Names:

ESP Lab Work **JUNIA**ISEN **2024-2025**

Instructions :

- Duration : 2 Hours
- The goal of this working lab is to simulate and find the magnification of a microscope

Ray Optics Simulation Lab

Website: https://ricktu288.github.io/ray-optics/

Part 1: Ideal Lens Setup

- **File to import:** *Lab_optics_ideal_lens*

1. **Place an ideal lens**
   - Go to *Glass* → *Ideal Lens.*
   - Set the height of the lens to at least 300 units.
   - Align the lens vertically, centered on the zero mark of the ruler grid.
2. **Adjust the focal length**
   - Set the lens to a +300 units focal length.
3. **Trace image formation**
   - Use *Light Source* → *Single Ray* to draw the three principal rays (parallel, focal, and central) from the top of your object to determine the image point.
   - (Optional) Repeat for other points on the object to complete the image.
4. **Is the image real or virtual?**
   - Observe the rays and justify your answer.

Part 2: Changing the Focal Length

5. **Explore magnification**
   - Adjust the focal length slider and observe the effect on the image position and magnification.
   - Based on your calculations, what focal length would produce an image three times larger than the object ?

$$f =$$

- Do a drawing for this configuration using three particular rays

Part 3: Real Lens vs. Ideal Lens

6. **Replace by a plano-convex lens**
    - Remove the ideal lens and place a plano-convex lens (convex on one side, flat on the other) *Glass → Spherical Lens.* Use a refractive index of 1.5 (e.g., glass in air).
7. **Apply the lens maker's formula**: $\frac{1}{f} = \left(\frac{n_{lens}}{n_{medium}} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$
    - Solve for r_1 (the convex side) to match the focal length used in Part 1.

$$r_1 =$$

8. **Repeat with a bi-convex lens**
    - Using the same focal length and refractive index, apply the **lens maker's formula** to find the **common radius of curvature** r of a **symmetrical bi-convex lens** (convex on both sides).

$$r =$$

! Tips for simulation! According to your calculation you may end up with a lens height that will be smaller than the object. In this case you can also use a beam of parallel rays (*Light Source → beam)* instead of your object.

9. **Simulation**
    - Are you able to **verify that the image remains consistent** with the previous cases?
    - If you're not able to replace the ideal lens by a real lens, **import file:** *Lab_optics_real_lens_2* and trace the 3 particular rays from 3 different points of the object.

    - What do you observe? How can you explain it?

Part 4 – Construction of a Microscope (with ideal lenses)

- **Import** *Lab_optics_microscope*

In this example:

- *The scale along the x-axis is: 100 units = 1 cm*
- *The scale along the y-axis is: 100 units = 50 µm*

10. **Place the objective lens**
    - Choose a **short focal length**, e.g., $\boldsymbol{f_{obj}}$ **= 50 units = 0.5 cm**
    - Place the objective lens somewhere on the optical axis, to the right of the bacteria (Yes, I did my best to draw that bacteria!)
    - What do the orange rays correspond to?

11. **Place the object**
    - Position the object (i.e., the starting point of the rays) slightly **beyond the focal point** of the objective lens, e.g., at $\boldsymbol{p}$ **= 80 units = 0.8 cm**, and 20 units above the central axis (which corresponds to a 10 µm height)
    - Where and how is the image formed? Is the image real or virtual? Inverted or upright?

12. **Place the eyepiece (ocular) lens**
    - Add a second ideal lens to act as the **eyepiece**, with a **longer focal length**, e.g., $\boldsymbol{f_{eye}}$**= 250 units = 2.5 cm** (You can choose different values as long as $f_{eye} > 5f_{obj}$)
    - Adjust the position of the eyepiece so that the rays **exit the eyepiece parallel**
    - What can you say about the relationship between the focal point of the eyepiece and the position $\boldsymbol{i}$ of the first image?
    - Where is the final (second) image in this specific case?
    - What about the observer looking through the eyepiece? Does they need to accommodate to see anything clearly?
    - What if the microscope is not perfectly set up?

- Draw a schematic of your microscope using particular rays

- Can you replace the ideal lenses by real lenses? Show your instructor
- What can we say about the final (second) image in this specific case?

- Optional: can you add a model of the eyeball in your simulation?

4. Magnification

The **total magnification** of the microscope in this setup is the product of two contributions:

$$M_{total} = m_{objective} \times m_{eyepiece} = m \times m_{\theta}$$

- m: the **lateral magnification** provided by the **objective lens.** If the object is just beyond the focal point of the objective, it produces a real, inverted image, with: $m = -\frac{i}{p} = -{}^{s}/_{f_{obj}}$ where s is the distance between the back focal plane of the objective and the front focal plane of the eyepiece. Using your measured values of, i, s and f_{obj}, verify whether the relation of lateral magnification holds true.

h	p	i	s	f_{obj}	f_{eye}	$m = -\frac{i}{p}$	$m = -\frac{s}{f_{obj}}$

5. **Angular Magnification**
   - m_θ : The **angular magnification** provided by the **eyepiece lens** (assuming the final image is at infinity) is given by: $m_\theta = \frac{D}{f_{eye}} = \frac{25cm}{f_{eye}}$ where D=25cm is the **near point** of the human eye. Compute:

$$m_\theta =$$

6. **Total Magnification**
   - Using your previous result for mmm (the lateral magnification by the objective), the **total magnification** of the microscope is:

$$M_{total} =$$

7. **Apparent Size of the Bacterium**
   - The **angular size without the microscope** is given by: $\theta_{ref} = \frac{h}{D}$ with h=10 µm is the object (here a bacteria) and D=25 cm. The **angular size through the microscope** is: $M_{total} \times \theta_{ref}$. and finally the **apparent size under the microscope**, as perceived at the near point, is $\theta_{app} \times D$.

$$Apparent\ size\ of\ the\ bacteria =$$

Part 5 – Polychromatic light

- **Import** *Lab_optics_microscope_chromatic*
- **And also import** *Lab_optics_microscope_chromatic_real*
- What do you observe? How can you explain it?

- What are the consequences for microscopy or astronomy? Find an image online that illustrates this effect.

Part 6 – Have fun

If you have time, visit the gallery and explore the different simulations to understand:

- What is a Frensel Lens?
  → https://phydemo.app/ray-optics/simulator/
- How do rainbows happen in the sky?
  → https://phydemo.app/ray-optics/gallery/rainbows
- How does a telescope work ?
  → https://phydemo.app/ray-optics/gallery/newtonian-telescope
- What is a Köhler Illumination ?
  → https://phydemo.app/ray-optics/gallery/koehler-illumination