Assignment #11 (Optional)

The problems below are optional; they have no due date. They cover the material of the last four lectures, and are only meant to help you in studying and digesting the content of these four lectures (in preparation for the Final Exam). Solutions to these problems will be posted on the web by Wednesday, May 15.

Problem 11.1
Single slit diffraction.
Giancoli 36-9.

Problem 11.2
Gratings - Physics and Candle Light - Home Experiment.
Your grating has 1000 lines per mm. **Isn't that amazing? Compare the spacing with the wavelength of red light which is about 0.63 μm!** The grooves are made on the transparent plastic film; keep your fingers off the plastic! Note, $1\,\AA = 10^{-10}\,\text{m}$.

(a) Calculate the spacing d between adjacent lines (grooves).

(b) Calculate the angle θ between zero order and first order maximum for red (6300 $\AA$) and for blue (4500 $\AA$) light, and calculate the angle (in first order) between the red and the blue.

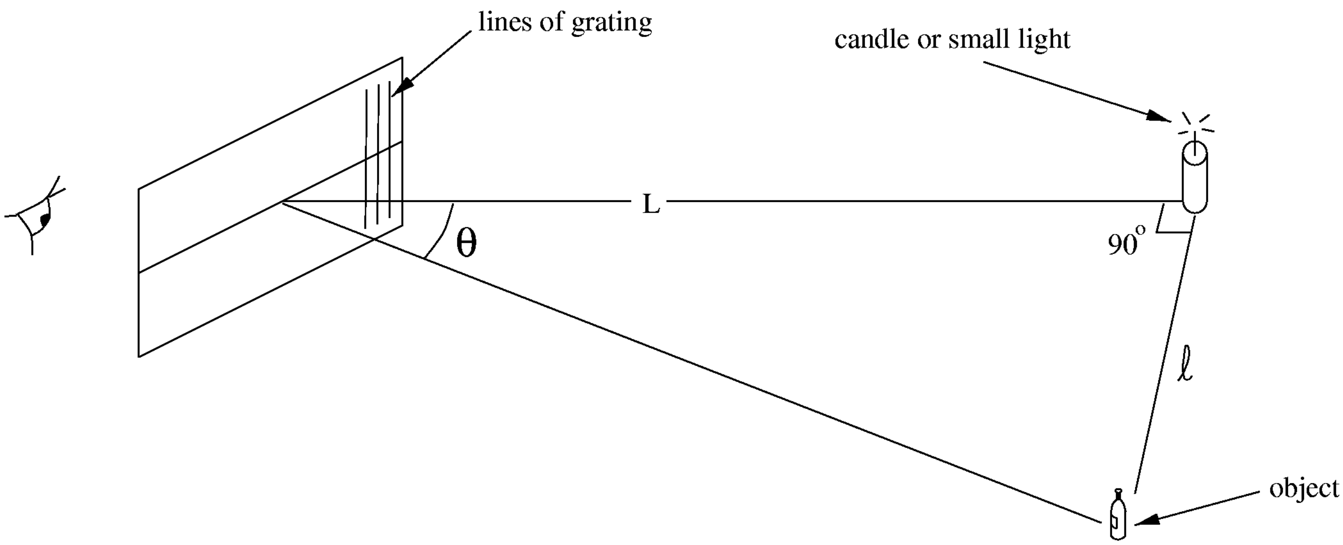
(c) Calculate how many orders there are in the red and how many in the blue? Notice, for large angles: $\sin\theta \neq \theta$.

When it is dark outside, and all lights are off in your room, light a candle or switch on a small bright bulb (2nd best). Hold the grating in front of one eye (close the other). Look at the candle and observe spectra. Rotate your grating (in its own plane) until the lines (grooves) are vertical. You should now see the 1st order spectra on the left and right side of the zero order.

(d) What colors do you observe in the zero order spectrum?

(e) How many maxima do you see in red and how many in blue? Compare this with your predictions under b. (Use your filters to avoid confusion due to possible overlap of different colors from different orders.)

(f) Place an object a distance ℓ away from the candle (as in the figure below) until you see the red light of the first order maximum in the same direction as the object (use your red filter). Measure the distances L and ℓ. Calculate from this the angle θ (see figure). Compare your result with that under b.



(g) Observe the two first order spectra as before (grooves in grating vertical). Now rotate the grating about the vertical; you observe an increase in θ. Why?

Use your grating to analyze the various spectra of street lights. The mercury lights show a remarkable spectrum!

Problem 11.3
Diffraction, interference and angular resolution of 2-element interferometers.
Equation 36-9 holds all the "secrets" of diffraction and interference for single-slits and double-slits. This is true for the entire range of the electromagnetic spectrum. See e.g. figure 36-10c and 36-11. Consider two radio telescopes, each with a diameter of 100 ft, separated by 1 km.

(a) Using only 1 of these telescopes, what would be the angular resolution at a wavelength of 21 cm?

(b) Using both telescopes as an interferometer, what now would be the angular resolution? For simplicity, think of the diameter of the radio dishes as an approximate "slit-width".

Problem 11.4
Destructive interference of sound.
Giancoli 36-55.

Problem 11.5
Resolving power of the human eye.
Giancoli 36-65.

Problem 11.6
Resolving power of optical telescopes.

(a) What is the maximum possible angular resolution (diffraction limitation) of an optical telescope with a 2.4 m mirror (in blue light)?

(b) What is the actual resolution of such ground-based telescopes of which many exist on the various continents?

(c) What is the angular resolution of the Hubble Space Telescope (it has a 2.4 m mirror)?

(d) Why is there such a large difference between the resolution of 2.4 m ground-based telescopes and Hubble?

Problem 11.7
Doppler Shift of Light I.
Giancoli 37-56.

Problem 11.8
Doppler Shift of Light II.
Giancoli 37-59.