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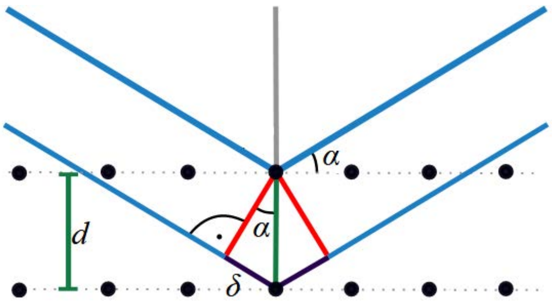
Exercises and Complements for the Introduction to Physics II for Students of Biology, Pharmacy and Geoscience

Sheet 9 / 29.04.2021 **Solutions**

Exercise 33.

The so-called Bragg condition is used to calculate the lattice plane spacing d, which can be derived in a similar way to the interference on thin layers (script p. 503-2).



The maxima in the measured spectrum occur when the maxima of the reflected light waves (at different planes) are superimposed. This happens e.g. at $\alpha \approx 7.5°$. So here the path difference 2δ must correspond exactly to the wavelength λ:

$$2\delta = \lambda \quad \text{or} \quad \delta = \frac{\lambda}{2}$$

According to the sketch, the following applies between two levels:

$$\sin\alpha = \frac{\delta}{d}$$

Thus for the lattice plane spacing d in question, it follows:

$$d = \frac{\delta}{\sin\alpha} = \frac{\lambda}{2 \cdot \sin\alpha} = \frac{7.0 \cdot 10^{-11}\ \text{m}}{2 \cdot \sin 7.5°} = 2.7 \cdot 10^{-10}\ \text{m}$$

Exercise 34.

(a) The following applies for the theoretical magnification (cf. p. 404-10):

$$\Gamma = \frac{s \cdot s_0}{f_1 \cdot f_2}$$

The following applies to the tube length s:

$$s = a - f_1 - f_2 = 0.168 \text{ m}$$

Hence it follows:

$$\Gamma = \frac{0.168 \text{ m} \cdot s_0}{f_1 \cdot f_2} = \frac{0.168 \text{ m} \cdot 0.25 \text{ m}}{0.012 \text{ m} \cdot 0.02 \text{ m}} = 175$$

(b) For the focal length of the eyepiece it follows:

$$\Gamma = \frac{s \cdot s_0}{f_1 \cdot f_2}$$

$$\frac{\Gamma \cdot f_2}{s_0} = \frac{a - f_1 - f_2}{f_1}$$

$$\frac{\Gamma \cdot f_2}{s_0} + 1 = \frac{a - f_2}{f_1}$$

$$f_1 = \frac{s_0(a - f_2)}{\Gamma \cdot f_2 + s_0}$$

$$f_1 = \frac{0.25 \text{ m} \cdot (0.2 \text{ m} - 0.012 \text{ m})}{100 \cdot 0.012 \text{ m} + 0.25 \text{ m}} = 3.2 \text{ cm}$$

(c) Accordingly, the following applies to magnification:

$$\Gamma = \frac{B}{G} = \frac{18.75 \text{ mm}}{2.5 \text{ mm}} = 7.5$$

For the focal length of the lens it follows analogously to (b):

$$f_2 = \frac{s_0(a - f_1)}{\Gamma \cdot f_1 + s_0} f_2 = \frac{0.25 \text{ m} \cdot (0.2 \text{ m} - 0.02 \text{ m})}{7.5 \cdot 0.02 \text{ m} + 0.25 \text{ m}} = 11.3 \text{ cm}$$

Exercise 35.

(a) See script 504-9.

$$d = \text{Lattice constant} = \frac{1}{1000} \text{ cm} = 1 \cdot 10^{-5} \text{ m}$$

Intensity maxima for the lattice with constant spacing d:

$$\sin\theta_m = m\frac{\lambda}{d} \quad \Rightarrow \quad \theta_1 = \arcsin\frac{\lambda}{d} = 3.73°$$

(b) The largest value for m in the equation for the intensity maxima occurs when $\sin\theta_m$ is maximal (i.e. $= 1$).

$$m_{max} = \frac{d}{\lambda} = \frac{1 \cdot 10^{-5} \text{ m}}{650 \text{ nm}} = 15.38 \quad \Rightarrow \quad \text{Maximum diffraction order} = 15$$

(c) The equation from (a) must be rearranged here for $m = 1$:

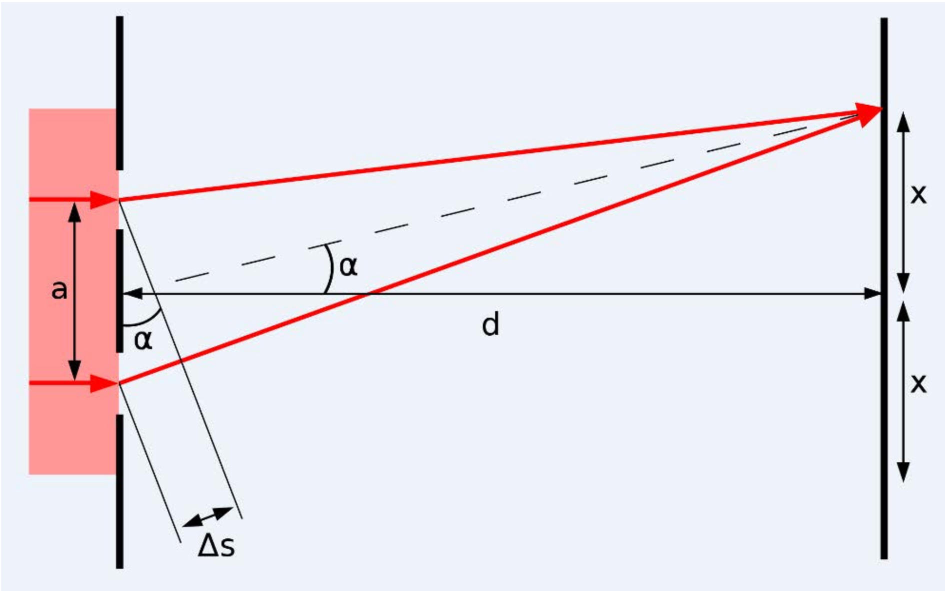
$$\lambda = d \cdot \sin\theta$$

So it follows:

$$\lambda_1 = 1 \cdot 10^{-5}\ \text{ m} \cdot \sin 2.46^\circ = 429.2 \text{ nm} \quad \text{und} \quad \lambda_2 = 1 \cdot 10^{-5}\ \text{ m} \cdot \sin 3.15^\circ = 549.5 \text{ nm}$$

Exercise 36.

The following sketch shows all the important relationships:



For the gap distance, the following relationship can now be established using the path difference Δs and the angle α:

$$\sin\alpha = \frac{\Delta s}{a} \quad \text{bzw.} \quad a = \frac{\Delta s}{\sin\alpha}$$

The following applies to the path difference at the 4th maximum:

$$\Delta s = 4 \cdot \lambda$$

Furthermore, the small angle approximation applies to the entire experimental setup:

$$\sin\alpha = \tan\alpha = \frac{x}{d}$$

Since the distance between the two 4th order maxima is $2x = 26$ mm, it follows that $x = 13$ mm. Hence for a:

$$a = \frac{\Delta s}{\sin\alpha} = \frac{4 \cdot \lambda \cdot d}{x} = \frac{4 \cdot 633 \text{ nm} \cdot 1700 \text{ mm}}{13 \text{ mm}} = 331.1\ \mu\text{m}$$