Indian Association for the Cultivation of Science
Kolkata 700032, India

First Year, Second Semester
2019-2020

PHS – 1201: ELECTRICITY, MAGNETISM & OPTICS

Assignment #3 - Diffraction, Polarization and Laser

UNDERSTANDING DIFFRACTION AND SOME OTHER ASPECTS

Sumanta Chakraborty

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INSTRUCTIONS

- You are free to discuss the questions among yourselves if you choose to do so. However, each one should write the answers independently at the end and submit it. You should be prepared to explain the steps and arguments in your answer if called upon to do so.
- Interpret the questions as a physicist; not as a mathematician. Make reasonable assumptions when required and mention them.
- Your answers can be brief and to the point, giving just the essential algebraic steps and arguments. The marks for each of the questions are given at the right end of the question. Total marks: **70**.
- I have tried to keep the questions clear, consistent with the notation used in the class and error-free. But if you have any difficulties on these counts, feel free to email me.

1. A convex lens of focal length 40 cm is employed to focus the Fraunhofer diffraction pattern of a single slit of width 0.3 mm. Calculate the linear distance between the first dark band from the central bright band. Take the wavelength to be 589 nm. [**5**]

2. A parallel beam of light of wavelength 500 nm is incident normally on a narrow slit of width 0.2 mm. The Fraunhofer diffraction is observed on a screen which is placed at the focal plane of a convex lens of focal length 20 cm. Calculate the approximate distance between the first two maxima. [**5**]

3. How many orders will be visible, if the wavelength of incident light is 589 nm and the number of lines in the grating is 104 per mm? [**5**]

4. Sodium light of wavelengths 589 nm and 589.6 nm are made incident normally on a grating having 500 lines per mm. Calculate the angular dispersion of these lines in the spectrum to first order. [**5**]

5. A diffraction grating, which is 2 cm wide is just able to resolve the Sodium lines at 589 nm and 589.6 nm as they are incident normally to the diffraction grating at second order. Hence find the number of rulings per mm. [**5**]

6. Consider a grating of width 5 cm with slits of width $a = 0.001$ mm separated by a distance of 0.002 mm. How many orders will be visible at $\lambda = 550$ nm? Calculate the width of principal maxima. Will there be any missing orders? [**5**]

7. Fraunhofer diffraction pattern is observed by a double slit having slit width $a = 0.16$ mm and separation between the slits is $b = 0.8$ mm. Find the missing orders. [**5**]

8. Find the least number of lines that a diffraction grating must have in order to resolve in the first order, the red doublet originating from the mixture of hydrogen and deuterium. The wavelength difference is 0.18 nm and the mean wavelength is 656.3 nm. [**5**]

9. Consider two gratings, one of width 2 cm has 2000 lines and the other of width 1 cm has 1000 lines. Compare their angular dispersion and resolving power in the second order. [**5**]

10. An un-polarized plane light wave of intensity 10 mW cm^{-2} passes through two polarizers whose pass axis are making an angle 30° to each other. Calculate the intensity of the transmitted wave. [**5**]

11. Suppose you have placed two polarizers at 90° between their pass axis. Another polarizer is placed between them, which is rotated at a constant angular velocity ω about their common central axis. If un-polarized light of intensity I_0 is incident on the first polarizer, then show that the intensity of transmitted light is $(I_0/16)(1 - \cos 4\omega t)$. [**5**]

12. Consider an elliptically polarized light incident normally on a quarter wave-plate (this just introduces a phase shift of $(\pi/2)$ for any light passing through its pass axis). Find the state of polarization of the transmitted light if the major axis of the ellipse makes an angle (i) 0°, (ii) 30° and (iii) 90° with the pass axis of the wave plate. **[5]**

13. Calculate the ratio of spontaneous emission rate to the stimulated emission rate at $T = 10^3$ K for visible light of frequency 5×10^{14} Hz and microwave of frequency 10^9 Hz. Thus comment on the result. **[5]**

14. A Laser beam of wavelength $\lambda = 6000$ Angstrom, power 10 mW and angular spread 1.5×10^{-4} rad is focussed by a lens of focal length 10 cm. Find (i) radius, (ii) power density of the image and (iii) the coherence width. **[5]**