Droplet microscope
Kvapkový mikroskop

Úvodné sústredenie Turnaja mladých fyzikov
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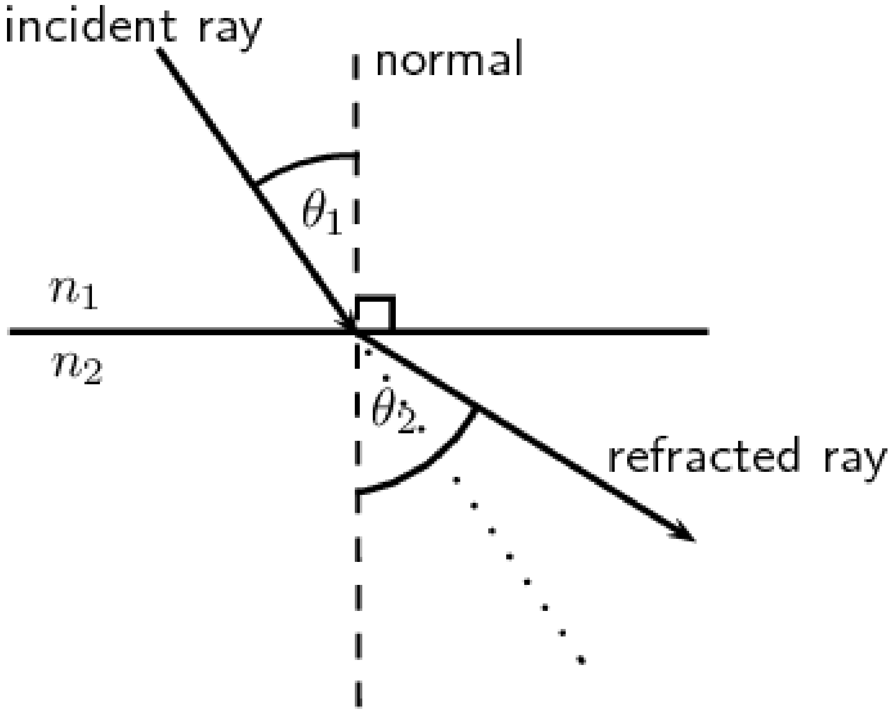
Problem n.2

- By looking through a single water droplet placed on a glass surface, one can observe that the droplet acts as an imaging system. Investigate the magnification and resolution of such a lens.

- Pri pozorovaní cez kvapku umiestnenú na skle vidíme, že kvapka pôsobí ako zobrazovací systém. Preskúmajte zväčšenie a rozlišovaciu schopnosť takejto šošovky.

Physics behind the problem
Snell's law



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

n_1 = incident index

n_2 = refracted index

θ_1 = incident angle

θ_2 = refracted angle

If $n_1 > n_2$ (e.g. water – air interface) – r
efraction from normal
If $n_1 > n_2$ (e.g. glass – water interface) –
refraction to normal

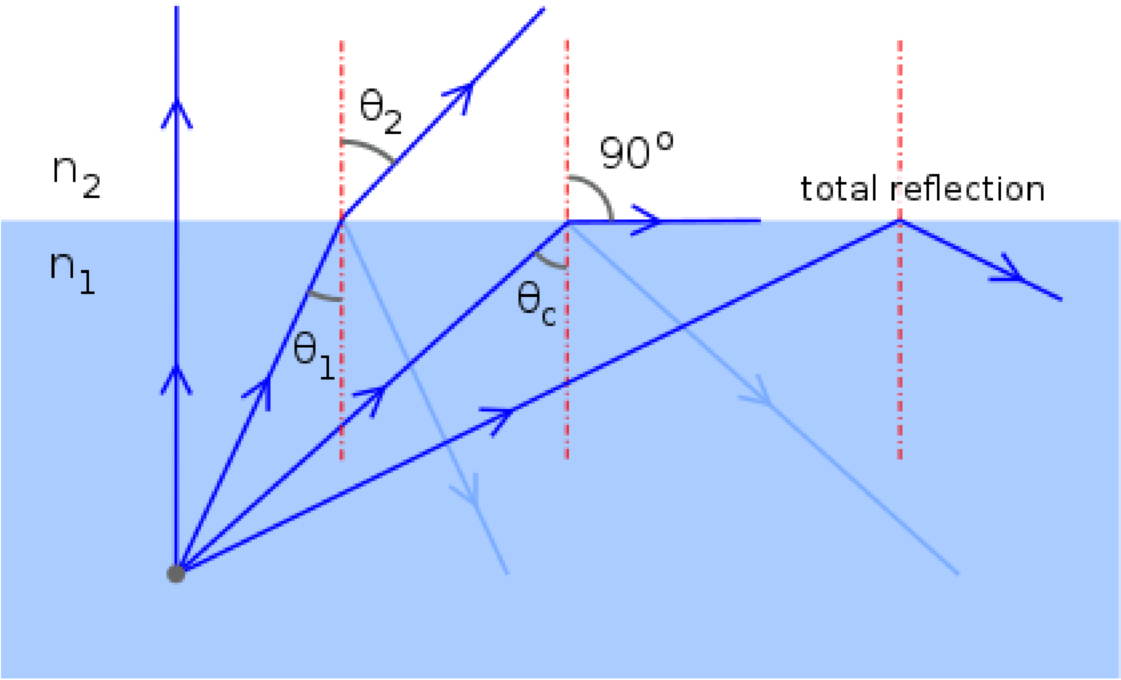
Light travels with different speed in different media – index of refraction:

$n = \frac{c}{v}$,

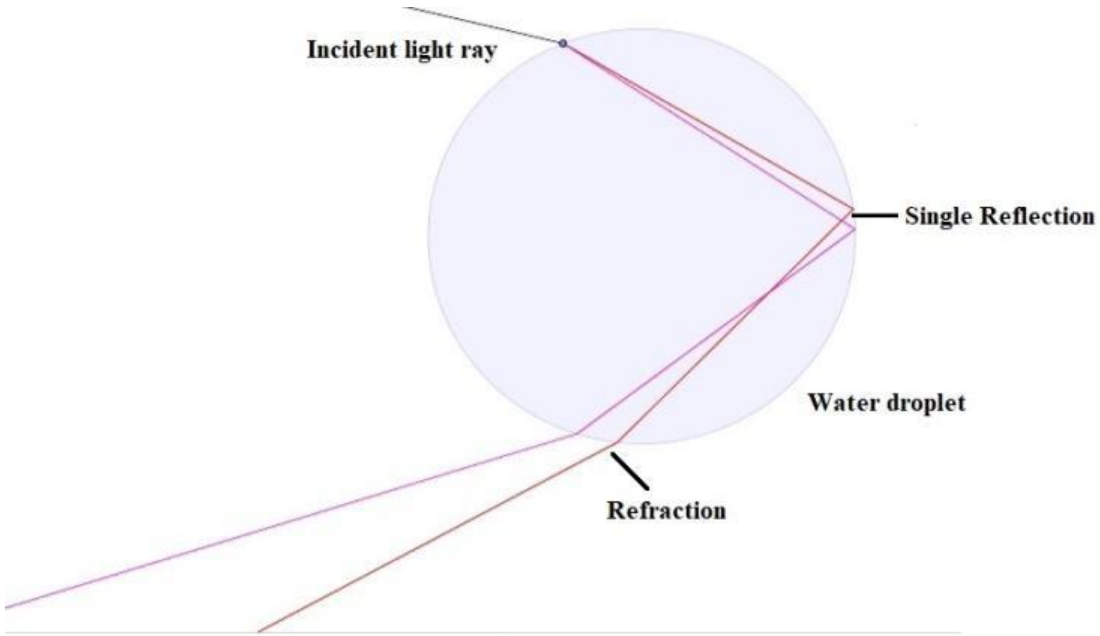
Where c is speed of light in vacuum and v is speed of light in the medium.

Physics behind the problem
Total internal reflection

$$\theta_c = \arcsin(n_2/n_1)$$



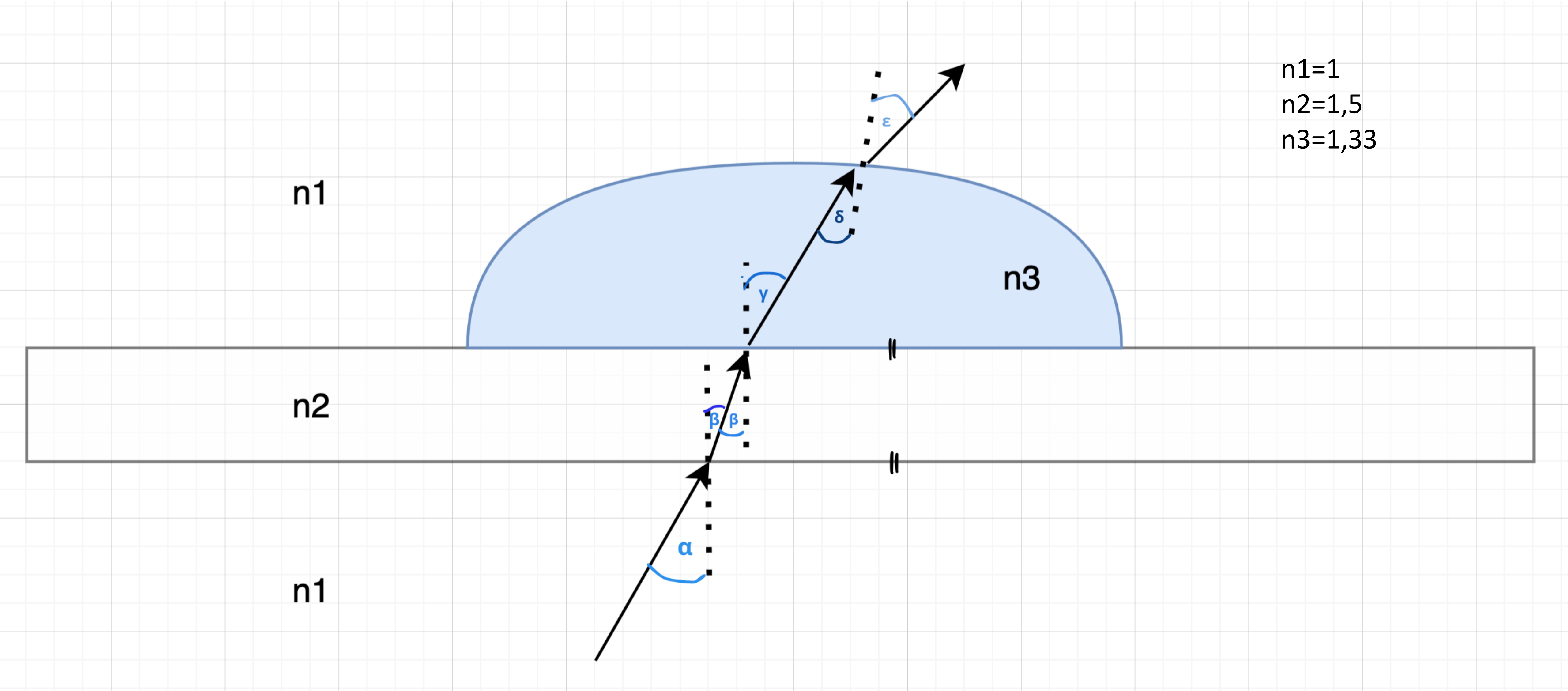
https://en.wikipedia.org/wiki/Total_internal_reflection



Formation of Primary rainbow

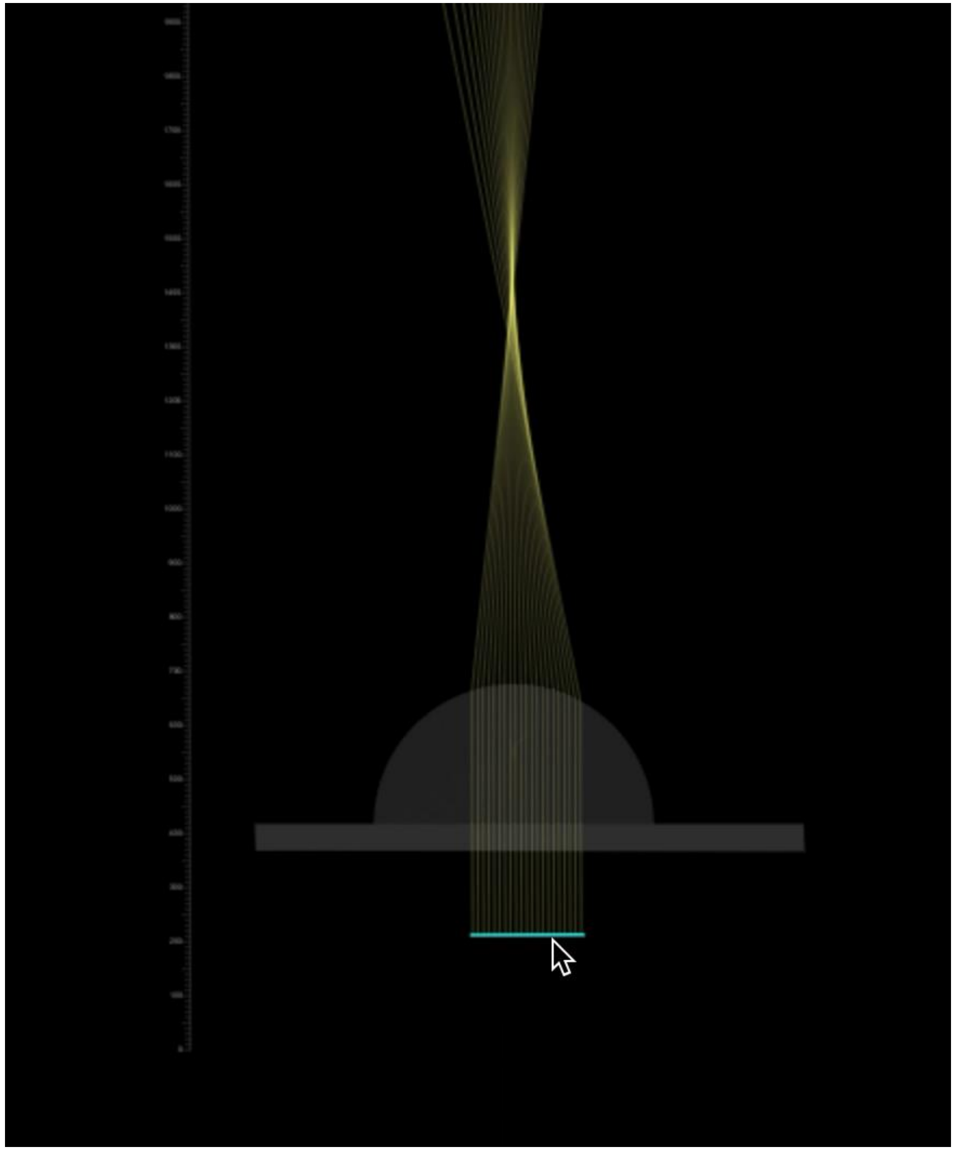
https://www.vedantu.com/question-answer/times-total-internal-reflection-occurs-in-class-12-physics-cbse-5f320f43744f3e53bdda668e

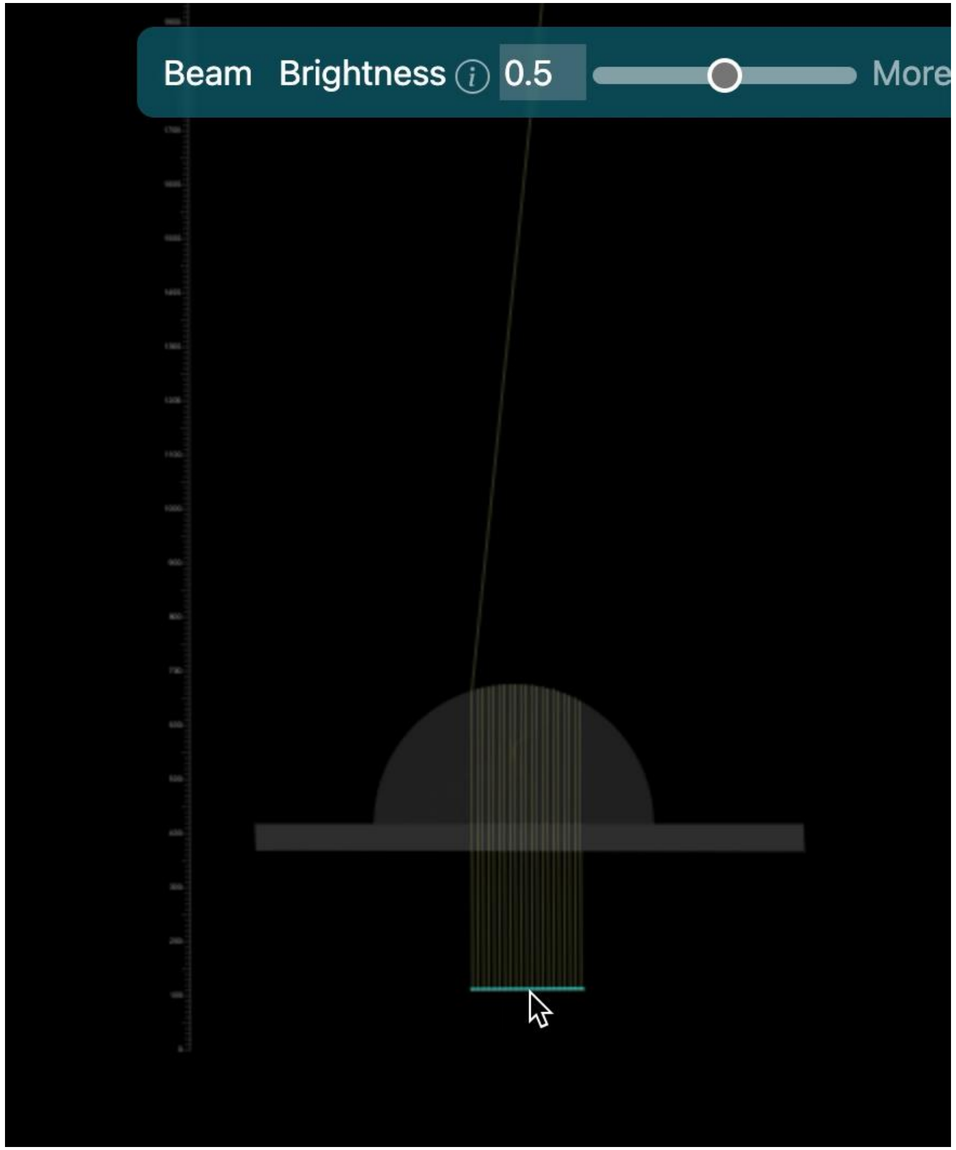
Illustration of refraction of a ray in a droplet microscope



Simulation of Droplet microscope

https://phydemo.app/ray-optics/





Simulation of Droplet Microscope

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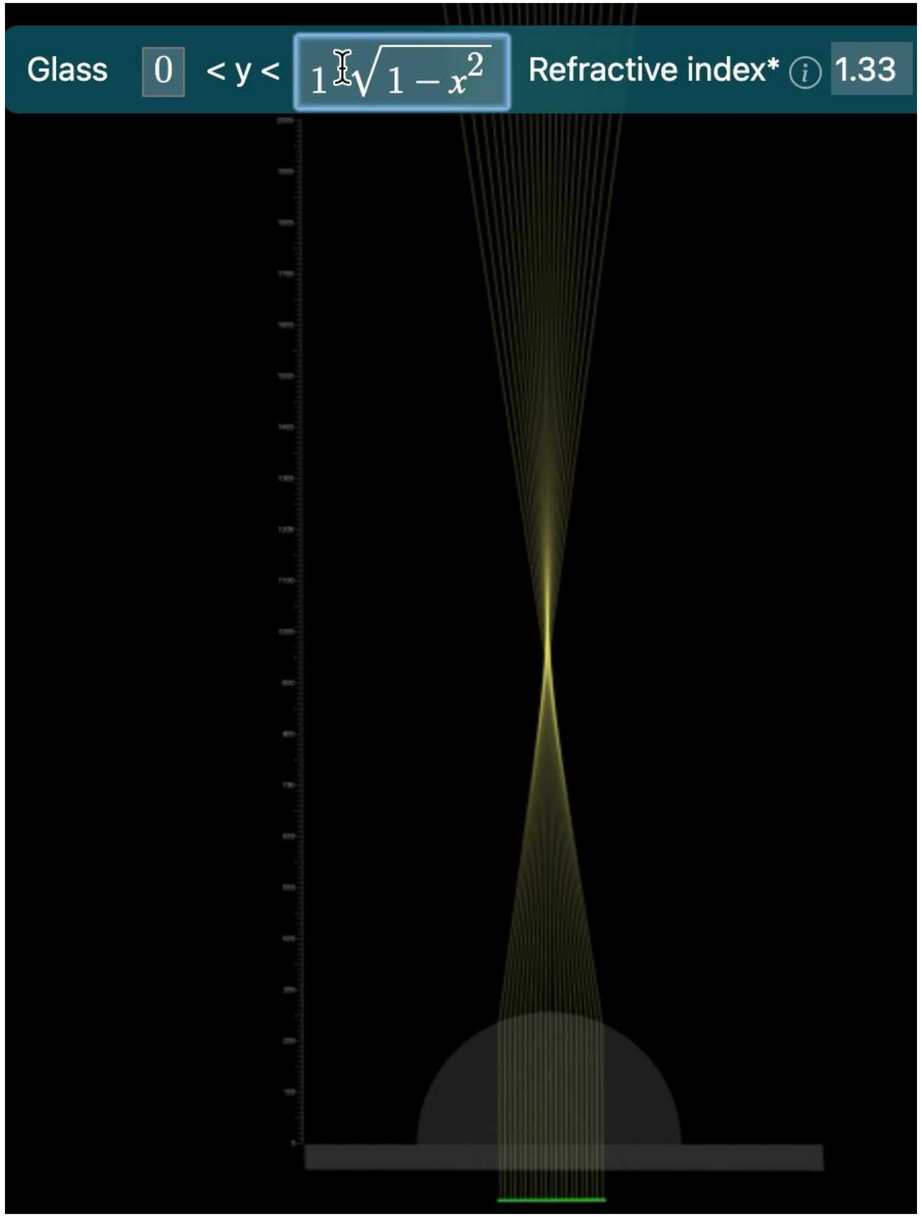


Properties of water droplet lens

- Magnification *M*:

$$M = \frac{D}{f}$$

D – distance of distinct vision (25 cm)

f - focal length of lens

$$M = \frac{a'}{a}$$

a – dimension of object

a' – dimension of image

- Focal length *f*:

$$\frac{1}{f} = \frac{n-1}{r_1}$$

n – index of refraction of water

r_1 - radius of spherical surface – determined by surface tension

Water droplet acts as a plano-convex lens – rays going through the droplet converge.

Myint, H & Marpaung, Mangasi & Kurniawan, Hiezkhia & Hattori, H & Kagawa, K. (2001). Water droplet lens microscope and microphotographs. Physics Education. 36. 97. 10.1088/0031-9120/36/2/301.

How does the droplet change with different parameters?

Properties of water droplet lens

- Resolution – the shortest distance between two objects, at which the two objects can be distinguished from each other

$r = \frac{0,61\lambda}{NA}$, where

λ – wavelength of light

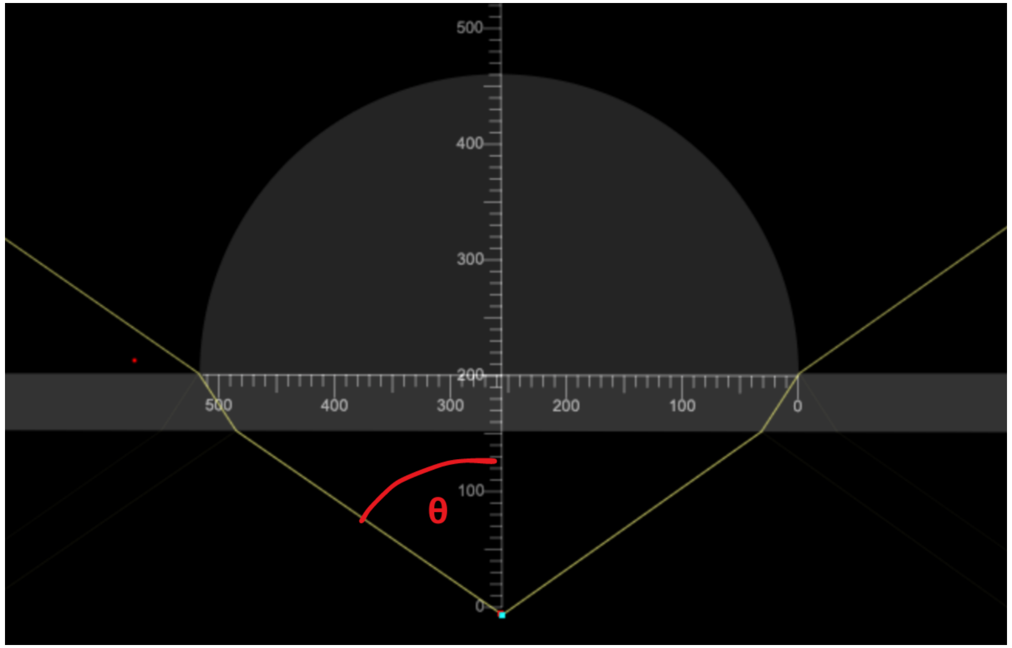
NA – numerical aperture of an optical system

– it is a dimensionless number that characterizes the range of angles over which the system can accept or emit light

– can be expressed as: $NA = n.\sin\theta$, where

n – index of refraction of medium in which the optical system is working (in our case air, n = 1)

θ – critical angle, from which the light does not enter the droplet lens



Using second formula, we can write resolution as:

$$r = \frac{0,61\lambda}{\sin\theta}$$

What affects the properties of water lens?

- Focal length

– may be varied by adding more water (bigger curvature – smaller focal length) or by changing surface tension of water (different temperatures or adding soap)

- Evaporation

– as time passes, water evaporates

– focal length changes

– enclosing the water droplet in a plastic vessel, or covering the droplet in a thin layer of oil

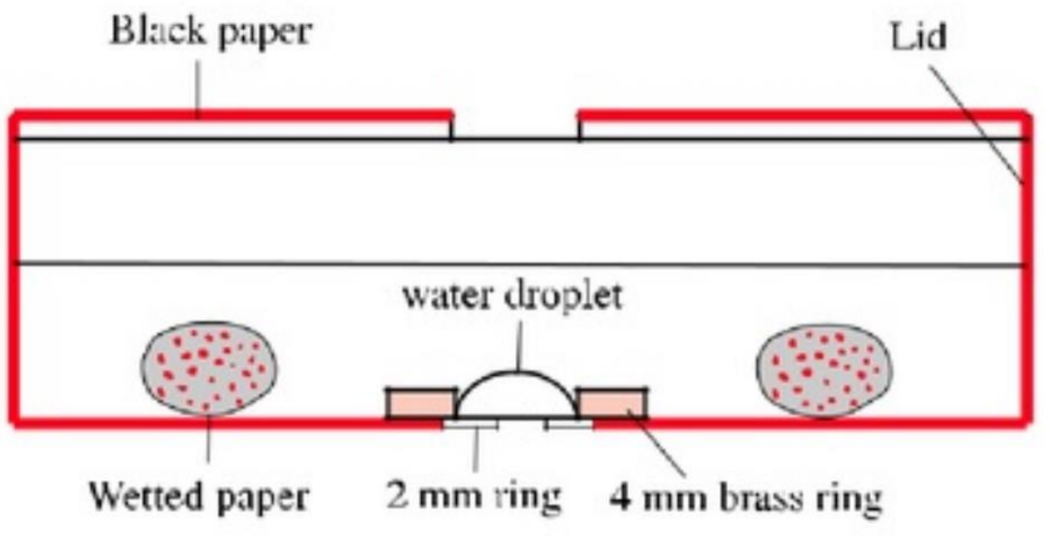


Figure 1. Cross-sectional view of the water droplet lens contained in a plastic vessel.

Myint, H & Marpaung, Mangasi & Kurniawan, Hiezkhia & Hattori, H & Kagawa, K. (2001). Water droplet lens microscope and microphotographs. Physics Education. 36. 97. 10.1088/0031-9120/36/2/301.

Useful resources

- https://phydemo.app/ray-optics/
- https://sipeg.unj.ac.id/repository/upload/similarity/TURNITIN-KUMB-2.pdf
- https://users.fmf.uni-lj.si/planinsic/articles/planin2.pdf
- https://optica.machorro.net/Optica/SciAm/WaterDropCatastrophe/1989-09-body.html
- https://opg.optica.org/directpdfaccess/e9f36989-a952-4cf3-81e4fa85d15c88db_429699/boe-11-5-2328.pdf?da=1&id=429699&seq=0&mobile=no
- https://faculty.cc.gatech.edu/~turk/my_papers/droplet.pdf
- https://www.microscopeworld.com/p-3468-microscope-resolution-explained-using-blood-cells.aspx
- https://en.wikipedia.org/wiki/Numerical_aperture
- https://scoutlife.org/hobbies-projects/projects/200/make-a-microscope/
- https://www.youtube.com/watch?v=cnKCbW75dIk&ab_channel=SquintScience