Boğaziçi University

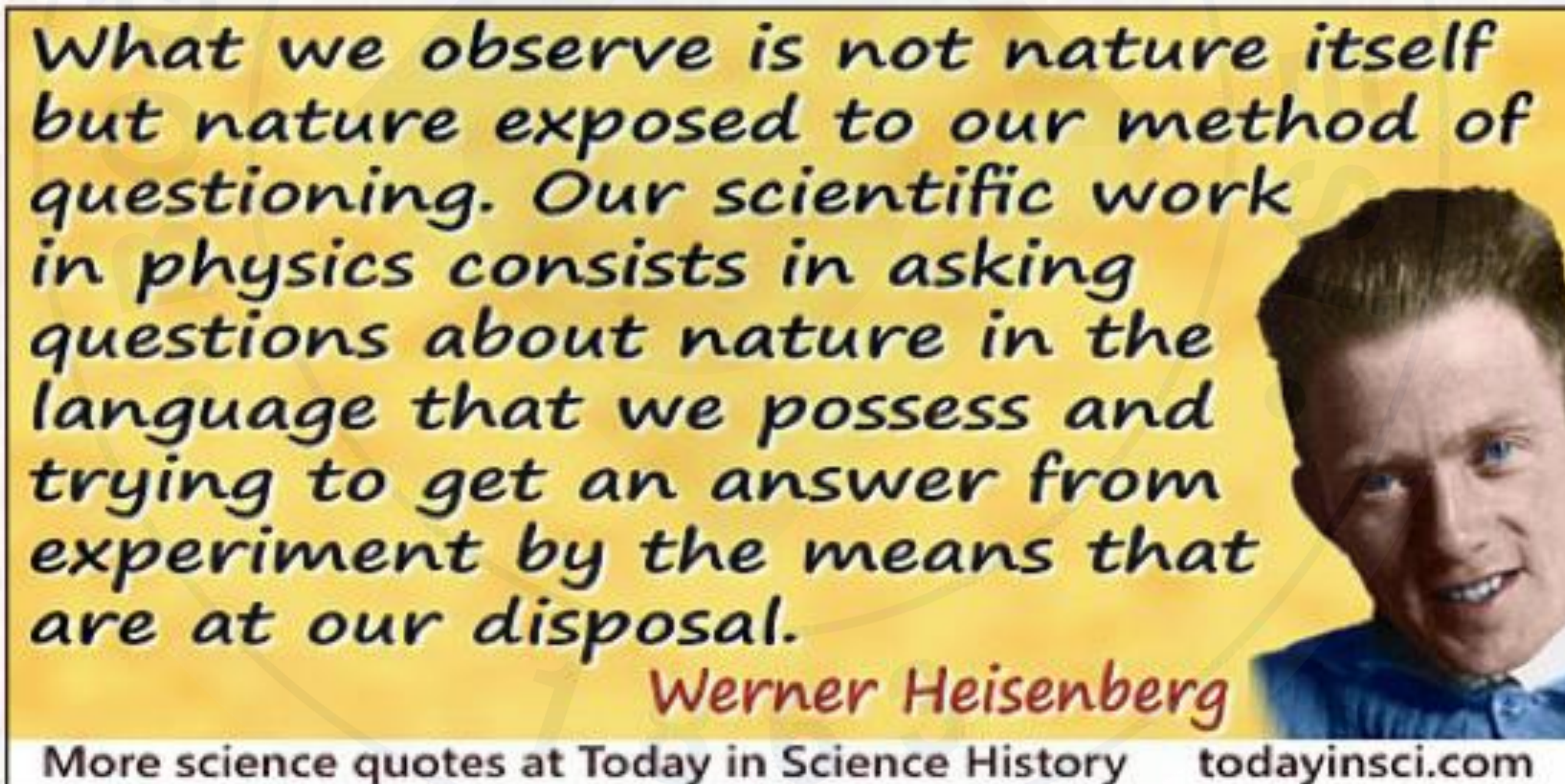
Introductory Phys Labs

EMPIRICAL EQUATIONS

PHYL102

THEORY

In science, an empirical relationship or phenomenological relationship is a relationship or correlation that is supported by experiment and observation but not necessarily supported by theory.



PhysLabs

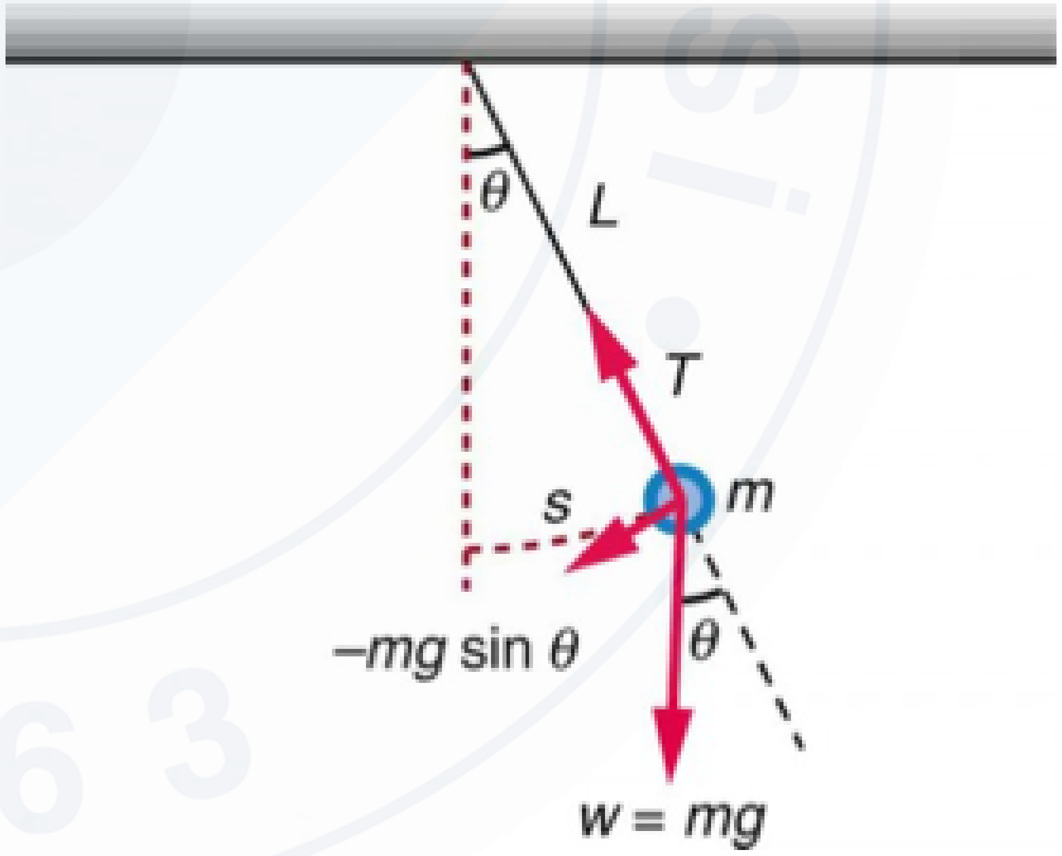
Recall The Simple Pendulum:

$$T = 2\pi\sqrt{\frac{L}{g}}.$$

T: Period

L: Cord Length

g: Acceleration due to gravity



Alternatively

$$T = AL^n,$$

where

$$A = \frac{2\pi}{\sqrt{g}}, \ n = \frac{1}{2}.$$

PhysLabs

Ring Pendulum:

In our experiment we have an oscillating ring instead of a simple pendulum.

The aim of the experiment is to check the period-diameter dependence.

We presume:

$$T = AD^n$$

***T*: Period**

***D*: Ring diameter**

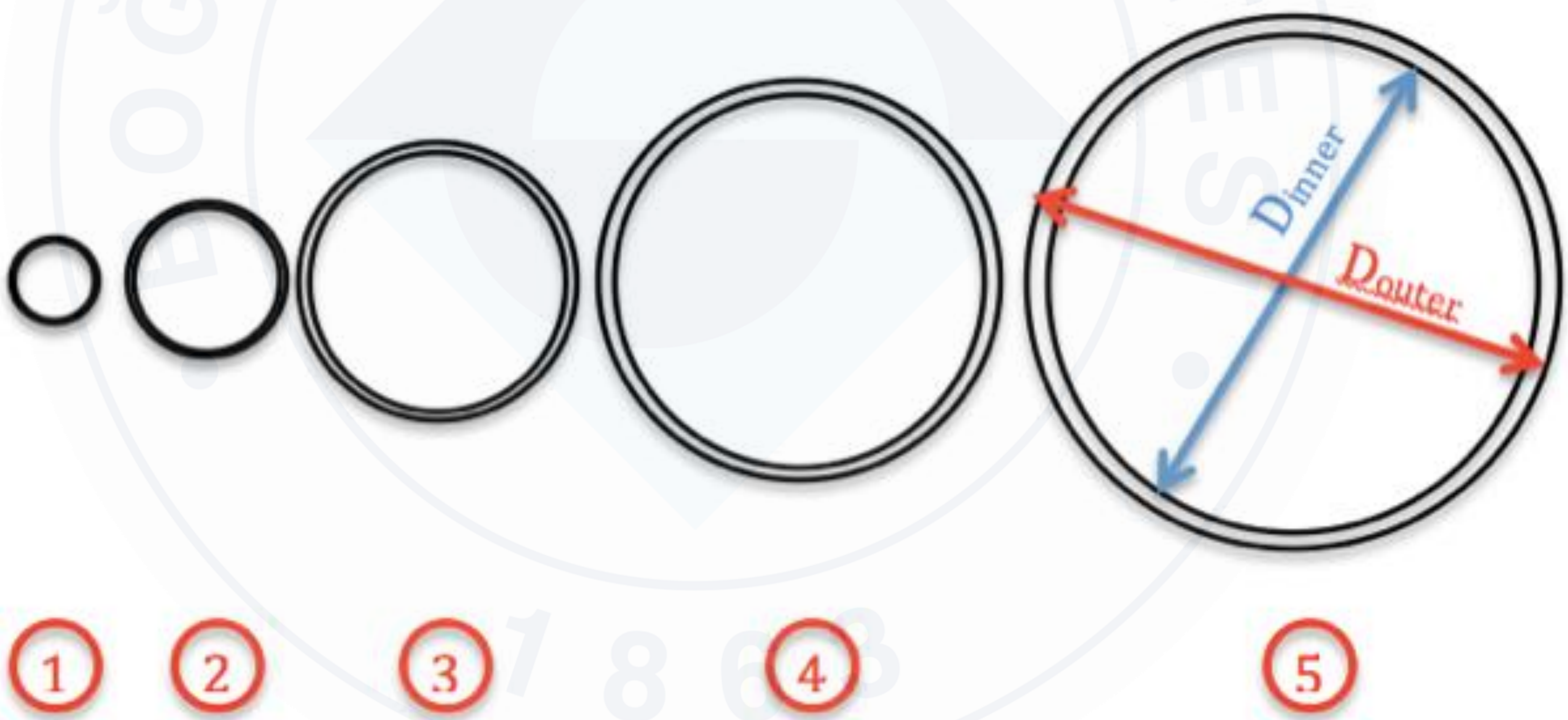
***A,n:* Physical constants to be determined**

APPARATUS

PhysLabs

Apparatus:

There are 5 rings made of same material with different diameters. Since the rings have thickness, both inner and outer diameter must be measured as shown below.



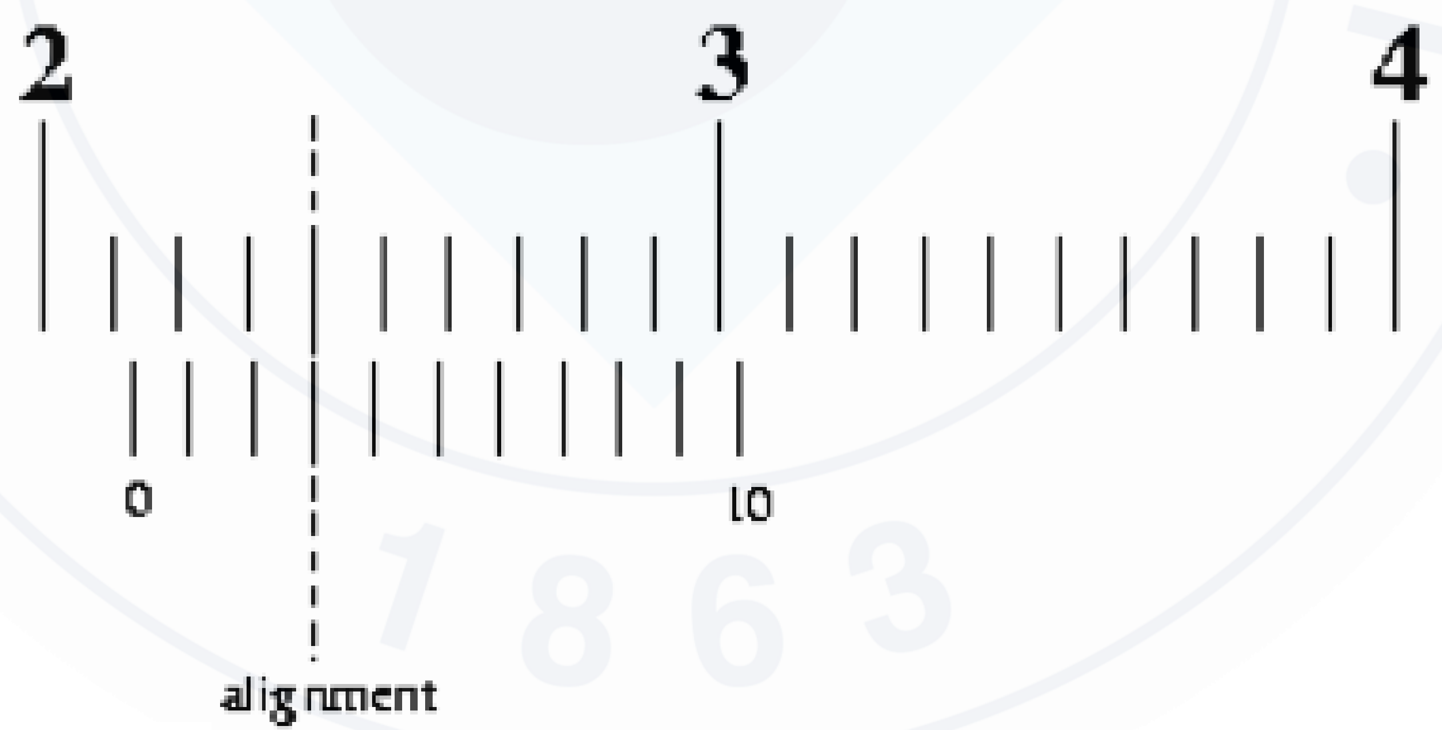
For Ring-1 and Ring-2 vernier calipers is used to measure the inner and outer diameters

PhysLabs

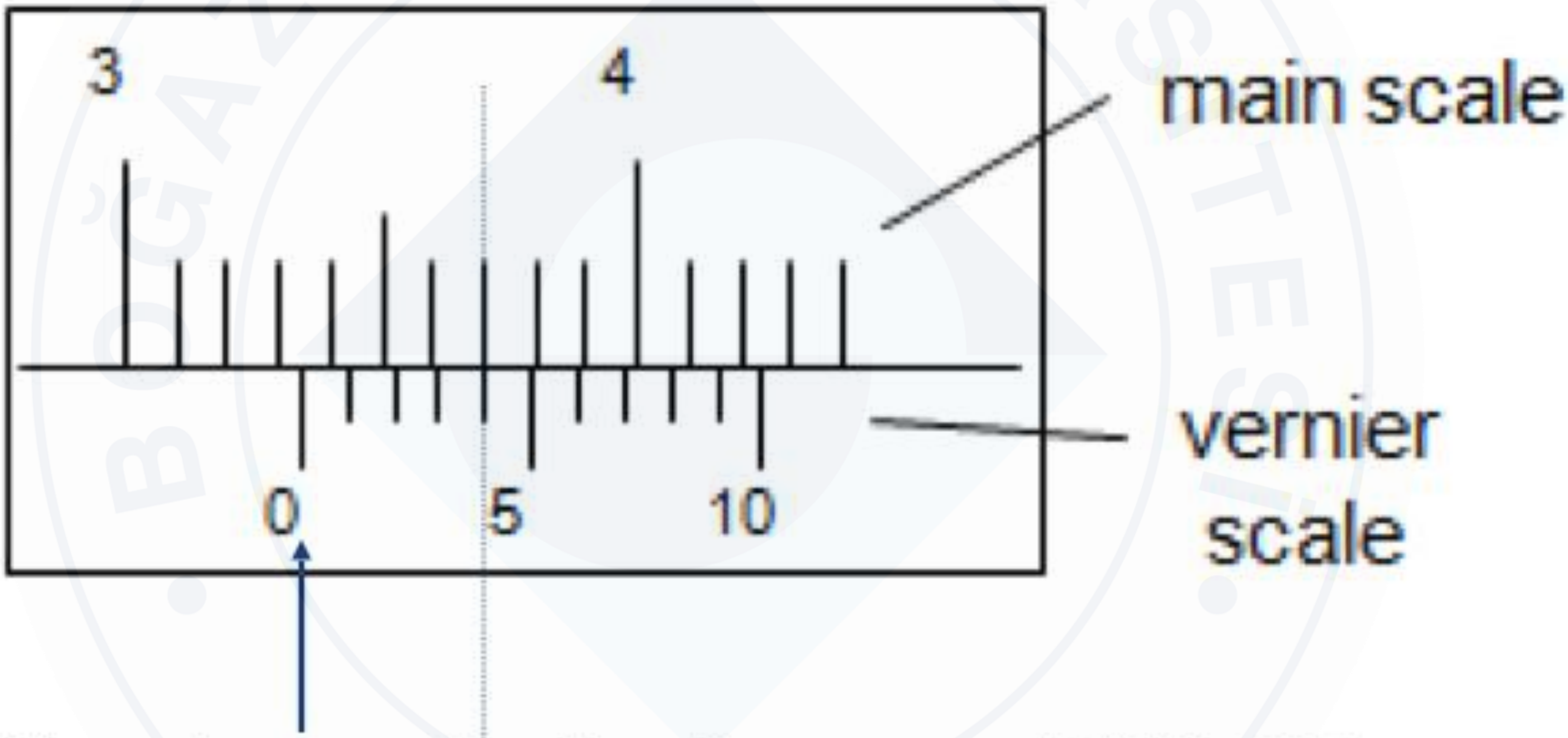
How to measure with vernier calipers:

If a vernier caliper output a measurement reading of 2.13 cm, this means that:

- **The main scale contributes the main number(s) and one decimal place to the reading (E.g. 2.1 cm, whereby 2 is the main number and 0.1 is the one decimal place number)**
- **The vernier scale contributes the second decimal place to the reading (E.g. 0.03 cm). Look at the image below and look closely for an alignment of the scale lines of the main scale and vernier scale. The aligned line corresponds to 3.**



Example:



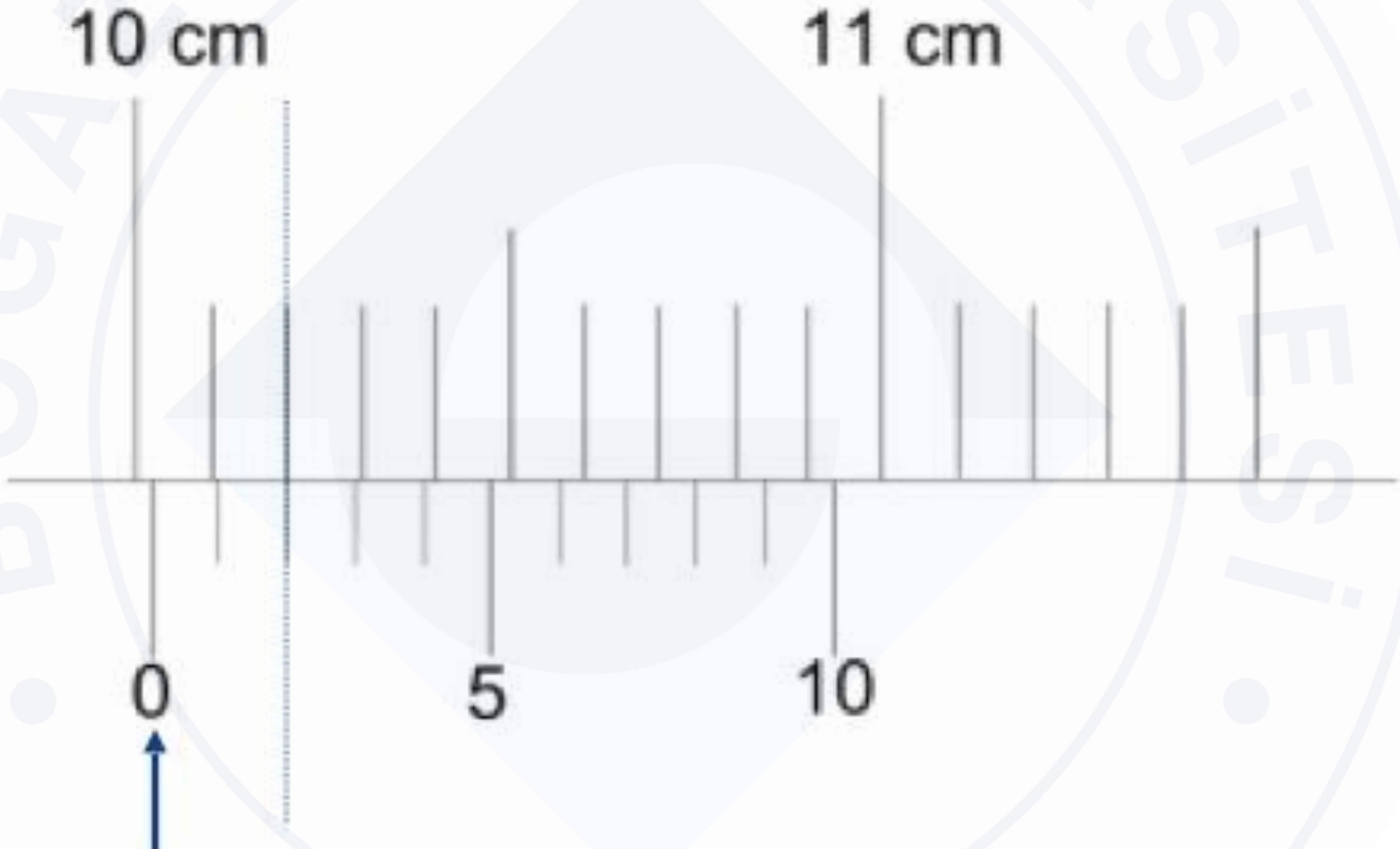
Main number: 3
One decimal: 3
3.3

The aligned line corresponds to 4.
0.04

RESULT: 3.34 cm

PhysLabs

Example:

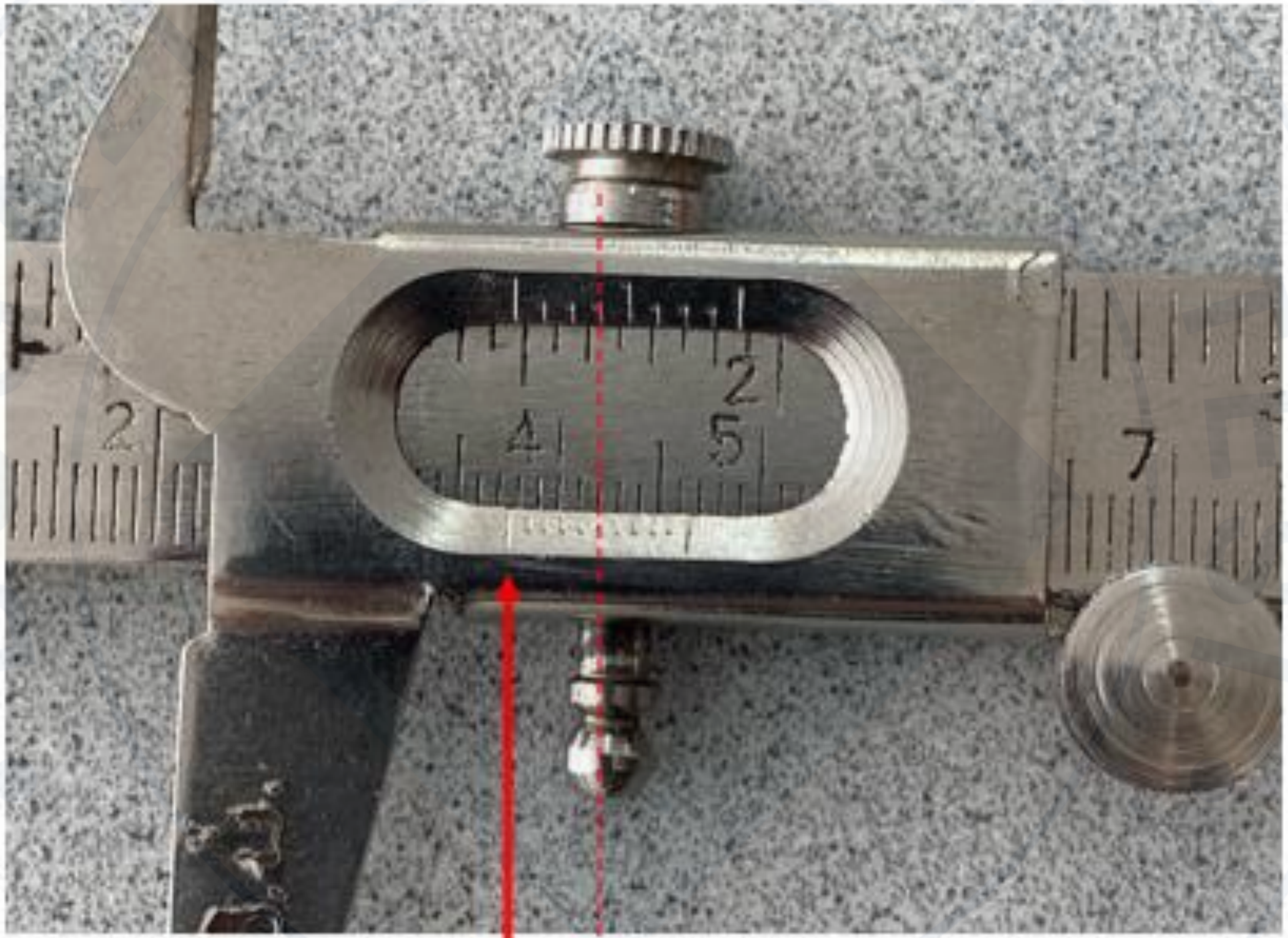


Main number: 10
One decimal: 0
10.0

The aligned line corresponds to 2.
0.02

RESULT: 10.02 cm

Example by using a real vernier calipers



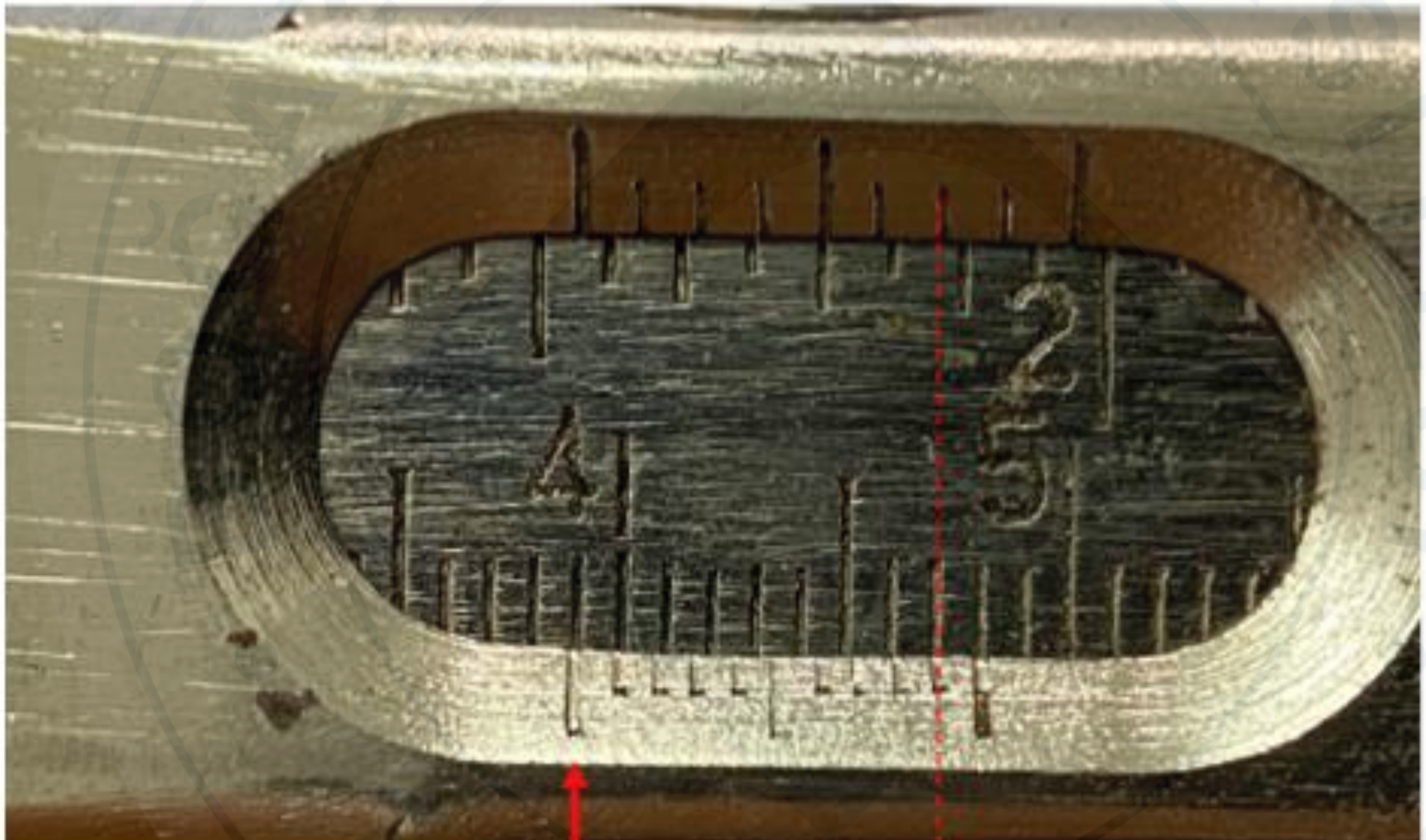
Main number: 3
One decimal: 7
3.7

The aligned line corresponds to 5.
0.05

RESULT: 3.75 cm

Special Case:

Reading of 3.89 cm, 3.90 cm and 3.91cm.



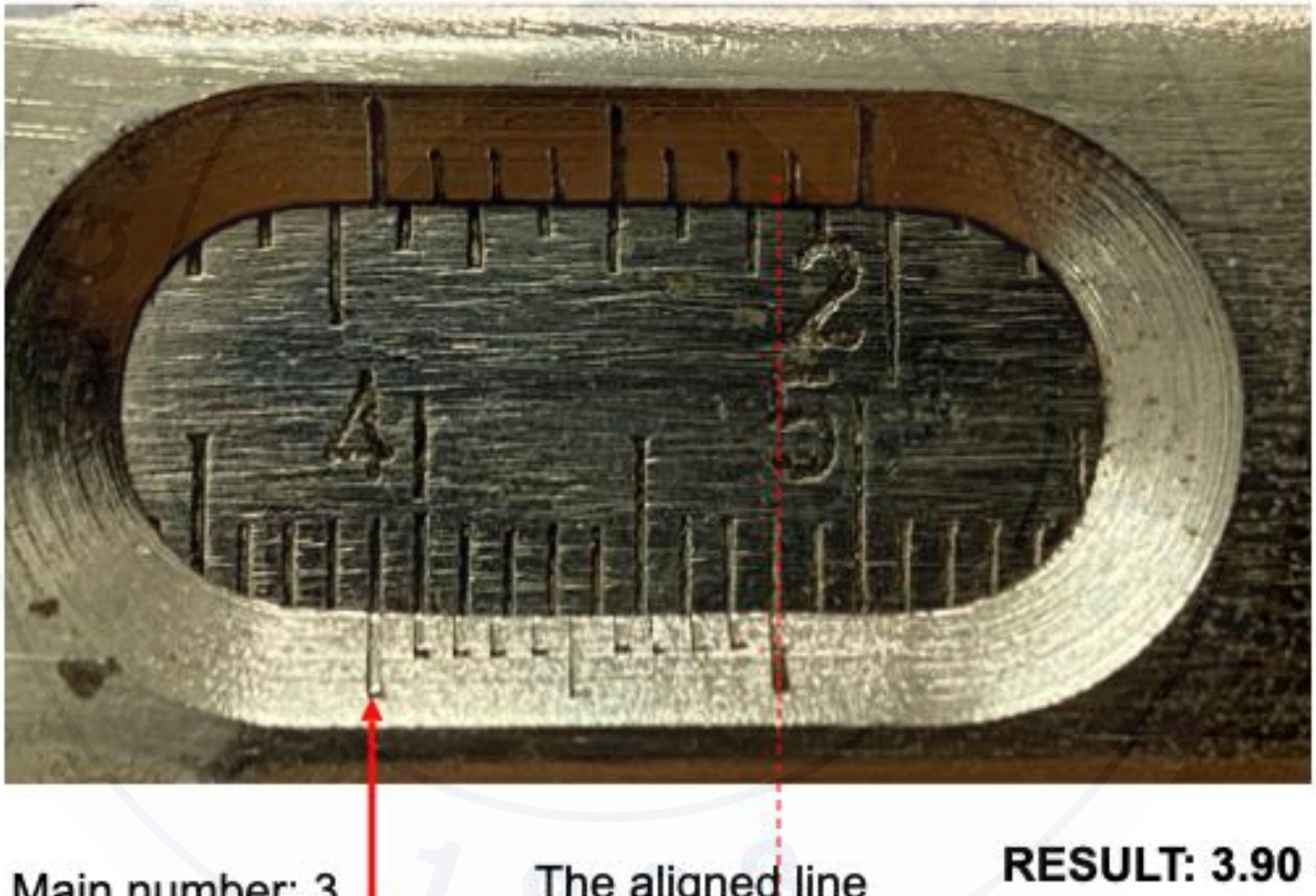
Main number: 3
One decimal: 8
3.8

The aligned line corresponds to 9.
0.09

RESULT: 3.89 cm

Special Case:

Reading of 3.89 cm, 3.90 cm and 3.91cm.



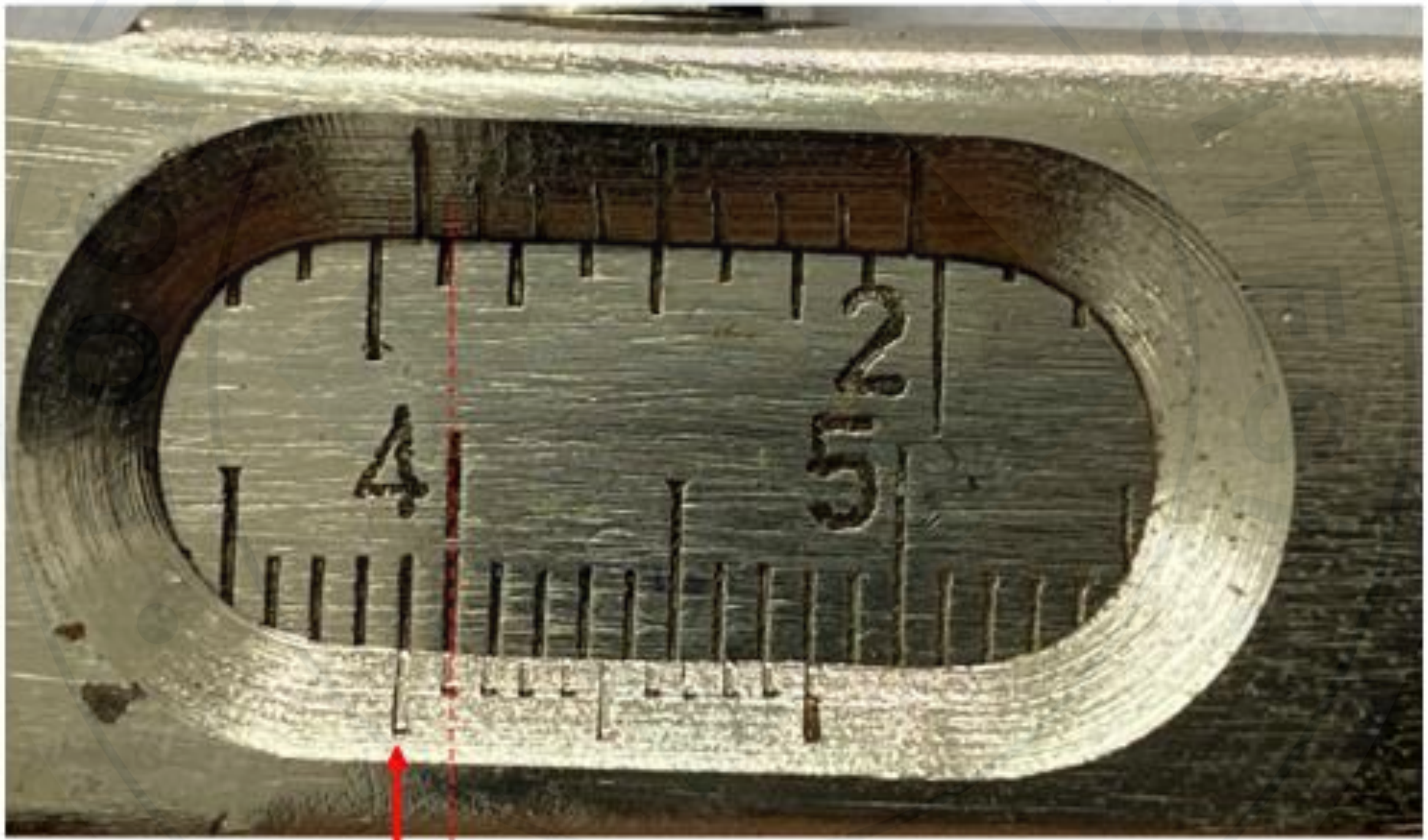
Main number: 3
One decimal: 9
3.9

The aligned line corresponds to 10.
0.00

RESULT: 3.90 cm

Special Case:

Reading of 3.89 cm, 3.90 cm and 3.91cm.



Main number: 3
One decimal: 9
3.9

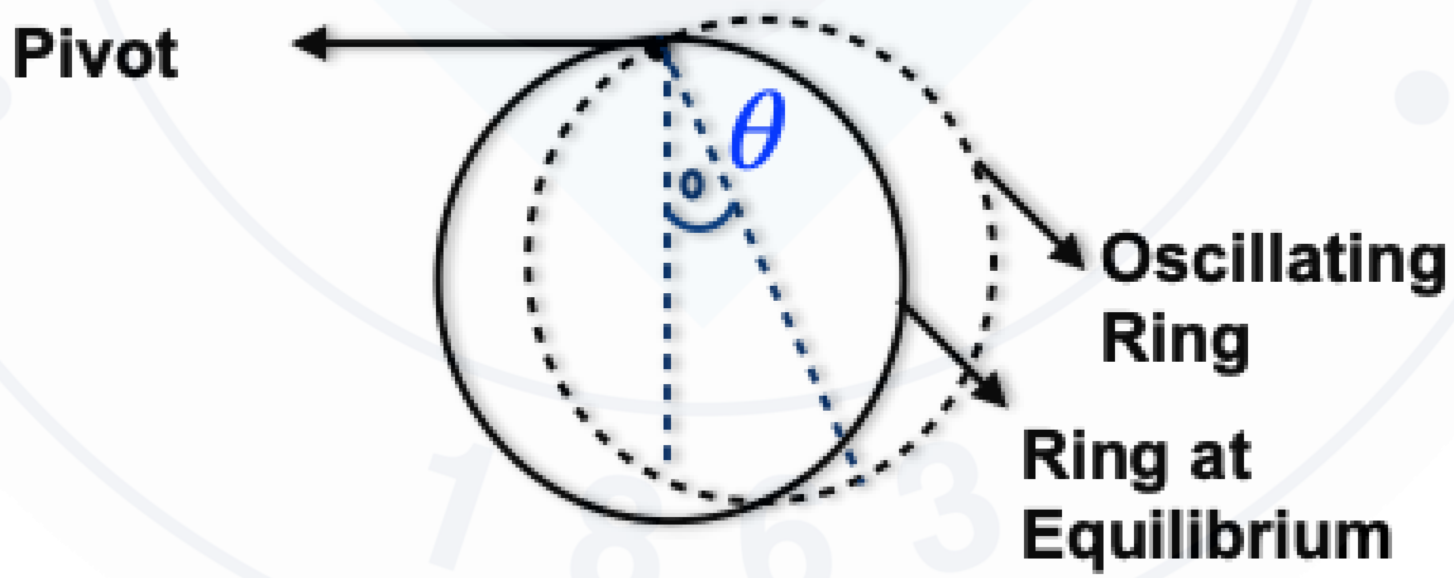
The aligned line corresponds to 1.
0.01

RESULT: 3.91 cm

EXPERIMENT

PhysLabs

- What to measure (Vernier calipers, ruler and stopwatch) : Inner and outer diameters D_i and D_o, some given number of periods of oscillations t
- What to calculate : Average diameters D_{ave}, one period of oscillation T
- Experimental findings : Physical constants A and n



PhysLabs

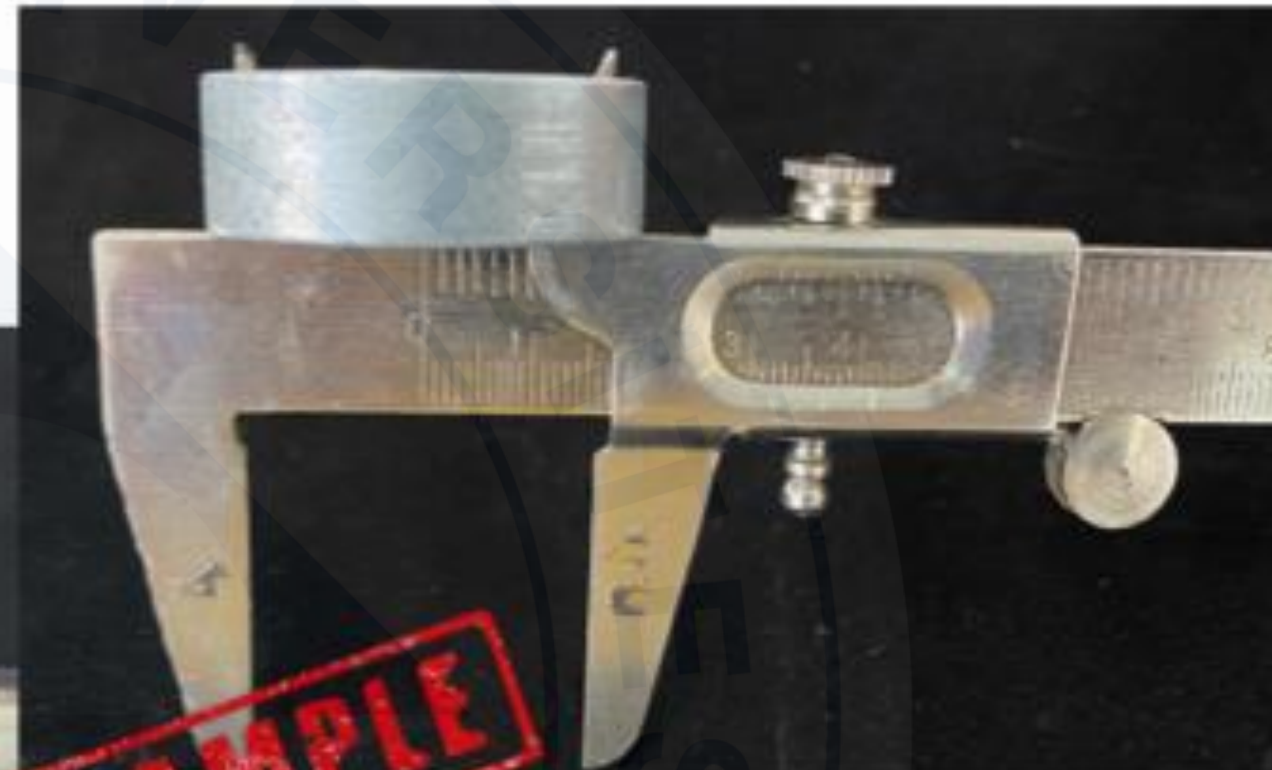
Since the rings may not be perfect their inner and outer diameters should be measured from two different positions.

Since the range of the Vernier caliper is restricted to 12 cm, for larger rings ruler is used.

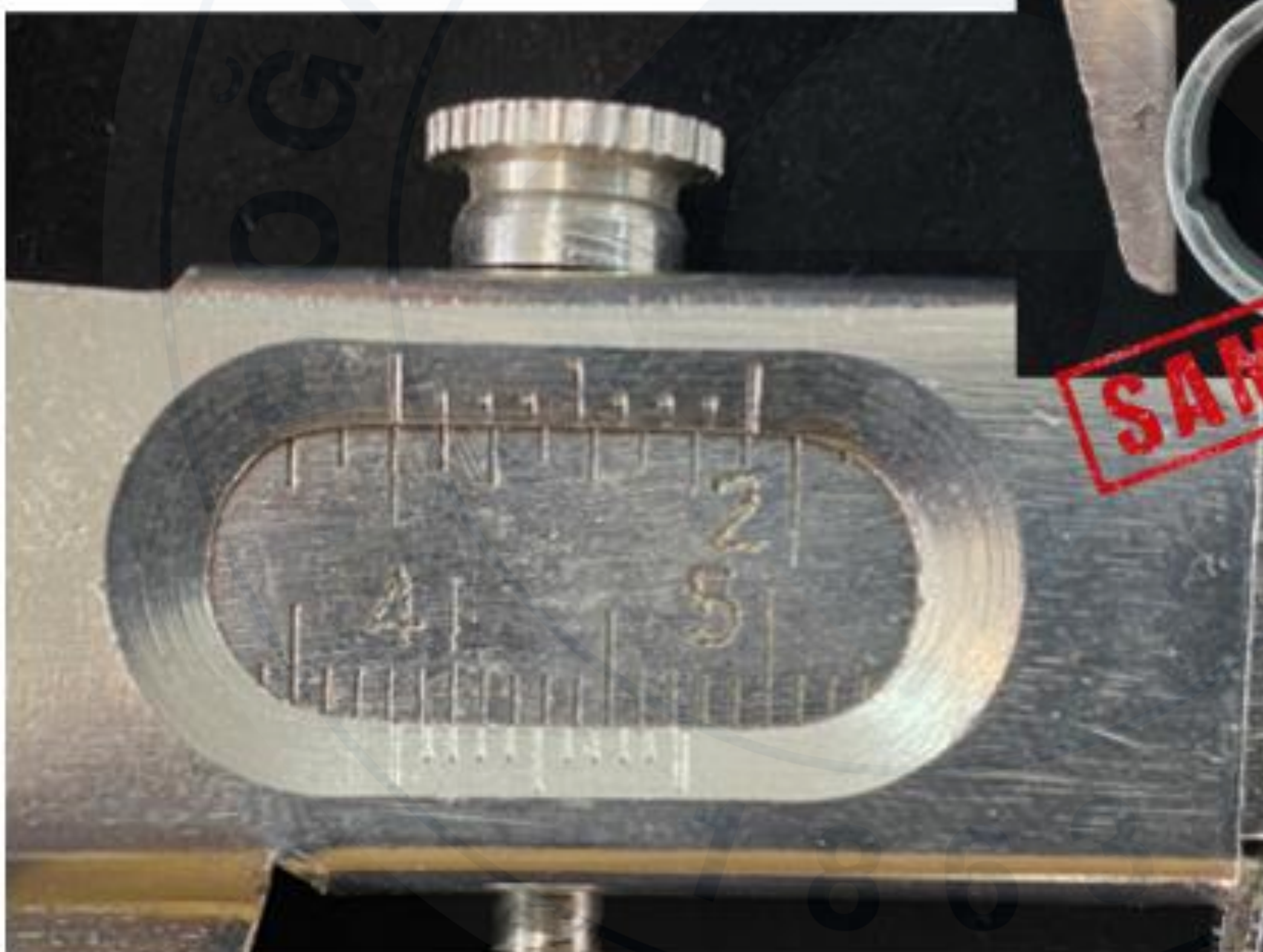
For each ring take the first and second measurements of inner and outer diameters

The following data is only used for demonstrational purposes. DO NOT use them.

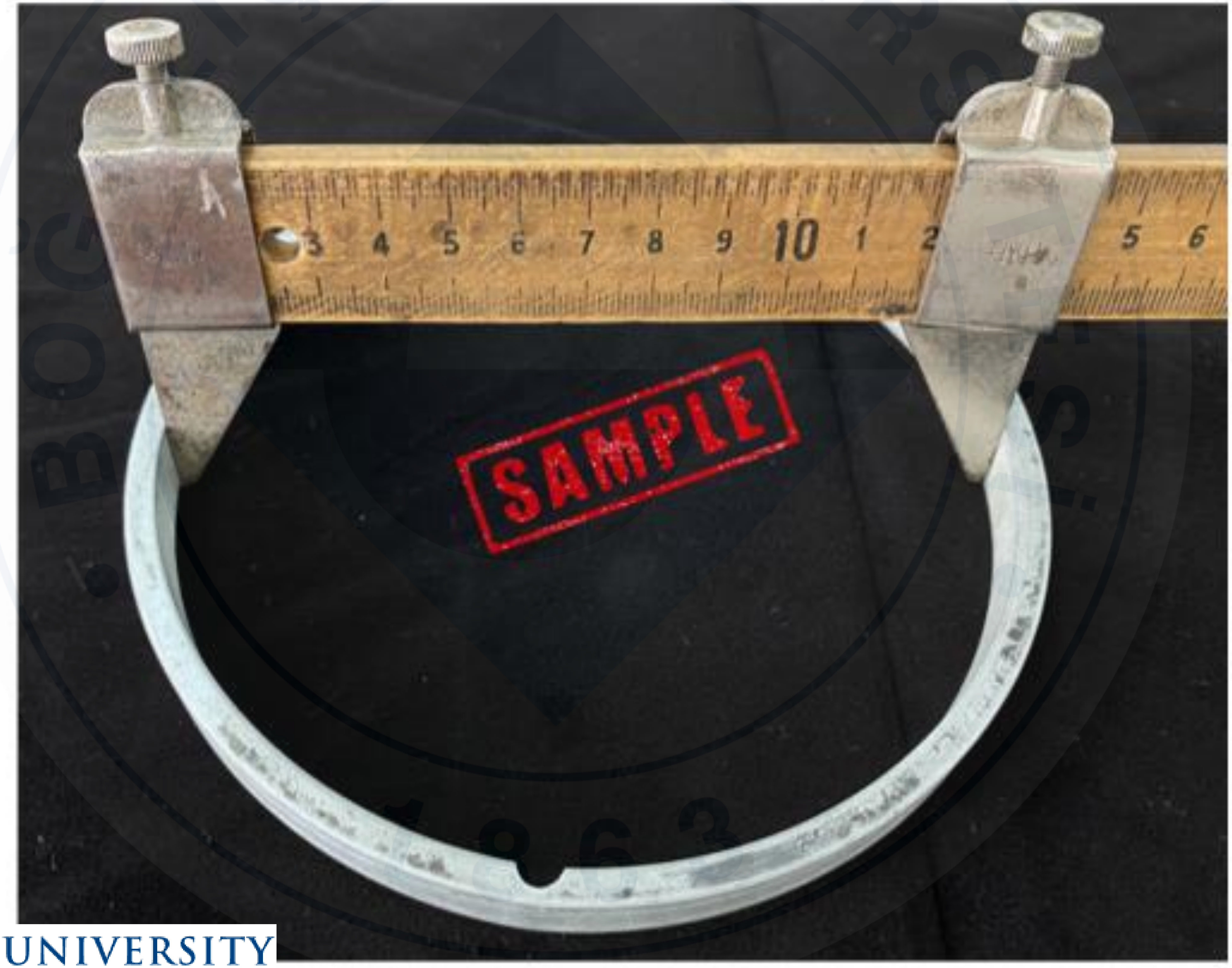
How to Measure the Inner Diameter of Small Rings



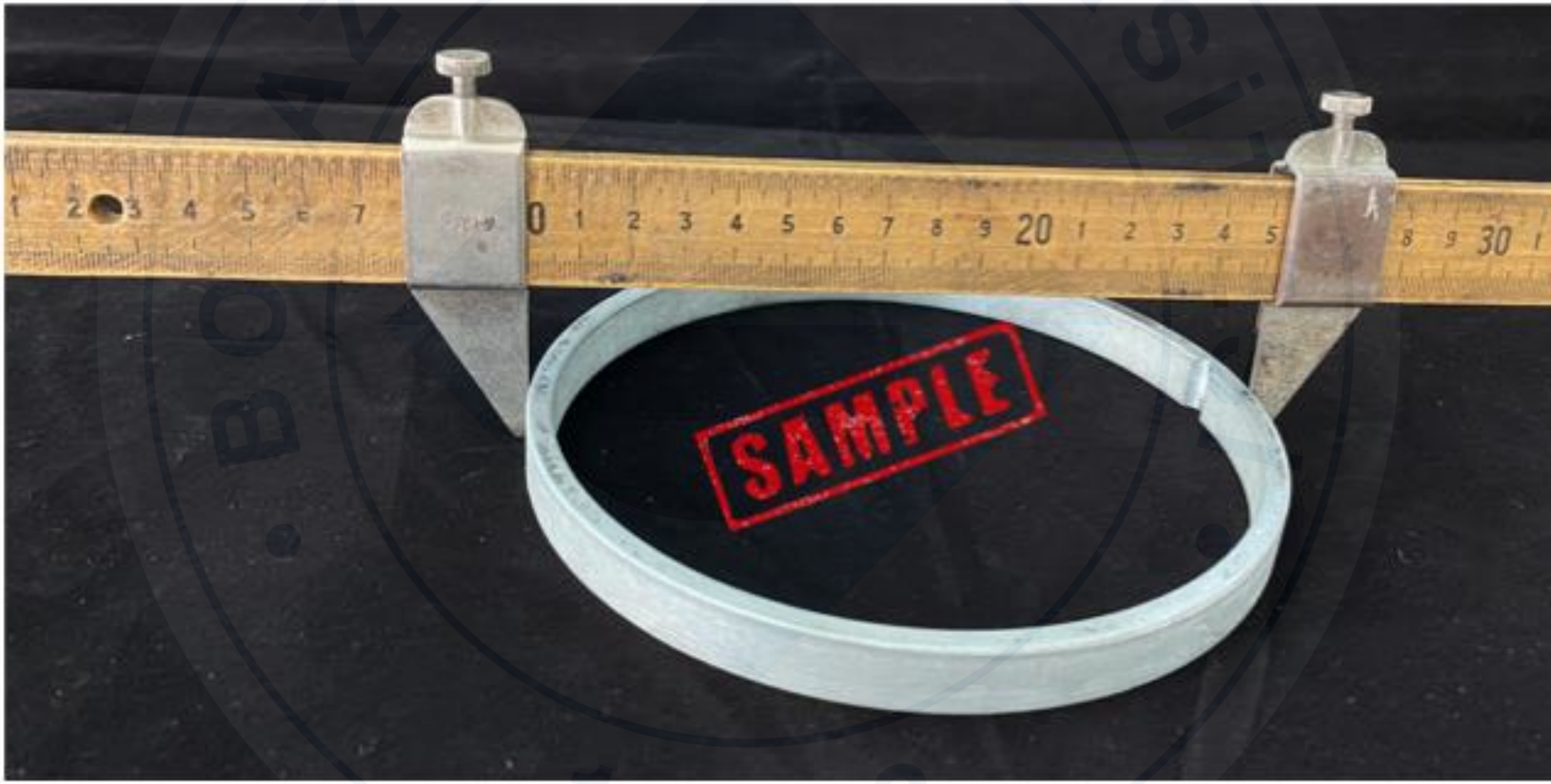
How to Measure the Outer Diameter of Small Rings



How to Measure the Inner Diameter of Large Rings



How to Measure the Outer Diameter of Large Rings



Oscillation of One of the Rings

Use your stopwatch to measure time for given number of oscillations in DataVideo.

DATA: Watch the DataVideo and fill the table on page 53.

DATA:

Description	Symbol (unit)	RING NUMBER				
		- 1 -	- 2 -	- 3 -	- 4 -	- 5 -
Inner Diameter *(first measurement)*	D_{i1} ( )					
Inner Diameter *(second measurement)*	D_{i2} ( )					
Average Inner Diameter	D_{iave} ( )					
Outer Diameter *(first measurement)*	D_{o1} ( )					
Outer Diameter *(second measurement)*	D_{o2} ( )					
Average Outer Diameter	D_{oave} ( )					
# of Periods	t ( )					

The number of periods of oscillations to be measured is given in the DataVideo. Please take that number into consideration, not the one in your Lab book.

CALCULATIONS: Fill the table on page 53.

CALCULATIONS:

Description	Symbol (unit)	RING NUMBER				
		- 1 -	- 2 -	- 3 -	- 4 -	- 5 -
Average Diameter	D_{ave} ( )					
One Period	T ( )					
Logarithm of D_{ave}	Log D_{ave}					
Logarithm of T	Log T					

PART-1:
Plotting of $logD$ vs $logT$ on a regular graph paper.
(A_1 and n_1 are calculated.)

It is not an easy task to fit $T = AD^n$ to our data.

Fit the line $logT = logA + nlogD$ instead. It looks like parametrization of a straight line $y = a + bx$.

logA is Intercept when logD = 0, D = 1.

$$n = Slope = \frac{logT_2 - logT_1}{logD_2 - logD_1}.$$

Take the logarithm first and plot your data points on a regular graph paper and also plot your data points without taking the logarithm on a log-log graph paper.

PhysLabs

PART-1: logT = logA + n logD

- Use a regular graph paper and draw logD vs logT graph.

Scale your axes in such a way that your graph fits the whole paper and y-Intercept is read properly.

- Choose 2 slope points.

$SP_1 \quad (logD_{SP1}, logT_{SP1})$

$SP_2 \quad (logD_{SP2}, logT_{SP2})$

- Calculate $n_1 = Slope = \dfrac{logT_{SP2} - logT_{SP1}}{logD_{SP2} - logD_{SP1}}$.

- Read Intercept and determine A_1.

PhysLabs

PART-1:

Fill in the empty spaces accordingly.

n_1 = ...

....

Intercept$_1$ = ...

....

A_1 = ...

....

$D_{\text{(for T=1 sec)}}$ = ...

PART-2:
Plotting of D vs T on log-log graph paper
(A_2 and n_2 are calculated.)

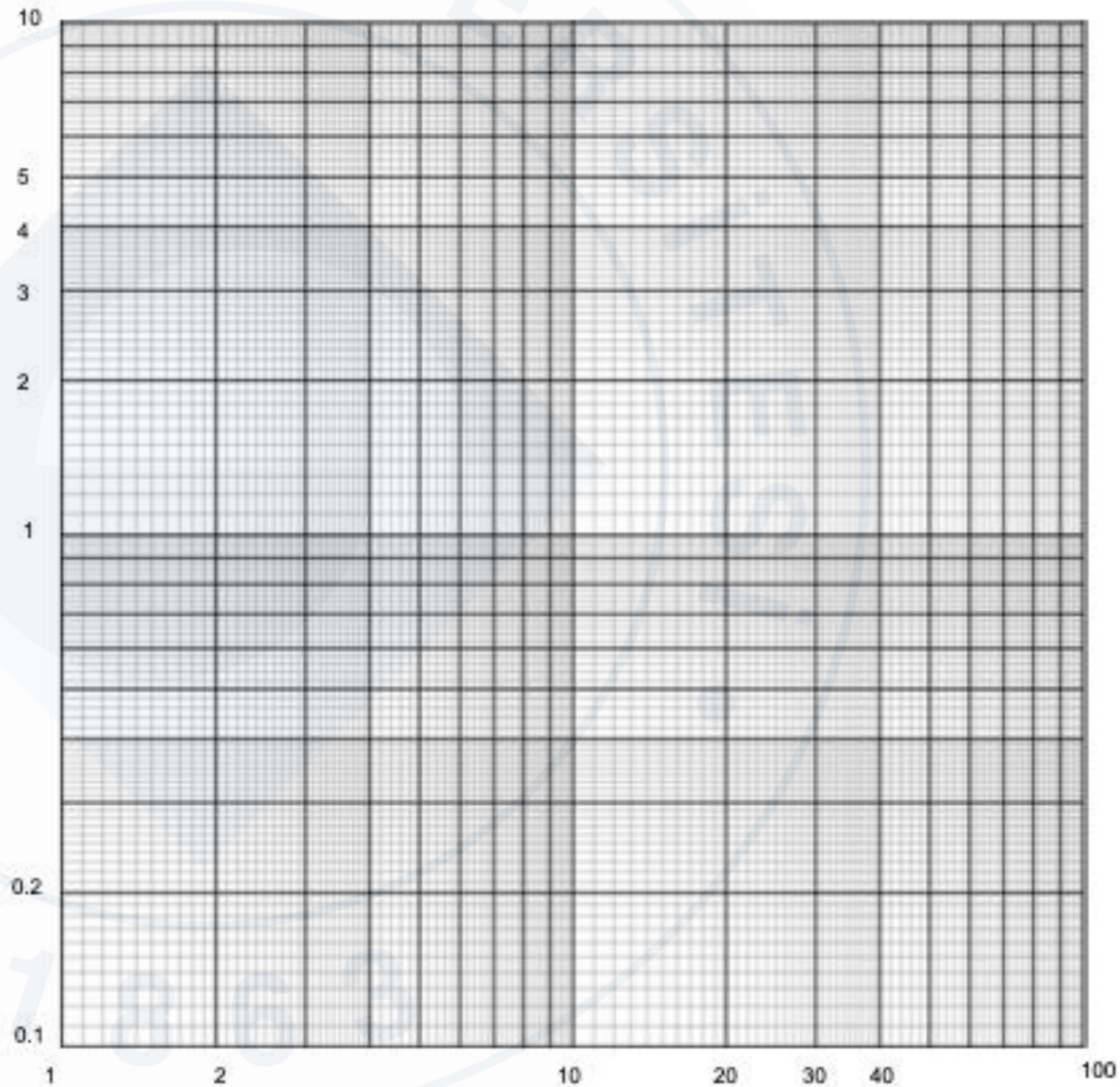
How to Draw Log-Log Graph:

Units on x- and y-axes are labelled by

$10^n, 2 \times 10^n, 3 \times 10^n \ldots 10^{n+1} \ldots$

where n is a positive or negative integer.

Paper actually takes the *log* for you!

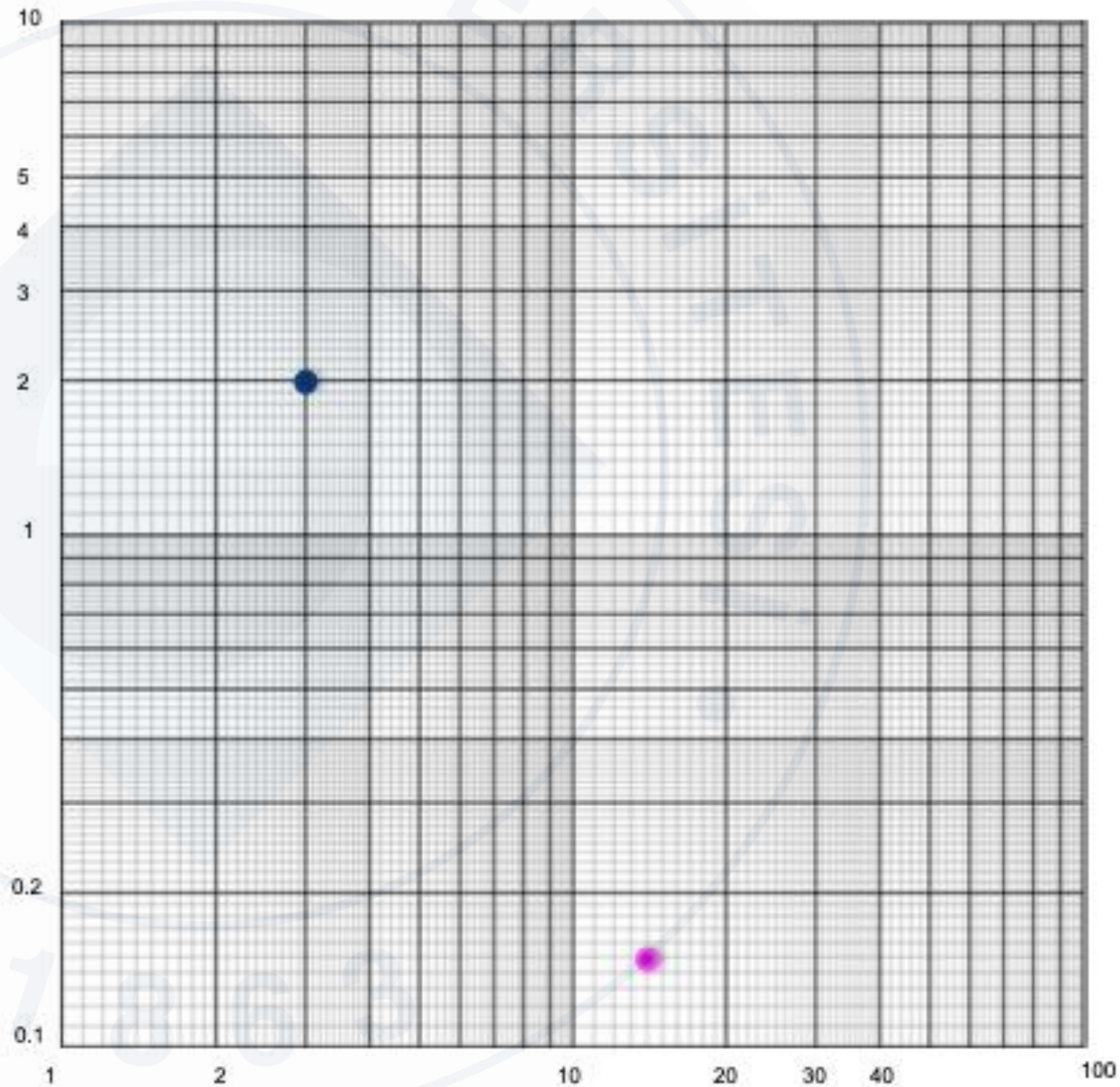


How to Draw Log-Log Graph:

Close picture of log-log graph paper is given.

As an example, coordinates of the blue point are (3.0, 2.0).

As another example coordinates of the pink point are (14, 0.15).



PART-2: $T = AD^n$

- **Use a log-log graph paper and draw D vs T graph.**

Scale your axes in such a way that your graph fits the whole paper and y-Intercept is read properly.

- **Choose 2 slope points.**

$SP_1 \quad (D_{SP1}, T_{SP1})$

$SP_2 \quad (D_{SP2}, T_{SP2})$

- **Calculate** $n_2 = Slope = \dfrac{logT_{SP2} - logT_{SP1}}{logD_{SP2} - logD_{SP1}}$.

- **Read Intercept and determine** A_2.

PART-2:

Fill in the empty spaces accordingly.

n_2 = ...

....

Intercept$_2$ = ...

....

A_2 = ...

....

D (for T=1 sec) = ...

Calculate the averages of A_1, A_2 and also n_1, n_2. Answer the question.

RESULTS:

Symbol		Calculations	Result	Dimension
n_{ave}	=	....	....	....
A_{ave}	=	....	....	....