light sources we discussed that are of use for infrared absorption spectroscopy. Briefly explain how each works, typical color temperatures accessible, materials used in their construction, the frequency (wavelength) region in which they are most useful for spectroscopy, and note any important operational characteristics (power, cooling, external circuitry, etc.).

(4) 3. Choose one, your answer should be only a couple of sentences!

a. Briefly explain why deuterium lamps are used in some high quality UV absorption spectrometers even though Xe arc lamps have much more power, yet Xe arc lamps are often used in fluorimeters (fluorescence spectrometers).

b. Briefly explain why Ar ion lasers (using the 514.5 nm line) are often used in Raman spectrometers while doubled YAG lasers yield much higher power (at 532 nm).

(10) 4. a) Briefly explain why correction of luminescence for interfering signals is simple (subtractive) but for transmittance (hence absorbance) it is more complex. [Do not give me formulas but provide a one or two sentence rationale.]

b) Clearly luminescence and transmittance are signals that vary monotonically with the intensity of the light source used in the spectrometer. Briefly explain how these signals can be manipulated to become linear in concentration. Note limitations of your analysis.

(5) 5. **Choose *one*:**

a. Explain how a **Yag-pumped dye laser** works, how it can be used to provide tunable radiation, and in what parts of the spectrum they are most useful.

b. Explain how **doubling and tripling** of a Nd:YAG laser can be achieved. Can these methods be extended to the vacuum uv region? Why or why not?

(5) 6. **Choose one** of the gas phase laser systems, excimer (e.g. XeCl) or atomic ion, e.g. Ar^+) and briefly explain how it works, what frequency (wavelength) region it is used in and note its operational characteristics with regard to timing, power and tunability. Give an example spectroscopic application where it is commonly used and state why, briefly. { Note: these are open-ended questions, but more than a page is too much.} **:**

(15) 7. If you have several 35 mm slides (length of the long "horizontal" or "landscape" direction) of your last vacation to the mountains and you wish to show them to several friends, how would you design a projector to make them appear 2 m wide along the "horizontal" (landscape view) on the screen? Assume that you need to operate in a room that is only 5 m deep in its longest direction but 3 m in the other, which certainly will be big enough to hold the screen and you pointing out each mountain peak. Since this will be a homemade device, assume the biggest lenses or mirrors you can afford are 5 cm in diameter. Furthermore assume that you cannot use optics faster than f/1.0 because they will distort your beautiful mountain views. Be sure to detail the focal length, diameter and f/# of any lenses or mirrors you use, the materials used to construct them, the wavelength region of concern here, the type of source used to illuminate the slides and the position and identity of the object, image and any optics. { Hint: for most of the credit you may focus on the object-image relationship, assuming you identify them properly. Some credit for the total design--minus the remote control!}