Boğaziçi University

Introductory Phys Labs

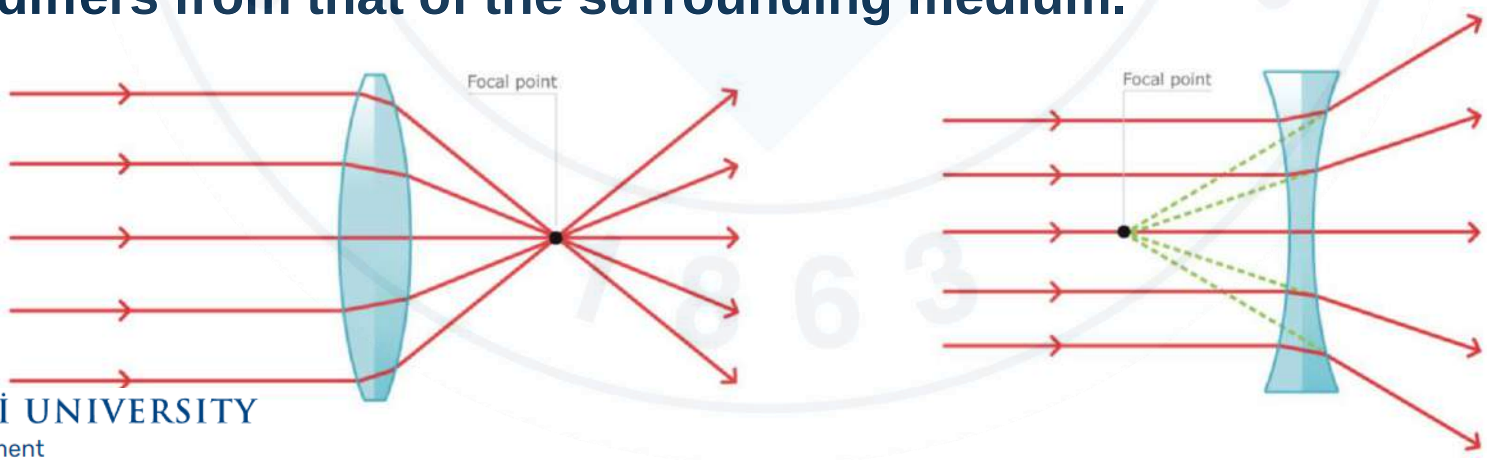
THIN LENSES

PHYL202

THEORY

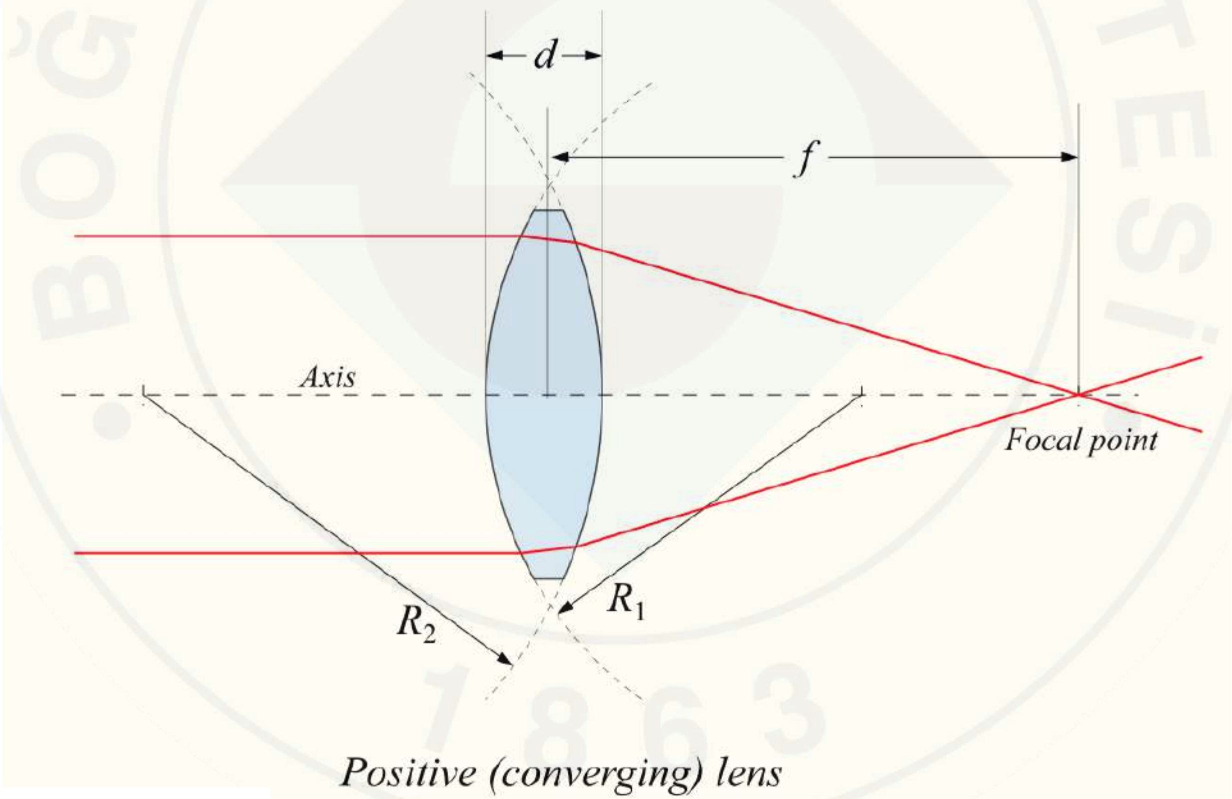
- **A lens is a transparent object with two refracting surfaces whose central axes coincide. The common central axis is the central axis of the lens. When a lens is surrounded by air, light refracts from the air into the lens, crosses through the lens, and then refracts back into the air.**
- **Each refraction may change the direction of travel of the light rays.**

- **A lens produce an image of an object because it can bend the light rays, but it can bend light rays only if its index of refraction differs from that of the surrounding medium.**

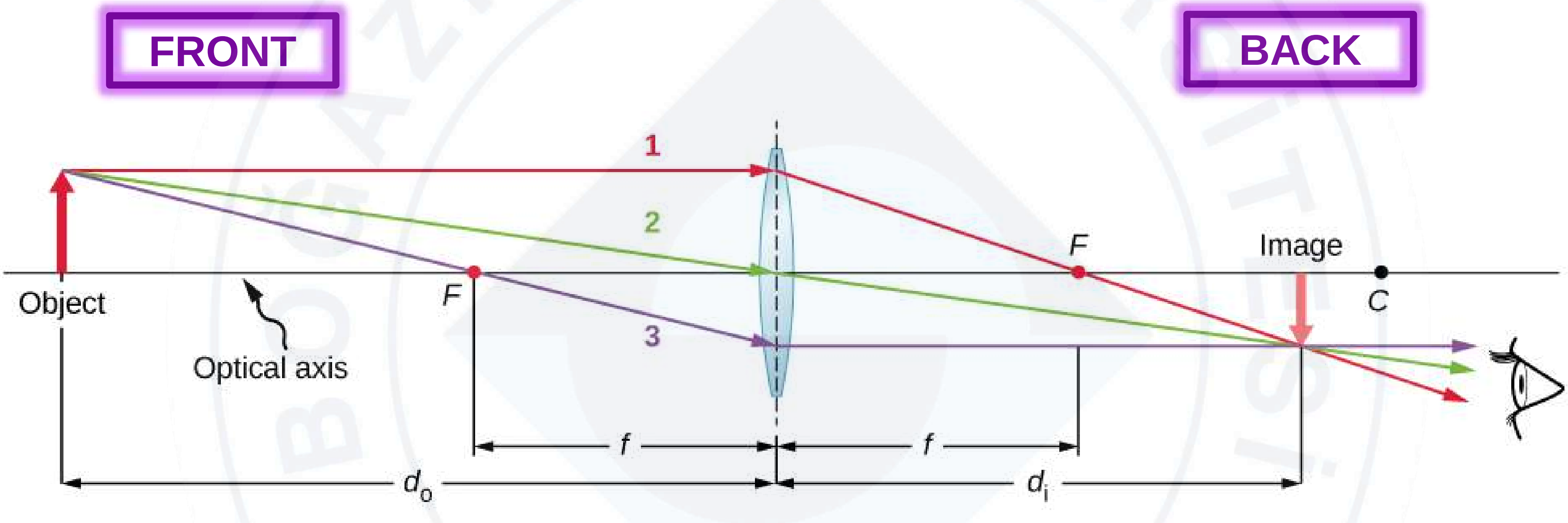


What is thin lenses?

- **A thin lens is a lens with a thickness (distance along the optical axis between the two surfaces of the lens) that is negligible compared to the radii of curvature of the lens surfaces.**



CONVERGING (convex) LENS:



(a)

o > 0
i < 0

Common Gaussian
form of Lens Equation

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

o < 0
i > 0

$$m=-\frac{i}{o}=\pm\frac{height\,of\,image}{height\,of\,object}$$

+ if object is not inverted
- if object is inverted

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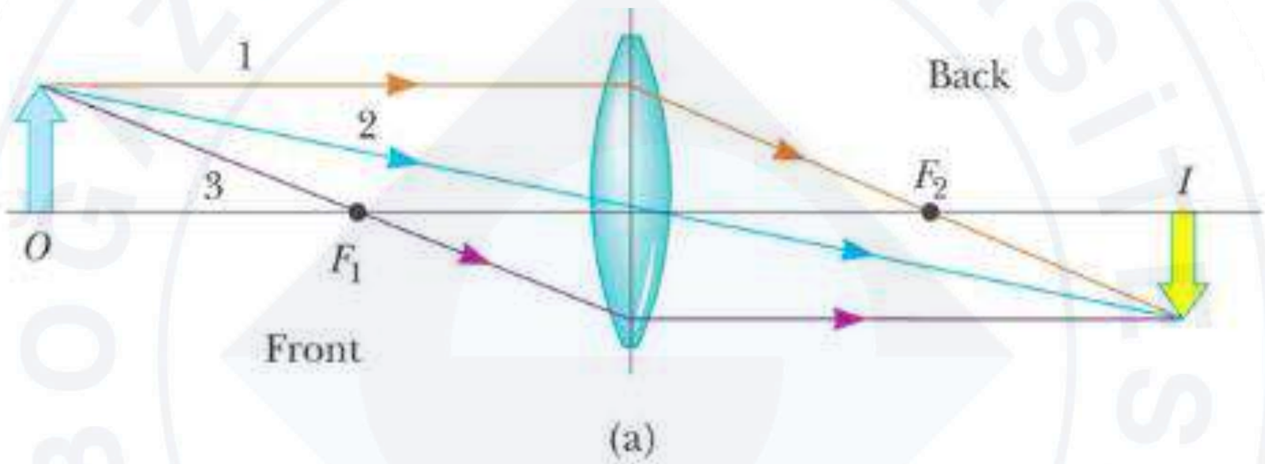
CONVERGING (convex) LENS: object distance > focal length

o > 0
i < 0

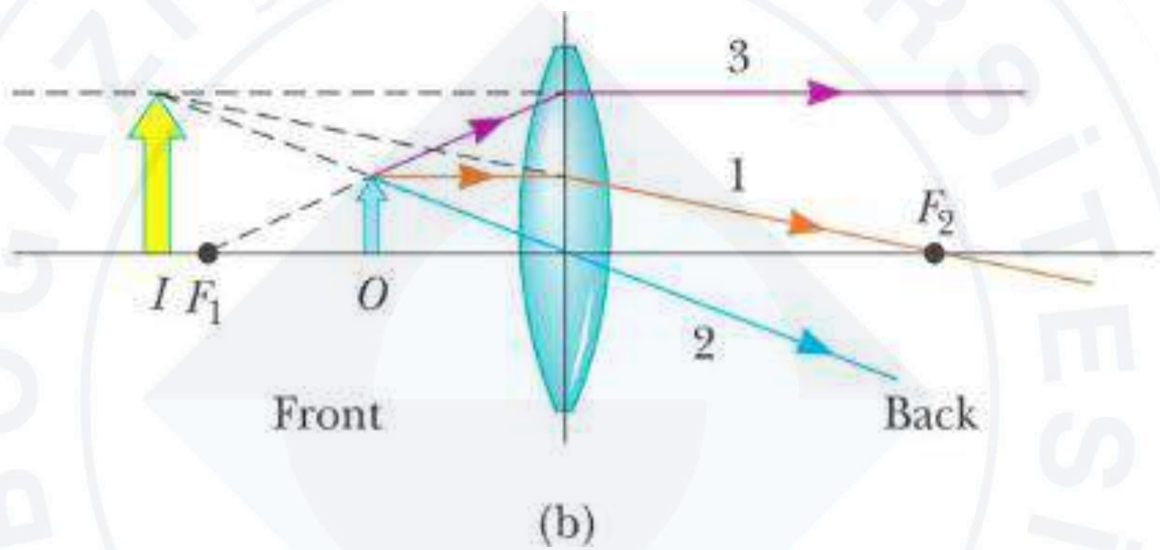


o < 0
i > 0

- The image is real
- The image is inverted
- The image is on the back side of the lens

CONVERGING (convex) LENS: object distance < focal length

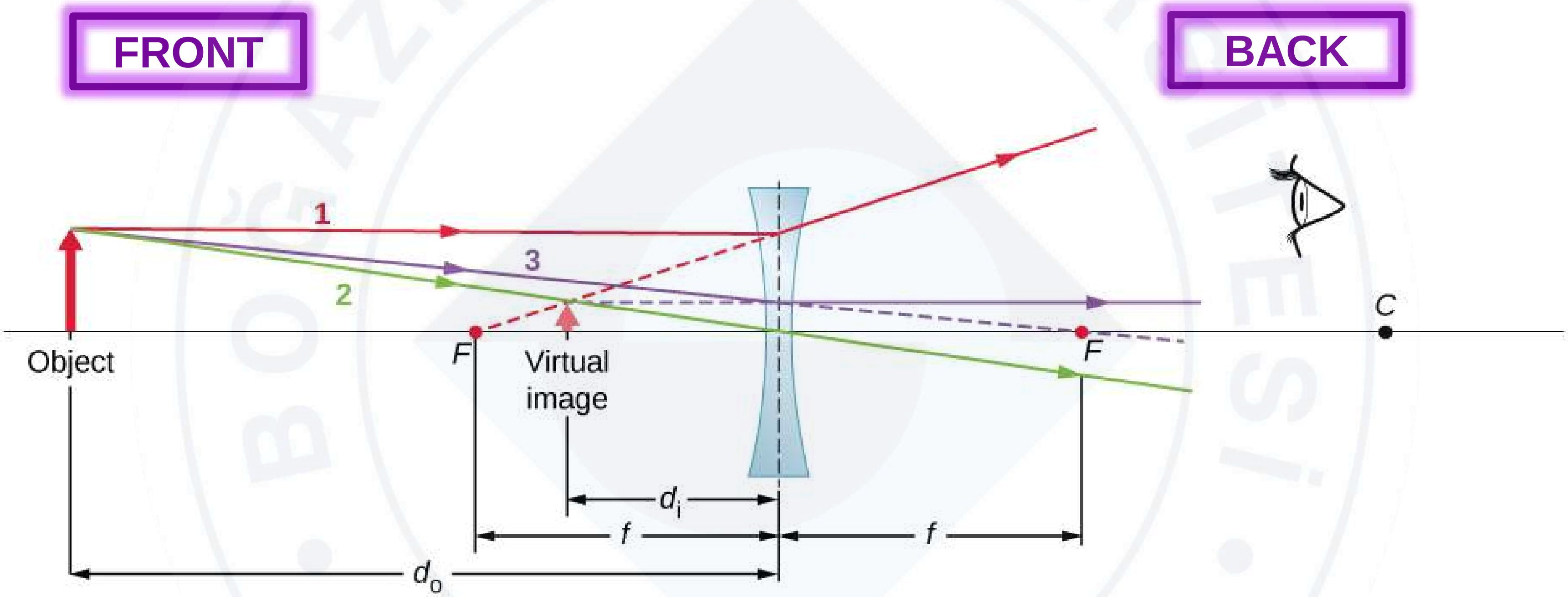
o > 0
i < 0



o < 0
i > 0

- The image is virtual
- The image is upright
- The image is larger than the object
- The image is on the front side of the lens

DIVERGING (concave) LENS



o > 0
i < 0

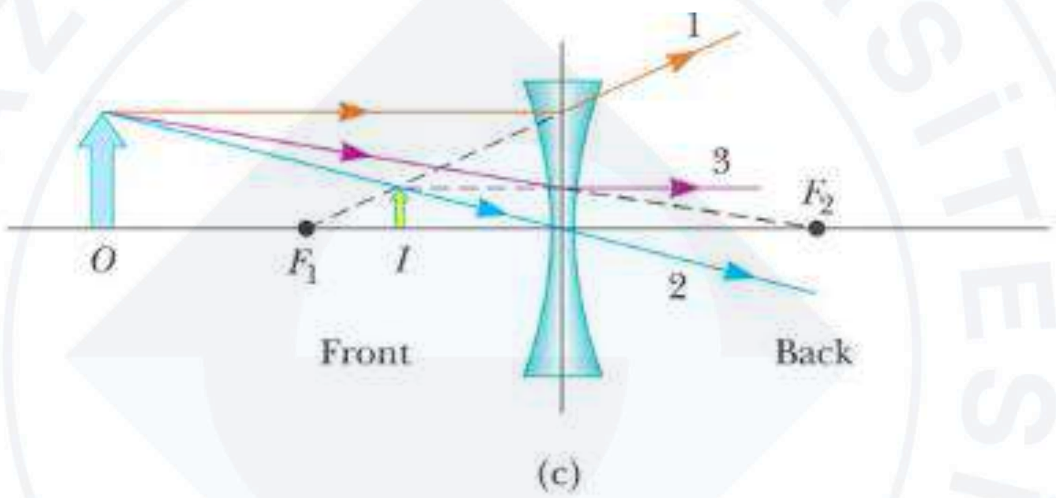
o < 0
i > 0

Common Gaussian form of Lens Equation

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

DIVERGING (concave) LENS

o > 0
i < 0



o < 0
i > 0

- The image is virtual
- The image is upright
- The image is smaller than the object
- The image is on the front side of the lens

LENS COMBINATION OF THIN LENSES

- The image formed by the first lens is located as though the second lens were not present
- The image of the first lens is treated as the object of the second lens
- The image formed by the second lens is the final image of the system

LENS COMBINATION OF THIN LENSES

- If the image formed by the first lens lies on the back side of the second lens, then the image is treated as a virtual object for the second lens
  - object distance will be negative
- The same procedure can be extended to a system of three or more lenses
- The overall magnification is the product of the magnification of the separate lenses.

APPARATUS

THIN LENSES

object

large converging lens

small converging lens

large diverging lens

image stand

ruler

EXPERIMENT

PART I: CONVERGING LENSES

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A) SMALL CONVERGING LENS

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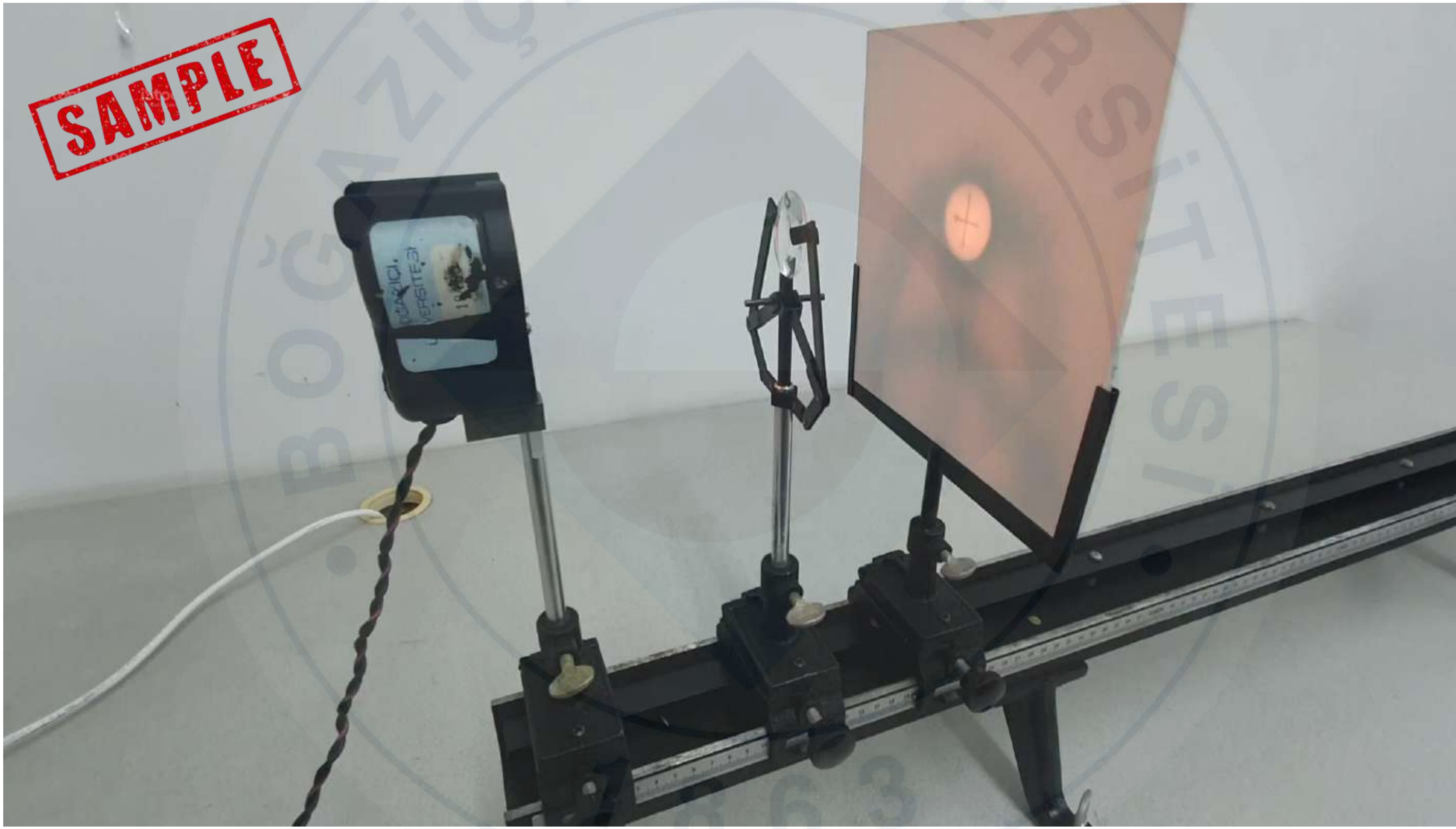
A) SMALL CONVERGING LENS - demonstration



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A) SMALL CONVERGING LENS

Fill the the empty spaces accordingly.

A) Small Converging Lens:

Object distance	$o_1 =$		Object distance	$o_2 =$ ....
Image distance	$i_1 =$		Image distance	$i_2 =$ ....
Focal length	$f_1 =$		Focal length	$f_2 =$ ....
Magnification	$m =$		Magnification	$m =$ ....

Average focal length $f_{average} =$ ....

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$m = -\frac{i}{o} = \pm\frac{height\,of\,image}{height\,of\,object}$$

+ if object is not inverted
- if object is inverted

Be aware! o > 0 and i > 0
object is at frontside
image is at backside

B) LARGE CONVERGING LENS

PhysLabs

B) LARGE CONVERGING LENS - demonstration

B) LARGE CONVERGING LENS

Fill the empty spaces accordingly.

B) Large Converging Lens:

Object distance o_1 = ...		Object distance o_2 = ...	
Image distance i_1 = ...		Image distance i_2 = ...	
Focal length f_1 = ...		Focal length f_2 = ...	
Magnification m = ...		Magnification m = ...	

Average focal length f_{average} = ...

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$m = -\frac{i}{o} = \pm\frac{height\,of\,image}{height\,of\,object}$$

→ + if object is not inverted
- if object is inverted

What is the sign of o and i?

PART II: LENS COMBINATION

C) LENS COMBINATION (large converging + small converging)

C) LENS COMBINATION (large converging + small converging)

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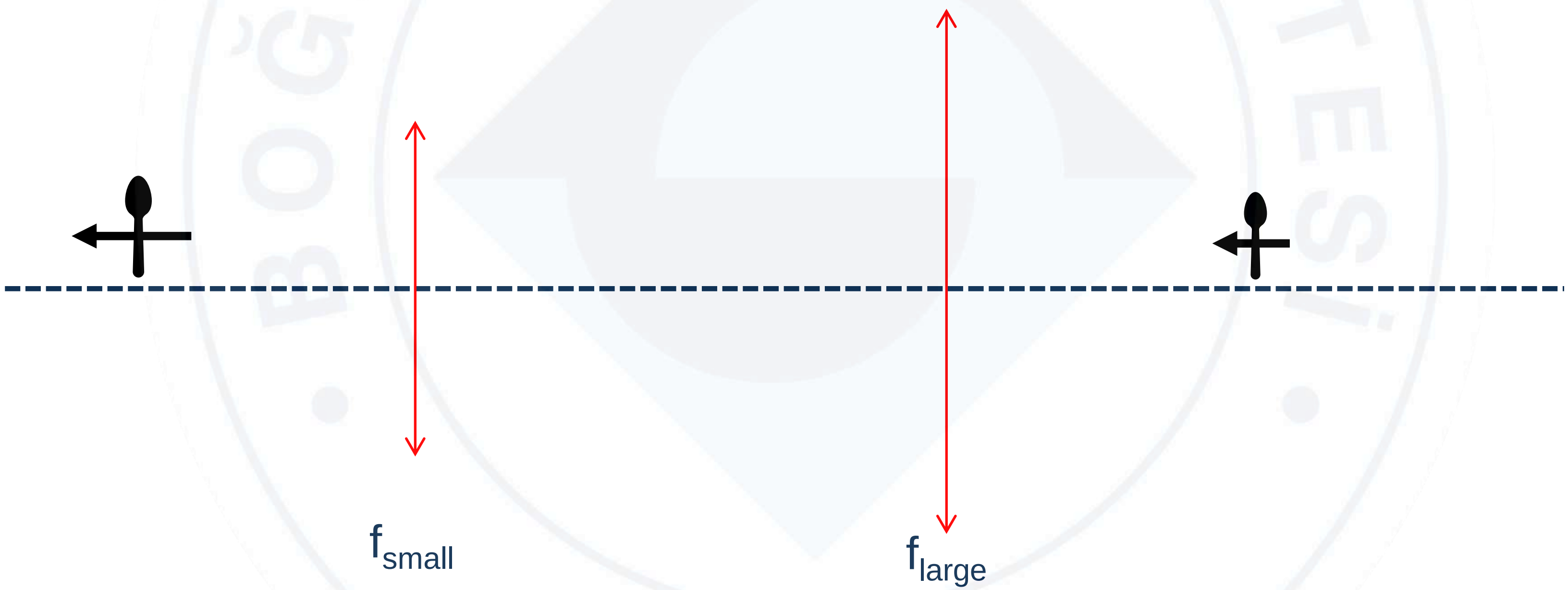
C) LENS COMBINATION (large converging + small converging) - demonstration

C) LENS COMBINATION (large converging + small converging)

C) **Two Converging Lenses:**

Draw the diagram of the system:



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C) LENS COMBINATION (large converging + small converging

Practicing combination of lenses with two known focal lengths.

i_2 has been chosen for testing the system

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$d - i_1 = o_2$$

$$o_2 \& f_2 \rightarrow i_2$$

i_2 (measured) is considered as true value

Measure:

Object distance for the first lens o_1 = ...

Image distance for the second lens i_2 = ...

Distance between the lenses d = ...

Calculate:

Image distance for the first lens i_1 = ...

....

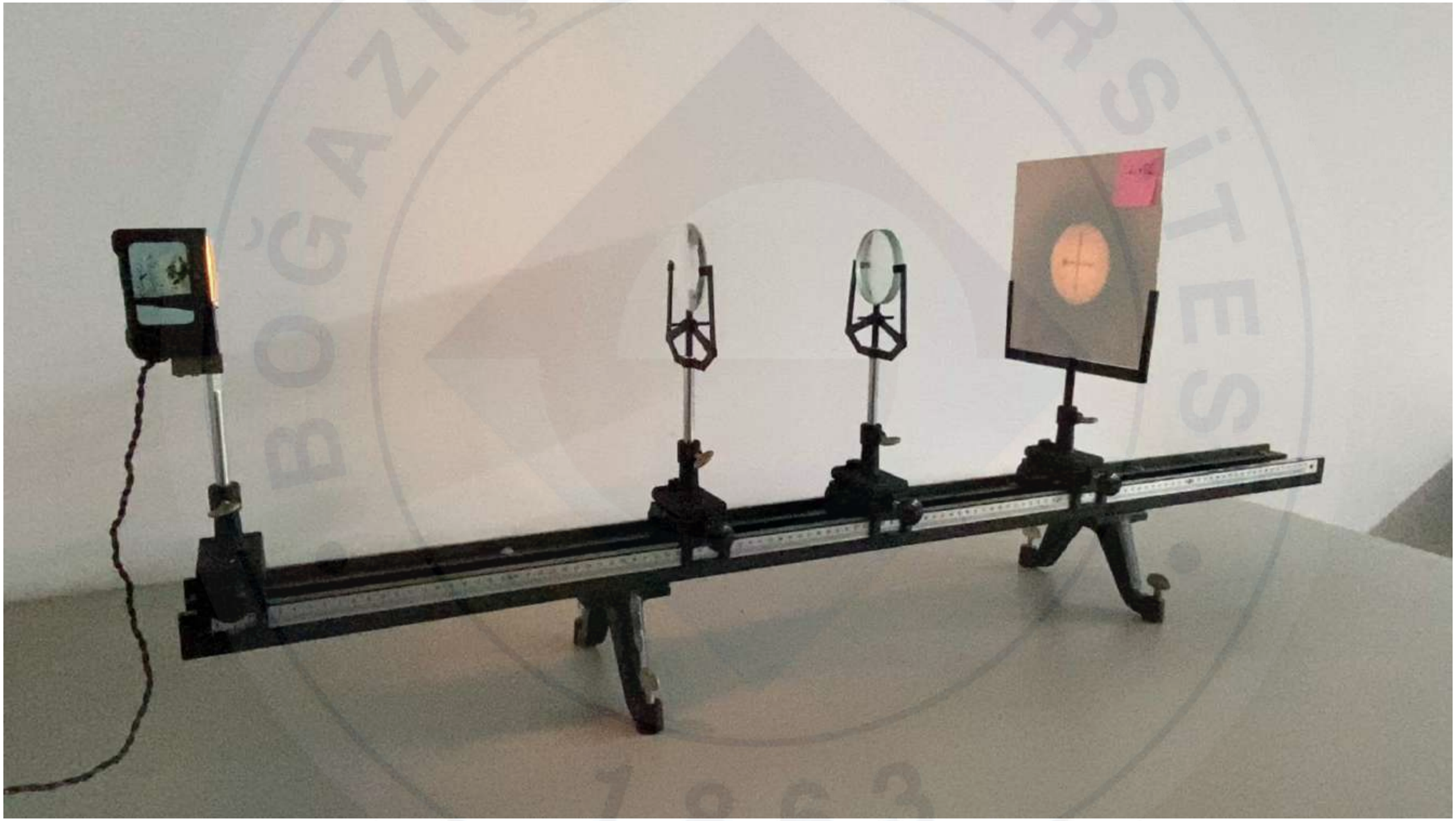
Image distance for the second lens i_2 = ...

....

% Error for i_2 = ...

D) LENS COMBINATION (large converging + diverging lenses)

LENS COMBINATION (large converging + diverging lenses)

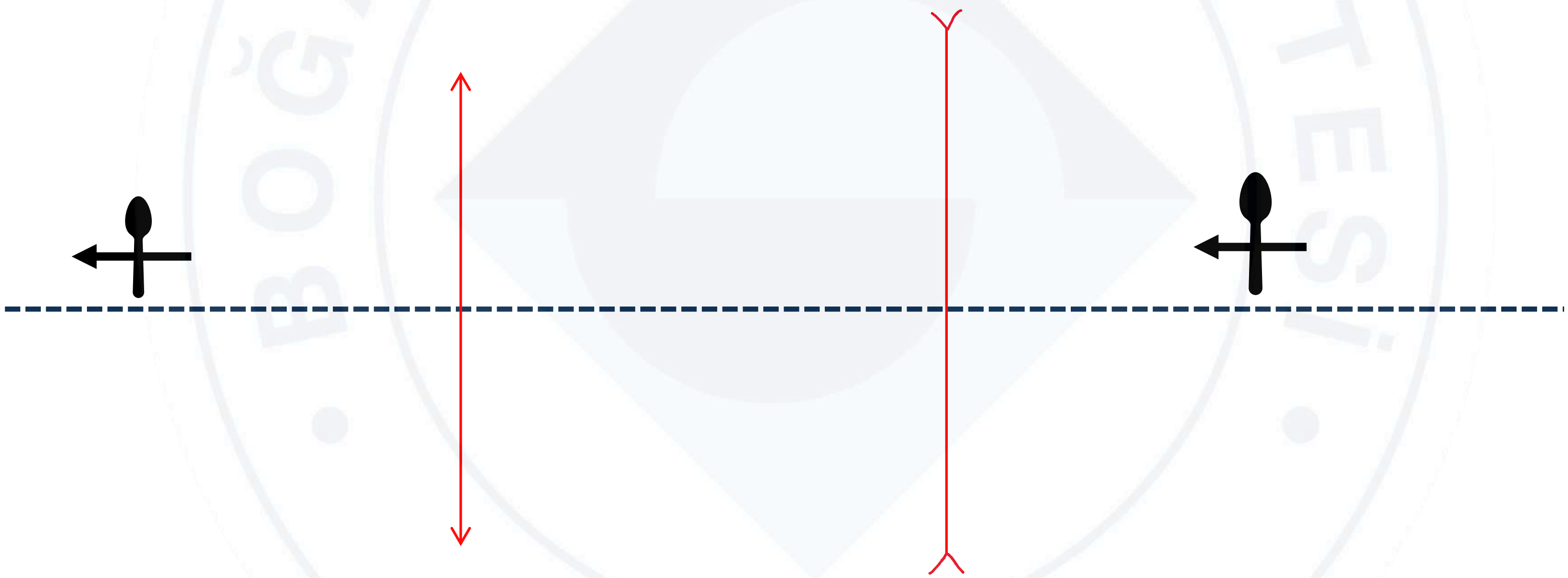


D) LENS COMBINATION (large converging + diverging lenses)-demonstration

D) LENS COMBINATION (large converging + diverging lenses)

D) Large Converging & Large Diverging Lenses:

Draw the diagram of the system:



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D) LENS COMBINATION (large converging + diverging lenses)

Determining the focal length of the diverging lens that has virtual image

Both o_2 and i_2 is at the **backside** that is why o_2 is negative and i_2 is positive

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$d - i_1 = o_2$$

$$i_2 \& o_2 \rightarrow f_{diverging}$$

f_2 is negative!

Measure:

Object distance for the first lens o_1 = ...

Image distance for the second lens i_2 = ...

Distance between the lenses d = ...

Calculate:

Image distance for the first lens i_1 = ...

....

Focal length of the diverging lens $f_{\text{diverging}}$ = ...

....

....

PART III: SPHEROMETER

E) SPHEROMETER

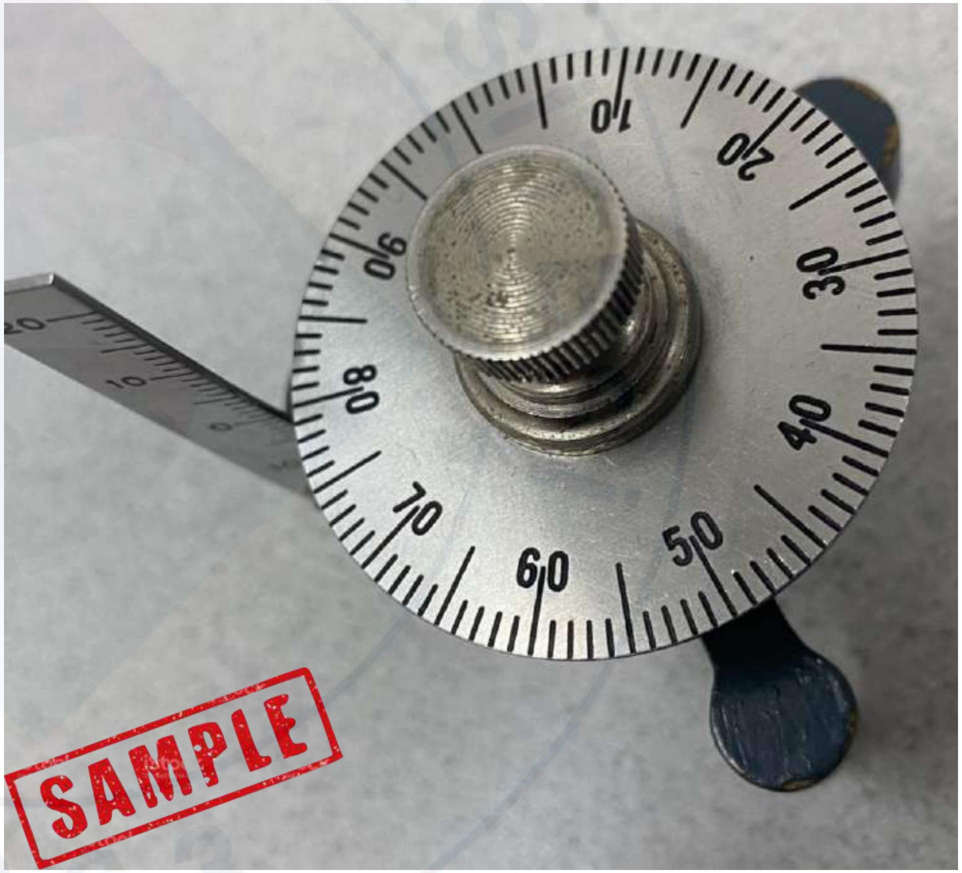
Spherometer is an instrument to determine very small thicknesses and the radius of curvature of a surface.

E) SPHEROMETER

First you should place the spherometer on a level surface to get a calibration reading (CR). You turn the knob at the top until all four legs touch the surface. When the middle leg also touches the surface, the knob will first seem to be free and then tight. The reading at this position will be the calibration reading (CR).

E) SPHEROMETER - demonstration

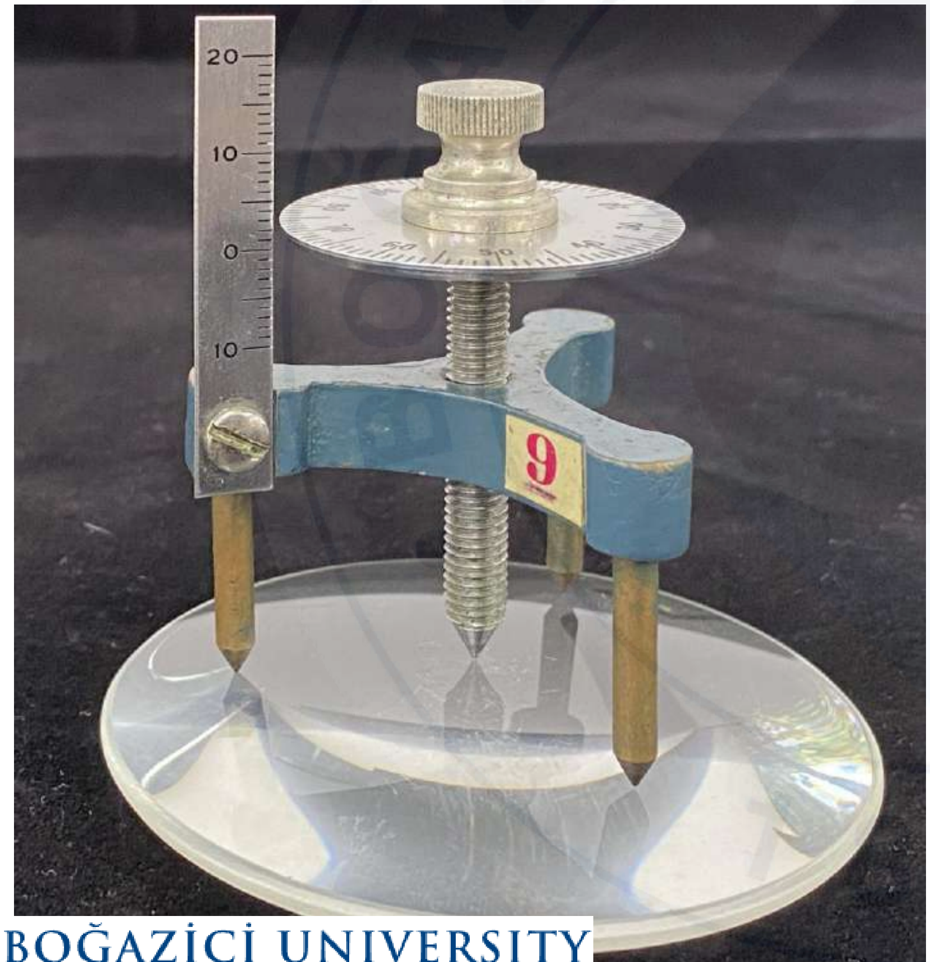
You will read the value from the vertical scale first and then the value on the dial will give you the fraction of a millimeter as calibration reading (CR).

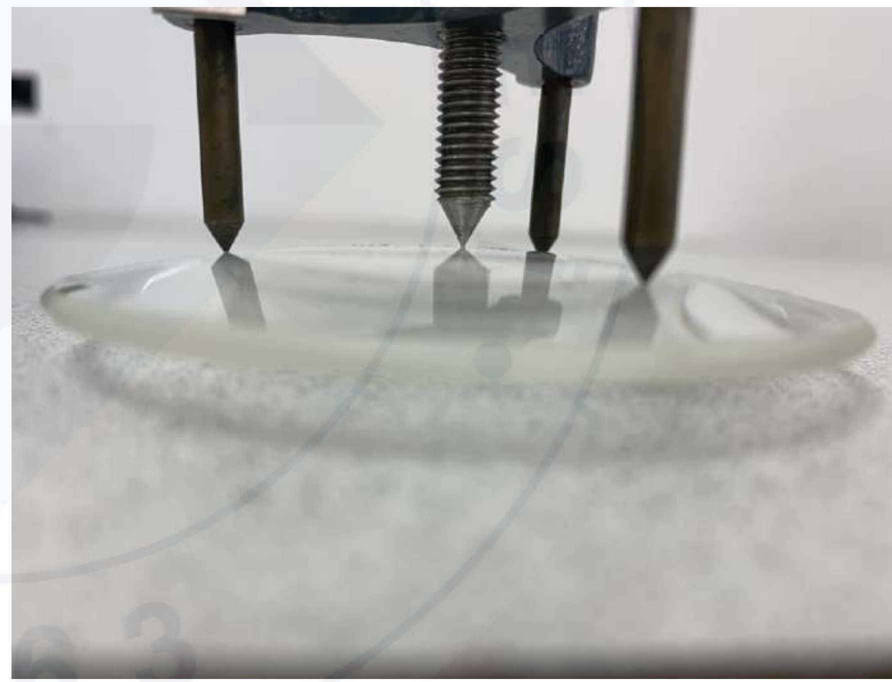


0.79 mm

E) SPHEROMETER

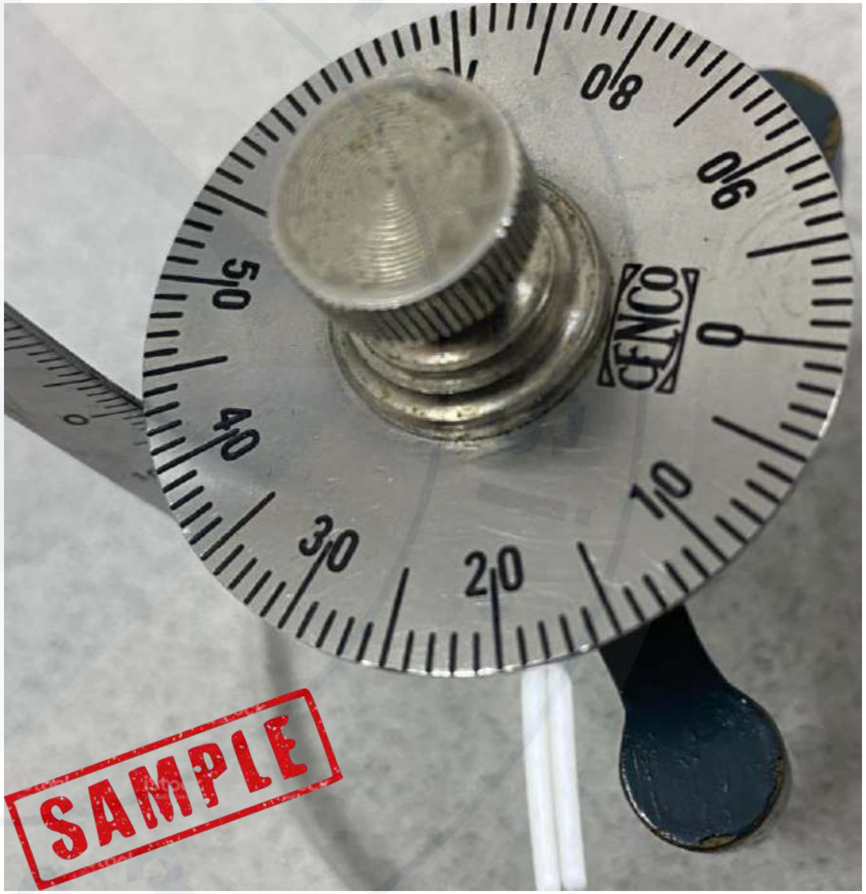
Then you should place the spherometer on the curved surface and turn the knob until all four legs again touch the surface. The reading at this position will be the measurement reading (MR).





E) SPHEROMETER - demonstration

You will read the value from the vertical scale first and then the value on the dial will give you the fraction of a millimeter as measurement reading (MR).



2.43 mm

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E) SPHEROMETER

Then you can calculate the radius of curvature of the surface as:

$$R = \frac{D}{2} + \frac{A^2}{6D}$$

where *D* = |CR-MR| and *A* is the distance between the outside legs.

E) SPHEROMETER

Fill the empty spaces accordingly.

Read from data video

True Value of the Index of Refraction	n_{TV}	=	....
Distance between the legs	A	=	....
Calibration reading	CR	=	....
Measurement reading	MR	=	....

Difference in readings $D = |CR - MR| =$ ....

....

E) SPHEROMETER

Then you can calculate the radius of curvature of the surface as:

$$R = \frac{D}{2} + \frac{A^2}{6D}$$

where *D* = |CR - MR| and *A* is the distance between the outside legs.

We measured the radius of curvature of converging large lens by a spherometer. (R1 = R2 = R).

Determine the refractive index of the lens.

E) SPHEROMETER

Fill the empty spaces accordingly.

Radius of curvature

of the lens surface $R = \frac{D}{2} + \frac{A^2}{6D} =$ ....

....

Index of Refraction n_{cal} = ...

....

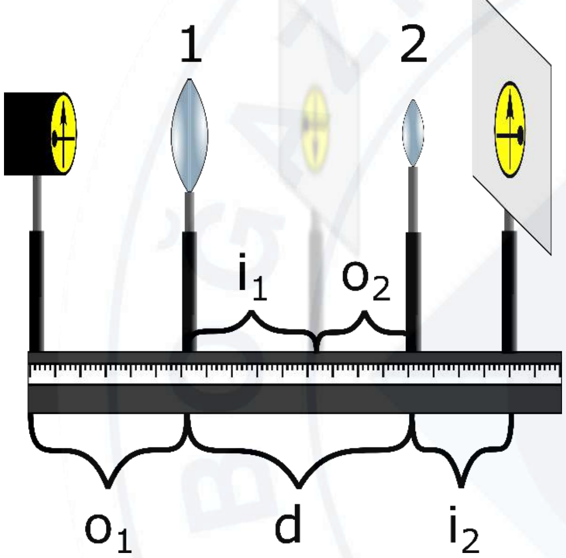
% Error for Index of Refraction, n = ...

Summary Sheet

$$m = -\frac{i}{o}$$

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

o > 0
i < 0



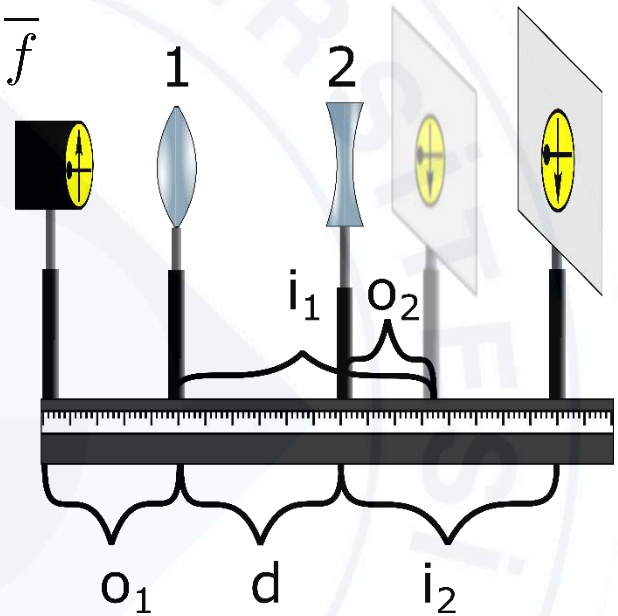
$$\frac{1}{o_1} + \frac{1}{i_1} = \frac{1}{f_1}$$

$$d - i_1 = o_2$$

$$\frac{1}{o_2} + \frac{1}{i_2} = \frac{1}{f_2}$$

$$o_2 \& f_2 \rightarrow i_2$$

o < 0
i > 0



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

$$d - i_1 = o_2$$

$$\frac{1}{o_2} + \frac{1}{i_2} = \frac{1}{f_2}$$

$$i_2 \& o_2 \rightarrow f_{diverging}$$