Experimental Physics III

Submission due: November 17, 2022, before the lecture starts

Exercise Sheet 5

5.1

For a single slit experiment light passes through a slit with a width a and the resulting diffraction pattern is recorded on a screen at a distance l which is much bigger than the slit width ($a \ll l$, Figure 1).

- Derive a general formula for the angles θ_m for destructive and θ_n for constructive interference at point P as well as derive a general formula for the positions y_m of the m-th minimum and y_n of the n-th maximum at the screen.
- Calculate the distance of the m-th minimum y_m for $m = \pm 1$ and ± 2 from the screen center ($y = 0$) and the width of the central intensity maximum. Use $a = 0.1$ mm, $l = 3$ m, and $\lambda = 635.0$ nm for your calculation.
- Derive a general equation for the intensity distribution $I = I(\theta)$ of the single slit diffraction pattern at the screen. Assume $N + 1$ partial waves emitted from equidistant positions across the slit; start at one edge. Use the phase difference between waves emitted from adjacent positions and derive an expression for the overall phase difference (between the waves emitted from the opposite edges of the slit). Moreover, use a vector diagram and sum over all partial waves (with its amplitudes and phase angles) in order to derive an expression for the amplitude of the resulting wave.

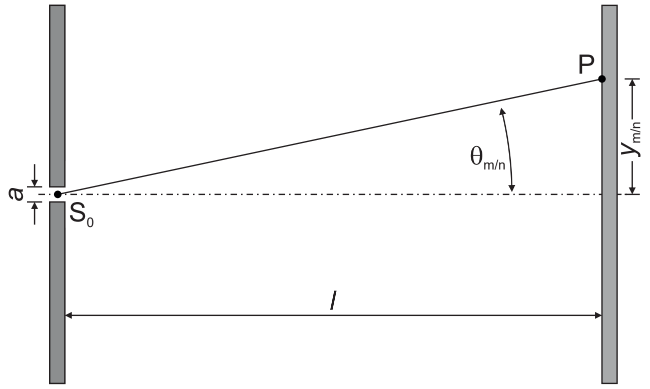

Figure 1: Principle geometry of a single slit experiment.

5.2

Sun light that is reflected from a layer of oil ($n = 1.6$) which is floating on water ($n = 1.3$) shines green ($\lambda = 500$ nm) for a tilted illumination of $\alpha = 45°$ (Figure 2). Calculate the thickness d of the oil layer.

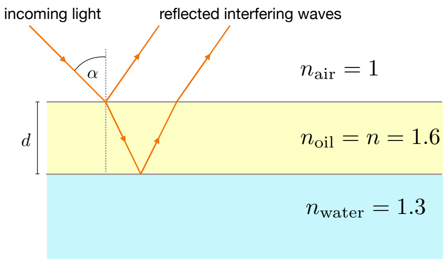

Figure 2: Light reflected from a floating oil film.

5.3

To prevent disturbing reflections from glass surfaces of, e.g., glasses or camera lenses, their surfaces are coated with a thin dielectric layer that causes destructive interference. Figure 3 shows an example of a single anti-reflective coating.

- Calculate the thickness of the single anti-reflective coating for the case $n_1 < n_2$ and such that U_1 and U_2 interfere destructively.
- Show that for $n_1 < n_2$ the relation

  $$n_1 = \sqrt{n_{\text{air}} \cdot n_2} \tag{1}$$

  for the refractive indices holds true. (Hint: Minimize the intensity $I_{\text{tot}} = |U_{\text{tot}}|^2$ of the reflected light and use the thickness calculated from the previous bullet point to evaluate the phase shift $\Delta\phi$ during the derivation.)

Hint: The reflectance between medium n_1 and medium n_2 is given by

$$R_2 = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2 . \tag{2}$$

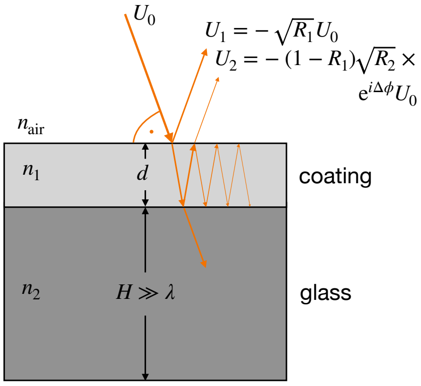

Figure 3: (s-polarized) light at initial amplitude U_0 hitting the anti-reflective coating of glass perpendicularly ($n_{\text{air}} < n_1 < n_2$). Absorption is neglected in this task. The sketch furthermore shows two example amplitudes of reflected light beams. U_2 has a phase shift of $\Delta\phi$ with respect to U_0.

5.4

A plane–convex lens with a radius of curvature of $R = 5$ m lays on a glass plate and is perpendicularly illuminated with a parallel light beam of a sodium lamp ($\lambda = 589.3$ nm) from above (Figure 4). The interstice is filled with water ($n_{\text{w}} = 1.34$). The refractive index of the lens and the glass plate is $n_{\text{g}} = 1.50$. The transmitted light exhibits Newton rings.

- Calculate the optical path difference of the two beams shown in Figure 4. Does the position at which the lens and the plate touch each other appear bright or dark?
- Derive a formula for the radius r of the Newton rings assuming $d \ll R$. How many rings are visible at most if the diameter of the lens is $D = 5$ cm?

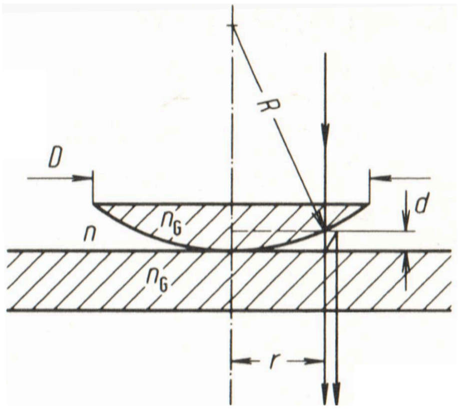

Figure 4: Newton rings due to a plane–convex lens laying on a glass plate.