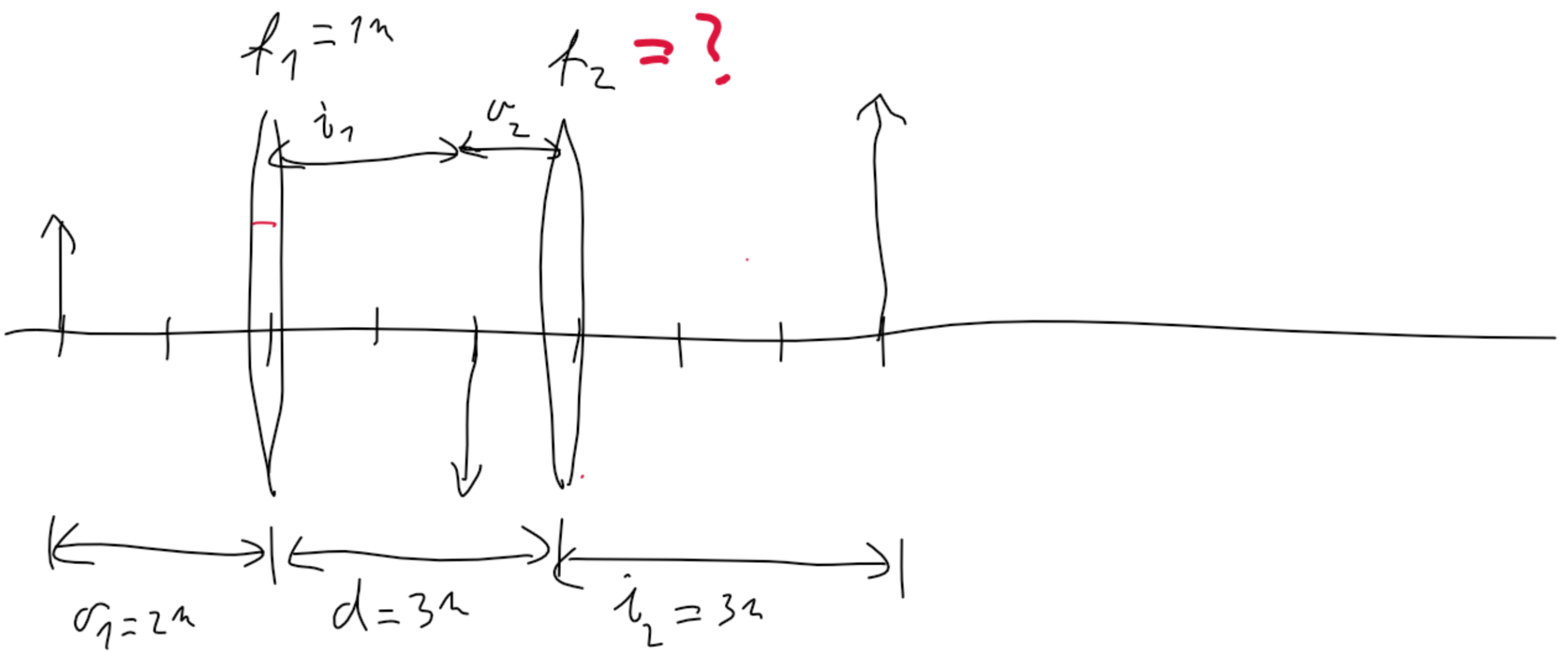


$$\frac{1}{f_1} = \frac{1}{o_1} + \frac{1}{i_1} \Rightarrow \frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} = \frac{o_1 - f_1}{f_1 o_1}$$

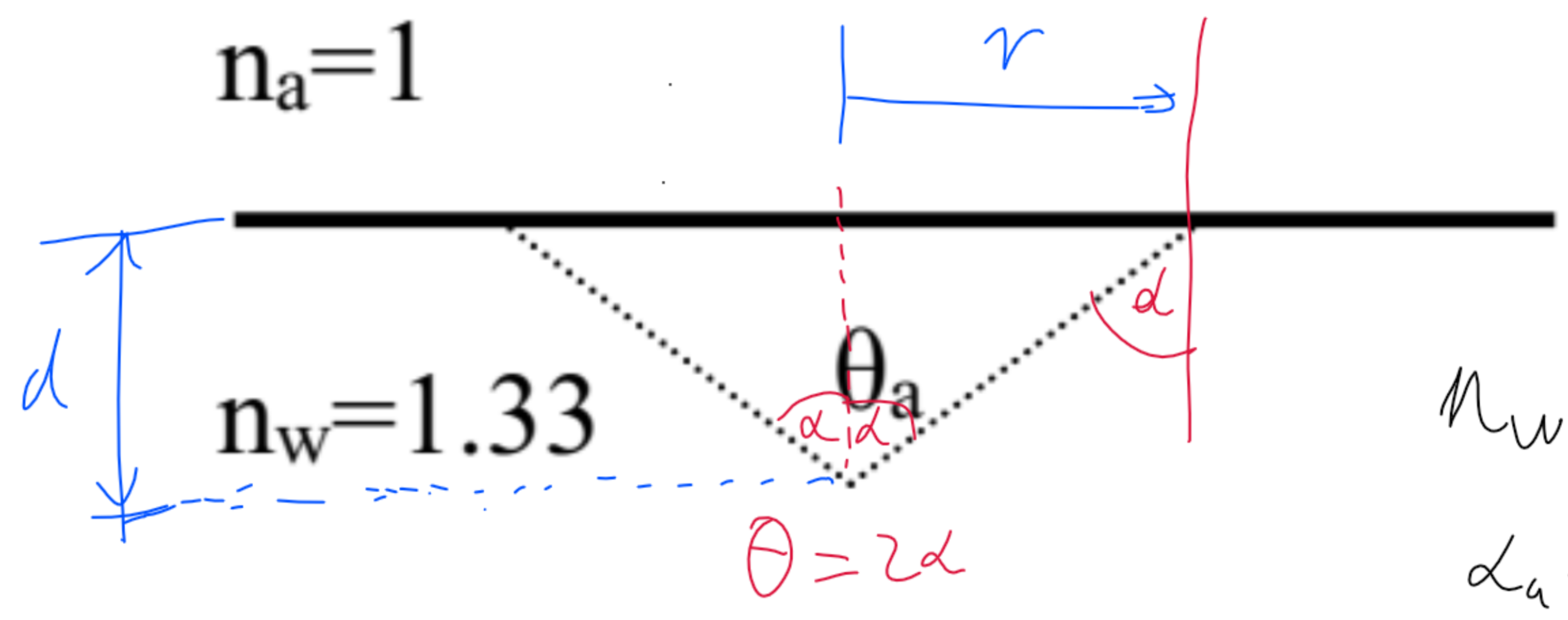
$$i_1 = \frac{f_1 o_1}{o_1 - f_1} = \frac{1 \cdot 2}{2-1} = 2\,m$$

$$\Rightarrow o_2 = d - i_1 = 1\,m$$

$$\frac{1}{f_2} = \frac{1}{o_2} + \frac{1}{i_2} = \frac{i_2 + o_2}{o_2 i_2} = \frac{3+1}{1 \cdot 3} = \frac{4}{3} \Rightarrow f_2 = \frac{3}{4}\,m = 0.75\,m$$

2. A scuba diver is swimming 10 m under the surface. When he looks up, he can see out of the water only in a certain angle, as if looking through a window. (There is air above the water. n_w=1.33, n_a=1)
a. Determine the aforementioned angle (θ) and the area of the "window".

a-b.



$n_w \cdot \sin\alpha_a \le n_a$

$\alpha_a = \arcsin \frac{n_a}{n_w}$

$\alpha_a = \arcsin \frac{1}{1.33}$

$\alpha_a = 48.75^\circ$

$\theta_a = 2 \cdot \alpha_a = 97{,}51^\circ$

$\tan\alpha_a = \frac{r_a}{d} \Rightarrow r_a = d \tan\alpha_a$

$r_a = 11{,}4\ m$

$A_a = r_a^2 \cdot \pi = 408.6\ m^2$

b. How do these parameters change, if the diver sinks to 15 m depth?

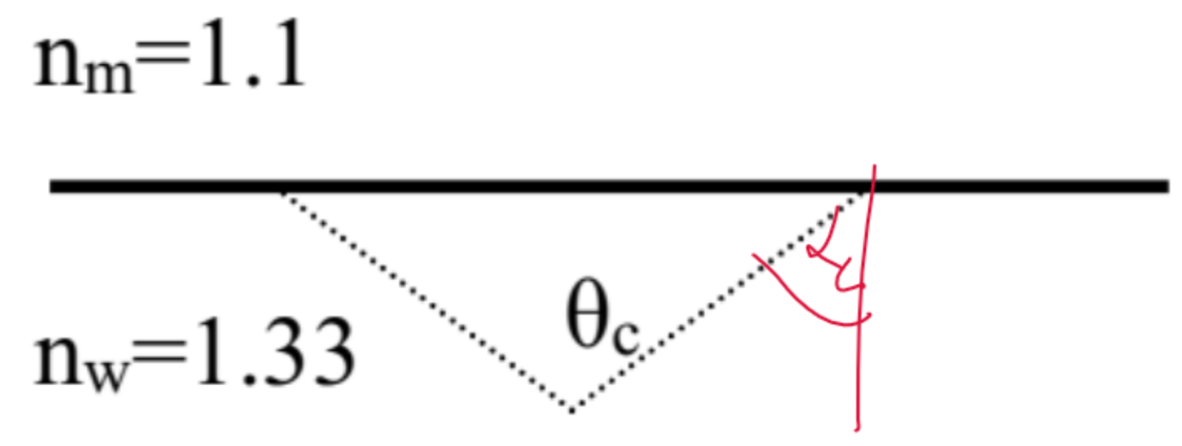
THE ANGLES REMAIN THE SAME $\theta_b = \theta_a = 97{,}51^\circ$

BUT $d_b = 1.5\, d_a \Rightarrow r_b = 1.5\, r_a$

$\Rightarrow A_b = 1.5^2 \cdot A_a = 919.3\ m^2$

c. Imagine, that the diver is swimming in an ocean on an alien planet, and there is not air but another medium above the surface of the water, whose refractive index is n_m=1.1. Determine the θ angle in this case!

c.



$n_w \cdot \sin\alpha_c \le n_m$

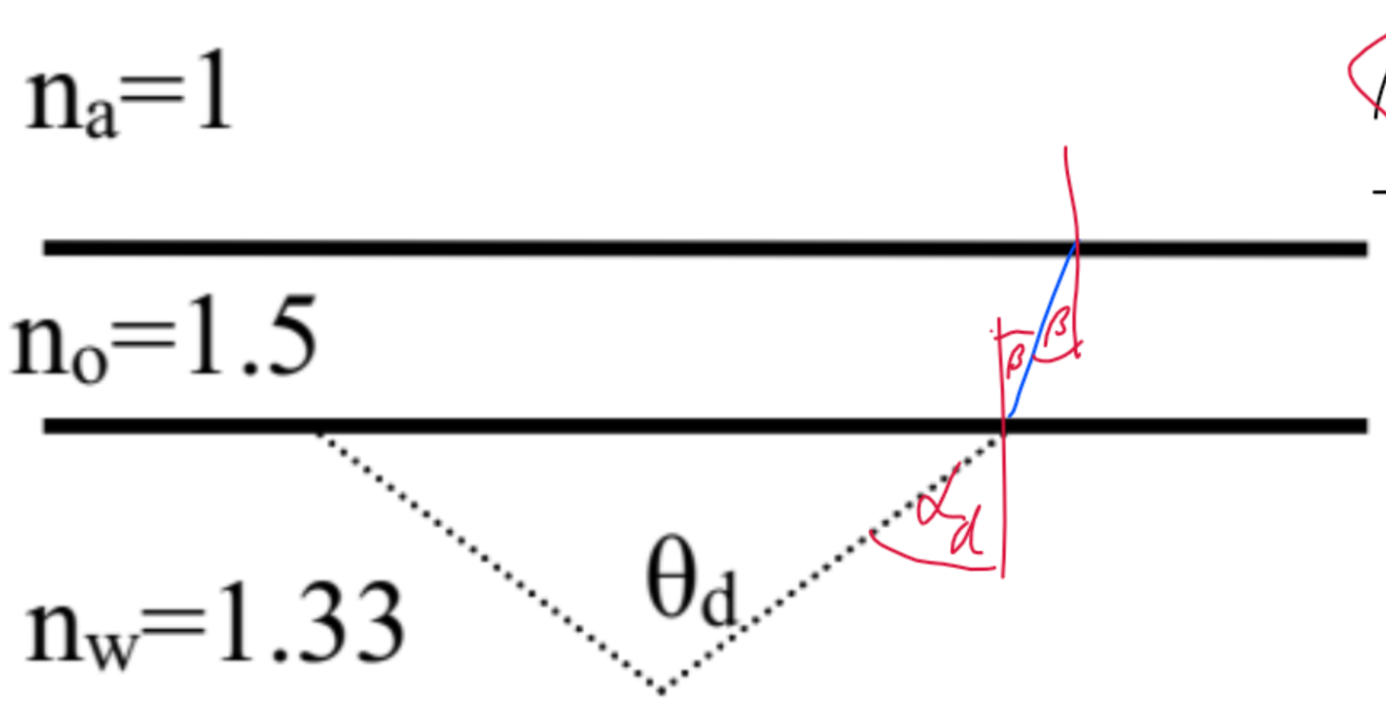
$\Rightarrow \alpha_c = \arcsin \frac{1.1}{1.33}$

$\alpha_c = 55.8^\circ$

$\theta_c = 2\alpha_c = 111.6^\circ$

d. Imagine, that the surface of the water is covered by a thin layer of oil (n_o=1.5). (There is air above the oil.) Determine the θ angle in this case!

d.



$n_w \cdot \sin\alpha_d = n_o \cdot \sin\beta$

$n_o \cdot \sin\beta \le n_a$

$n_w \cdot \sin\alpha_d = n_a$

$\alpha_d = \arcsin \frac{n_a}{n_w} = 48.75^\circ$

$\theta_d = 2 \cdot \alpha_d = 97{,}51^\circ$

(THE SAME AS a))

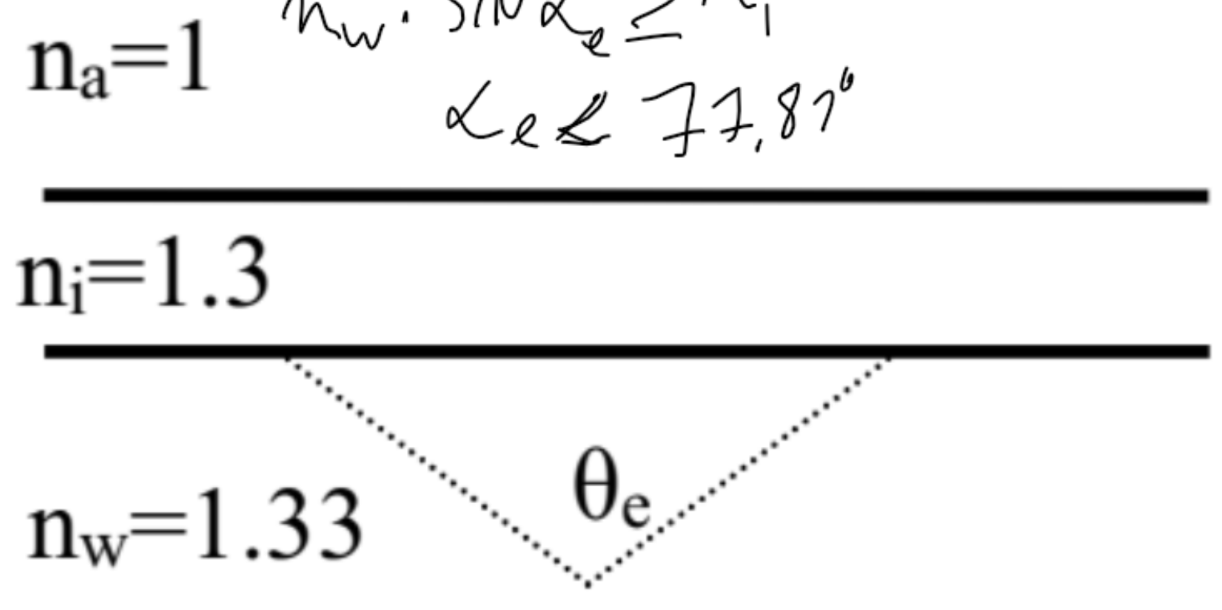
e. Imagine, that the surface of the water is covered by a thin layer of ice (n_i=1.3). (There is air above the ice.) Determine the θ angle in this case!

HERE WE HAVE TO CHECK BOTH INTERFACES

e.

$n_w \cdot \sin\alpha_e \ge n_i$

$\alpha_e \le 77{,}87^\circ$



$n_w \cdot \sin\alpha_e = n_i \sin\beta$

$n_i \cdot \sin\beta \le n_a$

$n_w \cdot \sin\alpha_e \le n_a$

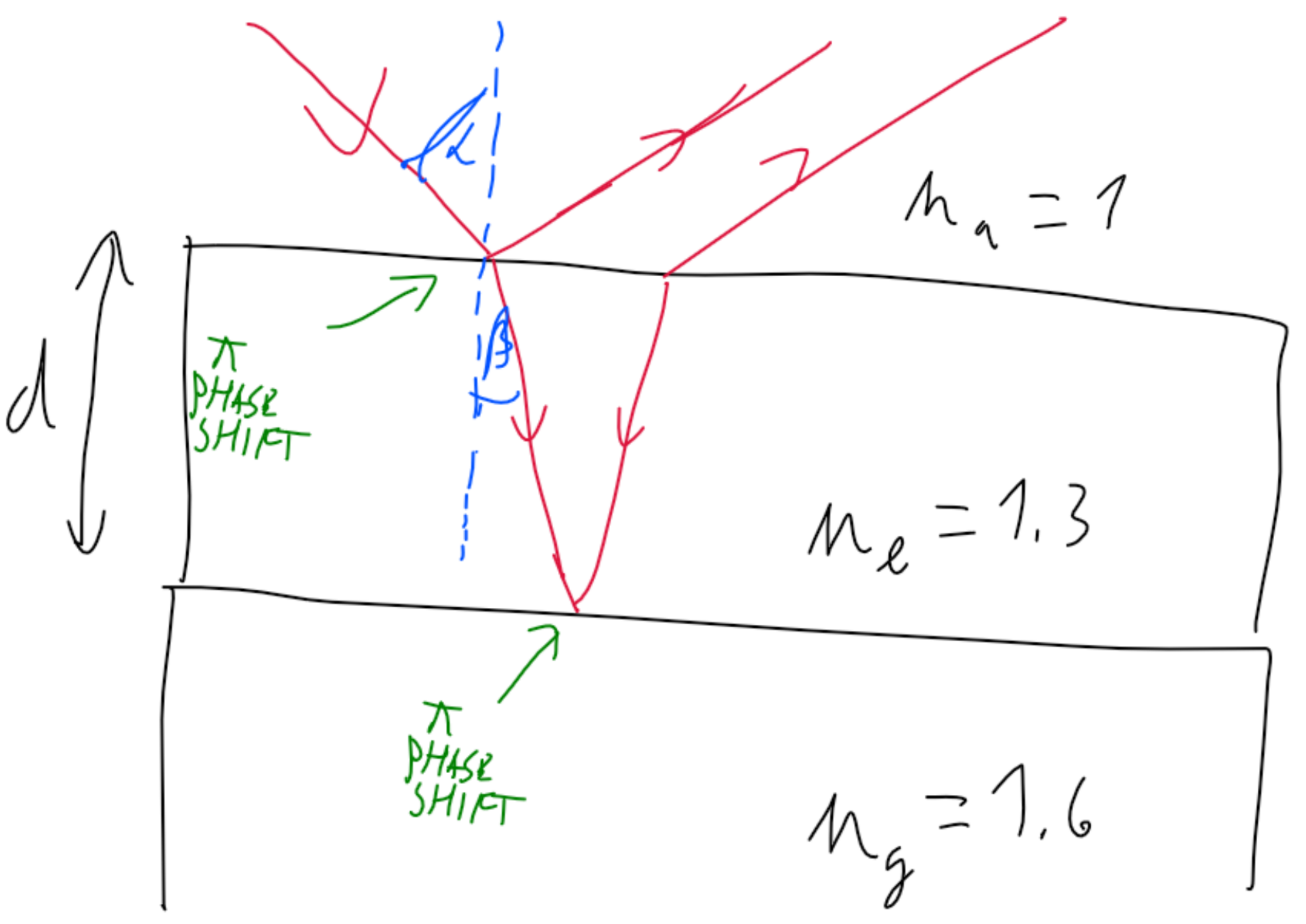
$\alpha_e = 48.75^\circ$

$\theta_e = 97{,}51^\circ$

3. A thin layer is deposited to a glass substrate. Their refractive indices are $n_l = 1.3$ and $n_g = 1.6$, respectively.

a. Determine the thickness of the layer if at normal incidence, it enhances reflection at 433 nm, and decreases it when the wavelength of light is 520 nm.

b. Are there other possible layer thicknesses that satisfy the above condition?



$$2 n d \cos\beta = \begin{cases} m\lambda_1 & \text{CONSTR.} \\ \left(\ell - \frac{1}{2}\right)\lambda_2 & \text{DESTR.} \end{cases}$$

$m, \ell \in \mathbb{Z}^+$

THE LEFT HAND SIDE IS THE SAME IN BOTH CASES

$\Rightarrow$ THE RIGHT HAND SIDE MUST ALSO BE THE SAME

$$\Rightarrow m\lambda_1 = \left(\ell - \frac{1}{2}\right)\cdot\lambda_2$$

$$\frac{m}{\ell - \frac{1}{2}} = \frac{\lambda_2}{\lambda_1}$$

$$\frac{2m}{2\ell - 1} = \frac{520}{433} = \frac{6}{5} \Rightarrow \begin{matrix} m = 3 \\ \ell = 3 \end{matrix}$$

$$\Rightarrow 2 n_l \cdot d \cdot \cos 0^\circ = m\lambda_1$$

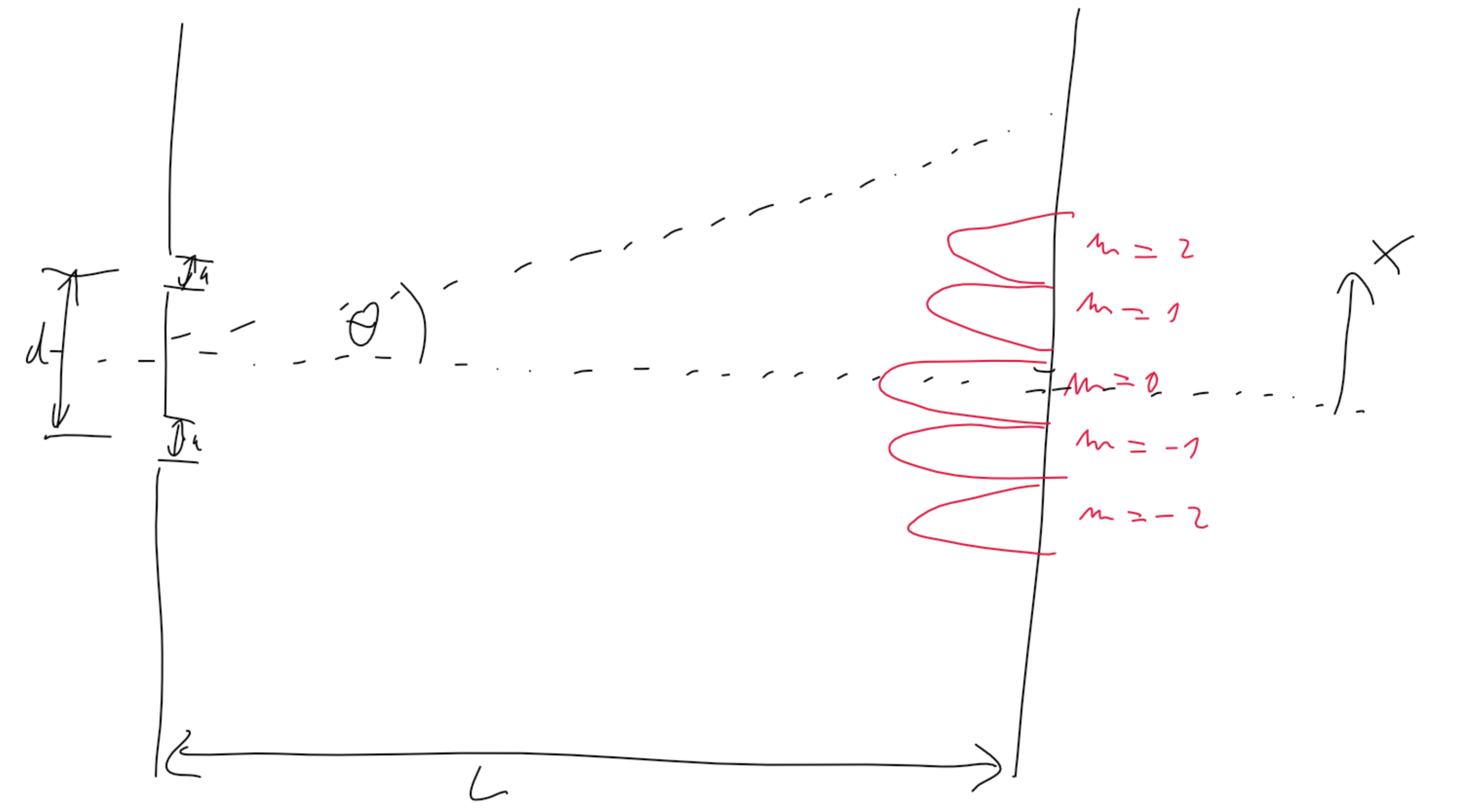
$$d = \frac{m\lambda_1}{2 n_l} = \frac{3 \cdot 433}{2 \cdot 1.3} = 499.6\ \text{nm} \approx \underline{\underline{500\ \text{nm}}}$$

b.) YES : $\frac{433}{520} = \frac{5}{6} = \frac{15}{18} = \frac{25}{30} = \frac{35}{42} \ldots$

m	3	9	15	21	...
ℓ	3	8	13	18	
d/nm	500	1500	2500	3500	...

$$\boxed{\left(\ell - \frac{1}{2}\right)\cdot 1000\ \text{nm} \quad \ell \in \mathbb{Z}^+}$$

4. We carry out Young's double slit experiment by using a HeNe laser of 632.8 nm wavelength and 0.1 mm coherence length. The spacing of the two slits is d=10 mm, the slit width is a=0.5 mm and the distance of the observation screen is L=10m. Determine the distance of the first two bright fringes of interference! Are any of the bright fringes missing? If your answer is yes, also determine which ones are missing!



CONSTRUCTIVE INTERFERENC IF:

$$m\lambda = d\cdot\sin\theta \qquad m\in\mathbb{Z}$$

$$\theta << 1 \Rightarrow \sin\theta \approx tg\,\theta = \frac{x}{L}$$

$$m\lambda \approx d\cdot\frac{x_m}{L} \Rightarrow x_m = \frac{m\lambda L}{d}$$

$$x_2 - x_1 = \frac{1\cdot\lambda L}{d} = \frac{632.8\cdot10^{-9}\cdot10}{10\cdot10^{-3}}$$

$$x_2 - x_{-2} = \underline{\underline{0.6328\cdot10^{-3}\,m}}$$

YES! SOME FRINGES ARE MISSING!

I $\quad m\lambda = d\cdot\sin\theta$ SHOULD BE BIGHT

II $\quad k\cdot\lambda = a\cdot\sin\theta$ DERK BECAUSE OF FRAUNHOFER DIFRÁCTION

$$\mathrm{I}/\mathrm{II} \quad \frac{m}{k} = \frac{d}{a} = \frac{10\,mm}{0.5\,mm} = 20$$

EVERY 20th BRIGHT FRINGE IS MISSING