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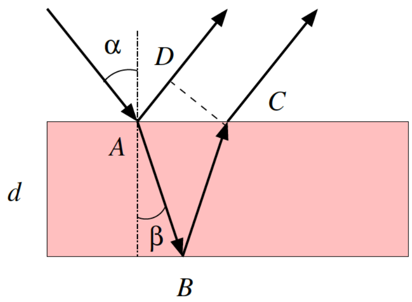
Exercises and Complements for the Introduction to Physics II

for Students

of Biology, Pharmacy and Geoscience

Sheet 8 / 20.04.2022 **Solutions**

Exercise 29.



First of all, the path difference between the two partial beams must be determined:

$$\Delta s = n_{oil} \cdot (\overline{AB} + \overline{BC}) - n_{air} \cdot \overline{AD}$$

The routes can be calculated as follows:

$$\overline{AB} = \overline{BC} = \frac{d}{\cos\beta} \quad \text{and} \quad \overline{AD} = \overline{AC} \cdot \sin\alpha = 2 \cdot \overline{AB} \cdot \sin\beta \cdot \sin\alpha = 2 \cdot d \cdot \tan\beta \cdot \sin\alpha$$

Thus with $n = n_{oil}$ it follows:

$$\Delta s = \frac{2nd}{\cos\beta} - 2d\tan\beta\sin\alpha$$

From the law of refraction it follows that $\sin\alpha = n \cdot \sin\beta$. From this and by inserting $\tan\alpha = \frac{\sin\alpha}{\cos\alpha}$ we have :

$$\Delta s = \frac{2nd}{\cos\beta} \cdot (1 - \sin^2\beta)$$

Using the relationship $\sin^2\beta + \cos^2\beta = 1$:

$$\Delta s = 2nd \cdot \cos\beta = 2nd\sqrt{1 - \sin^2\beta}$$

Since the law of refraction implies $\sin\beta = \frac{\sin\alpha}{n}$, and with $n = \sqrt{n^2}$:

$$\Delta s = 2d\sqrt{n^2\left(1 - \frac{\sin^2\alpha}{n^2}\right)} = 2d\sqrt{n^2 - \sin^2\alpha}$$

Using:

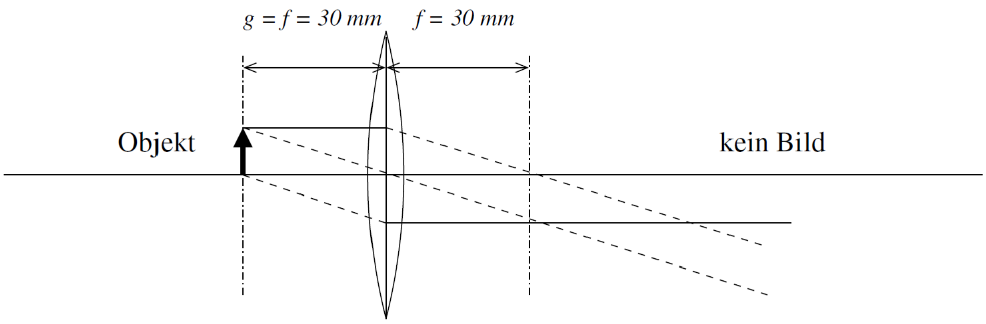
$$2d\sqrt{n^2 - \sin^2\alpha} = (m + \frac{1}{2})\lambda$$

and inserting $m = 0$, $\alpha = 45°$ and $\lambda = 500$ nm, the result is:

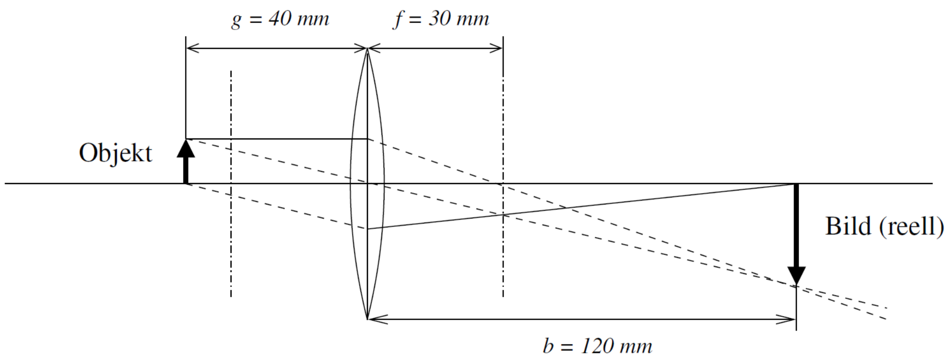
$$d = \frac{\lambda}{4\sqrt{n^2 - \sin^2\alpha}} = 8.7 \cdot 10^{-8}\ \mathrm{m}$$

Exercise 30.

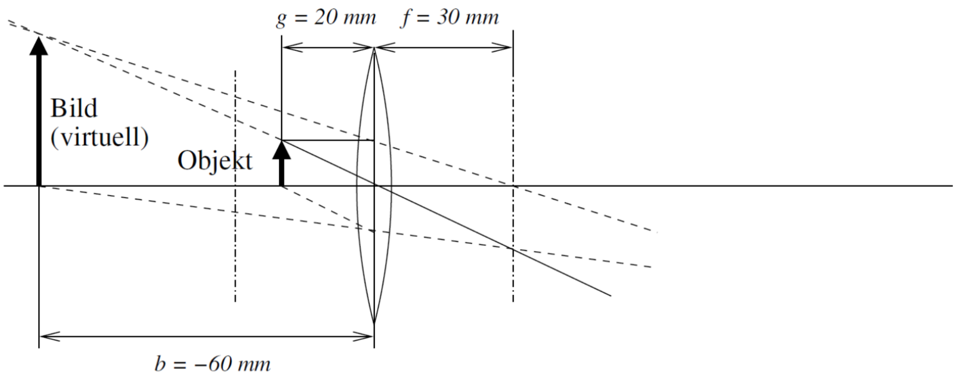
a) $f = g$



b) $g = 40$ mm



c) $g = 20$ mm

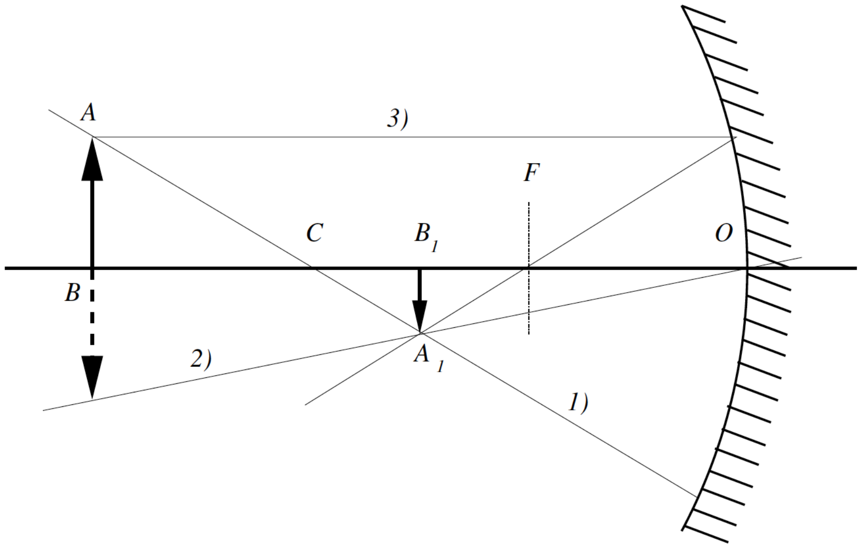


Exercise 31.

1) The ray from A to A_1 intersects the optical axis B-B_1-O at point C, the center of curvature. This is at a distance r, the radius of curvature of the mirror. The focal length of a concave mirror is $f = \frac{r}{2}$.

2) The ray from O through A_1 hits the top of the object if it is reflected on the optical axis.

3) The focal point F can be determined from $f = \frac{r}{2}$. One can then draw the focal ray 3).



Exercise 32.

a) The mapping law:

$$\frac{1}{f} = \frac{1}{g} + \frac{1}{b} \quad \Rightarrow \frac{1}{g} = \frac{1}{f} - \frac{1}{b}$$

Lateral enlargement:

$$\gamma = \frac{B}{G} = \frac{b}{g}$$

$$B = \frac{1}{g}Gb = \left(\frac{1}{f} - \frac{1}{b}\right)Gb = G\frac{b-f}{f} = 2.4 \quad \text{m} > 2.0 \quad \text{m}$$

b) The image distance b has now become larger compared to a). According to the movement rule (if the object moves towards the converging lens, the real image moves away from the lens), the object distance g can be reduced (thus the mapping law remains fulfilled).

$$\frac{1}{f} = \text{constant} = \frac{1}{g} + \frac{1}{b}$$

The distance between the slides and the lens needs to be decreased.

c) With the formula from a) and $b = 3.0$ m the fillowing applies:

$B(f = 45 \text{ mm}) = 2.4$ m picture too big for the canvas of 2.0 m×2.0 m
$B(f = 60 \text{ mm}) = 1.8$ m optimal solution
$B(f = 90 \text{ mm}) = 1.2$ m Picture unnecessarily small

⇒ Choose the lens with 60 mm focal length.