Due Mar. 12, Thursday

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**All problems must be solved symbolically first. Then, any numerical answer, when required, can be computed by substituting numbers into the symbolic expression at/near the very end.** Solving problems symbolically means deriving the answer in terms of symbols, instead of numerical values. All problem numbers refer to those in the textbook. (Not all problems may be graded in detail, due to limited man power; however, you must do all problems.)

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**For each problem, you are required to use sensible symbols, by defining or adopting them yourself, for your symbolic solution.** If you are unsure how to do so, feel free to ask (or look back at homework 1)!

**Problem 1** (10 points) Problem 35.11 (Young's single slit).

**Problem 2** (20 points) Problem 35.28 (Telescope and Rayleigh criterion).

**Problem 3** (10 points) Problem 35.43 (Diffraction grating).

**Problem 4** (10 points) Problem 35.46 (Diffraction grating, Resolving power).

**Problem 5** (20 points) A non-monochromatic light is incident on a diffraction grating with 2400 rulings/mm and the total number of rulings $N = 15000$. This problem concerns how we can generate a monochromatized light using this setup.

(a) Prove that the ratio $(\lambda/\Delta\lambda)$ is equal to $\omega/\Delta\omega$, where $\Delta\lambda$ ($\Delta\omega$) is the width of the wavelength (angular frequency) in the monochromatized light. Note that *any* real monochromatic light has a *distribution* of wavelength (and thus frequency). So, here $\lambda$ ($\omega$) corresponds to the "mean value" or the "average value" of the wavelength (angular frequency) distribution, and $\Delta\lambda$ ($\Delta\omega$) is the width of the wavelength (angular frequency) distribution. When we refer to a monochromatic light or a monochromatized light what we really mean is that $\Delta\lambda \ll \lambda$, which is what we assume here.

(b) Your goal is to obtain a monochromatic light with $E_{photon} = \hbar\omega = 13.600$ eV (corresponding to wavelength[1] $\lambda = 911.6$ Å) with high resolution $\Delta E_{photon} = \hbar\Delta\omega = 1$ meV. You like to achieve this goal by placing a screen normal to the diffracted beam and cutting a thin "exit slit" on the screen. The light passing through the exit slit is the monochromatized light, which you could

[1] The energy of a single photon, $E_{photon} = \hbar\omega$, in unit of eV, is given by $12398/\lambda$, if $\lambda$ is given in Å. Here, $\lambda$ is defined as the wavelength of light in vacuum.

use for your prize-winning experiment. Let us assume that the screen is placed at $r = 1$ m from the grating. What should be the angular position ($\theta$) of the exit slit and its width ($w = r\Delta\theta$) if you were to use (i) the 1st order light and (ii) the 2nd order light?

(c) Let us say that you are given a specification that photons in the incident light have a continuous energy distribution from 5 to 20 eV, or, equivalently, a continuous wave length distribution from 620 to 2480 Å. Explain why the goal stated in the previous part would be achieved when the first order light is collected, but the goal is not achieved when the second order light is collected due to the contamination of the outgoing light by light of unwanted frequencies.

**Problem 6** (10 points) Problem 35.81 (X-ray diffraction).

There won't be any homework for chapters 12 and 13. However, you are advised to try some problems yourself, e.g., 12.9, 12.53, 12.57, 13.15, 13.40, and 13.54.