Boğaziçi University

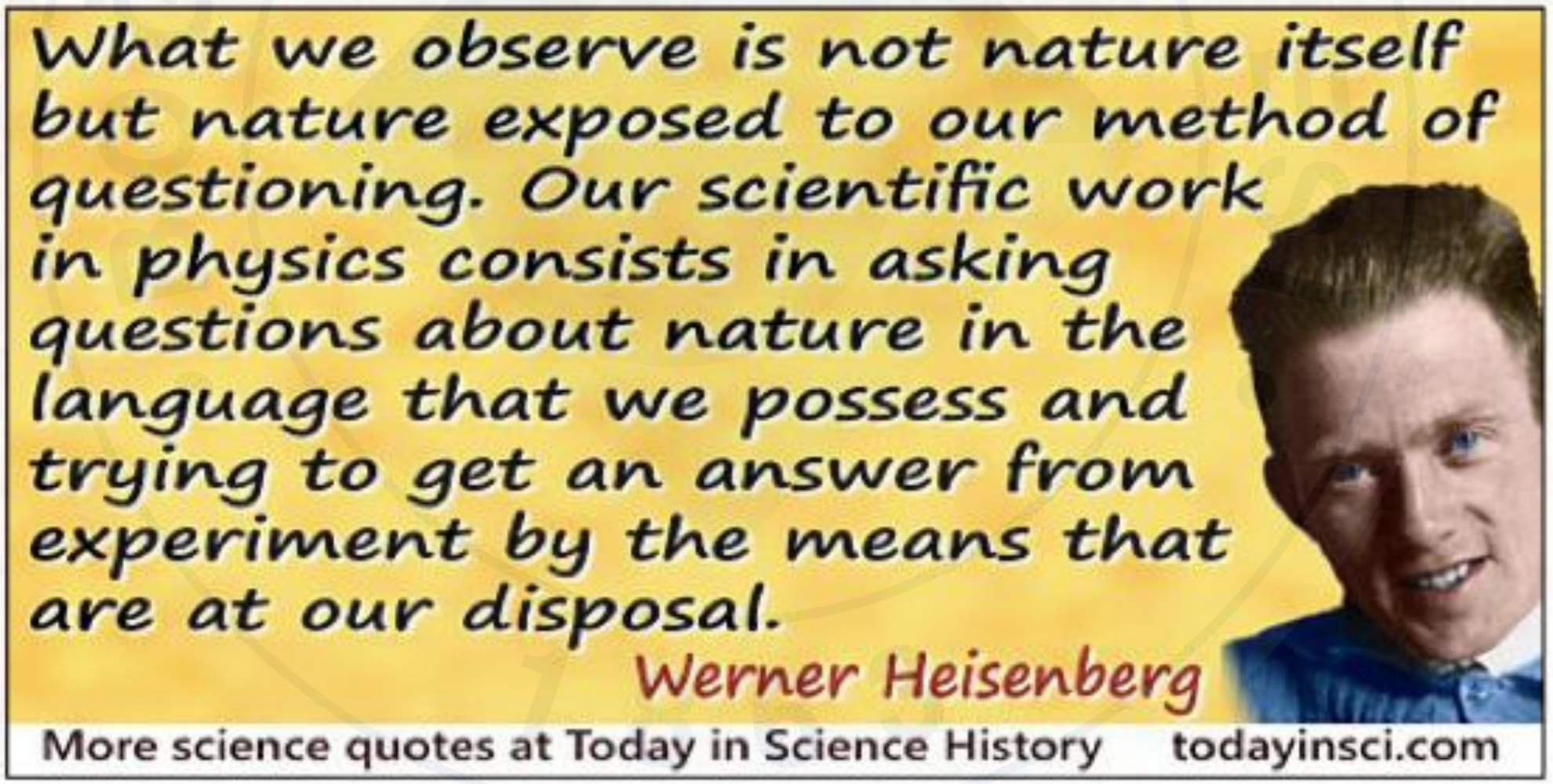
Introductory Phys Labs

APPLIED EXAM – 1
EMPRICAL 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.



Recall The Simple Pendulum:

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

***T*: Period**

***L*: Cord Length**

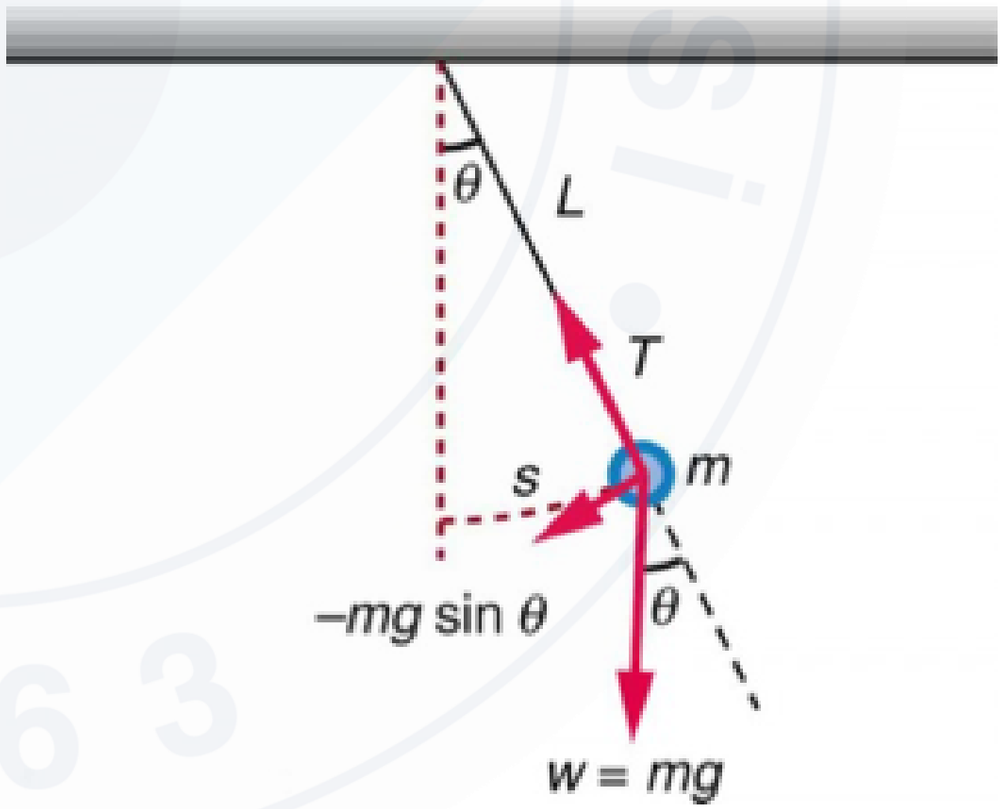
***g*: Acceleration due to gravity**

Alternatively

$$T = AL^n,$$

where

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



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.

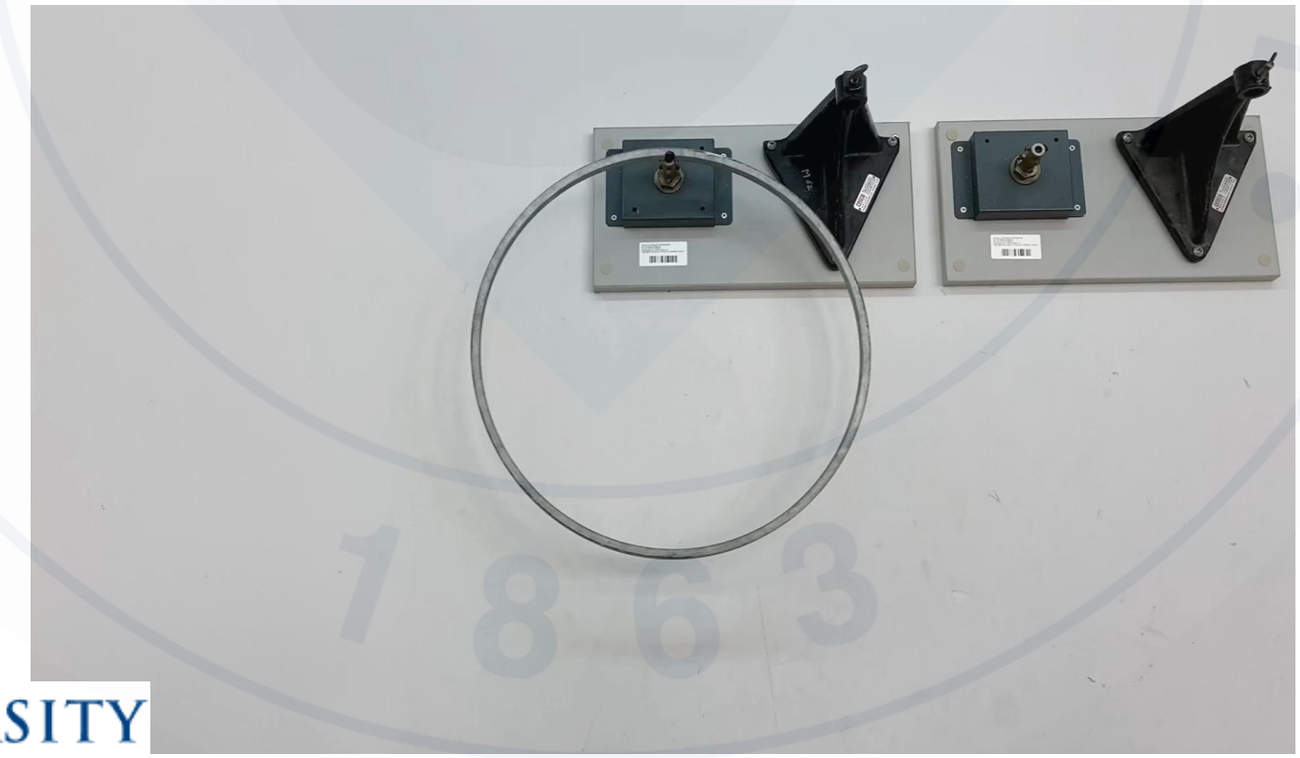
We presume:

$$T = AD^n$$

***T*: Period**

***D*: Ring diameter**

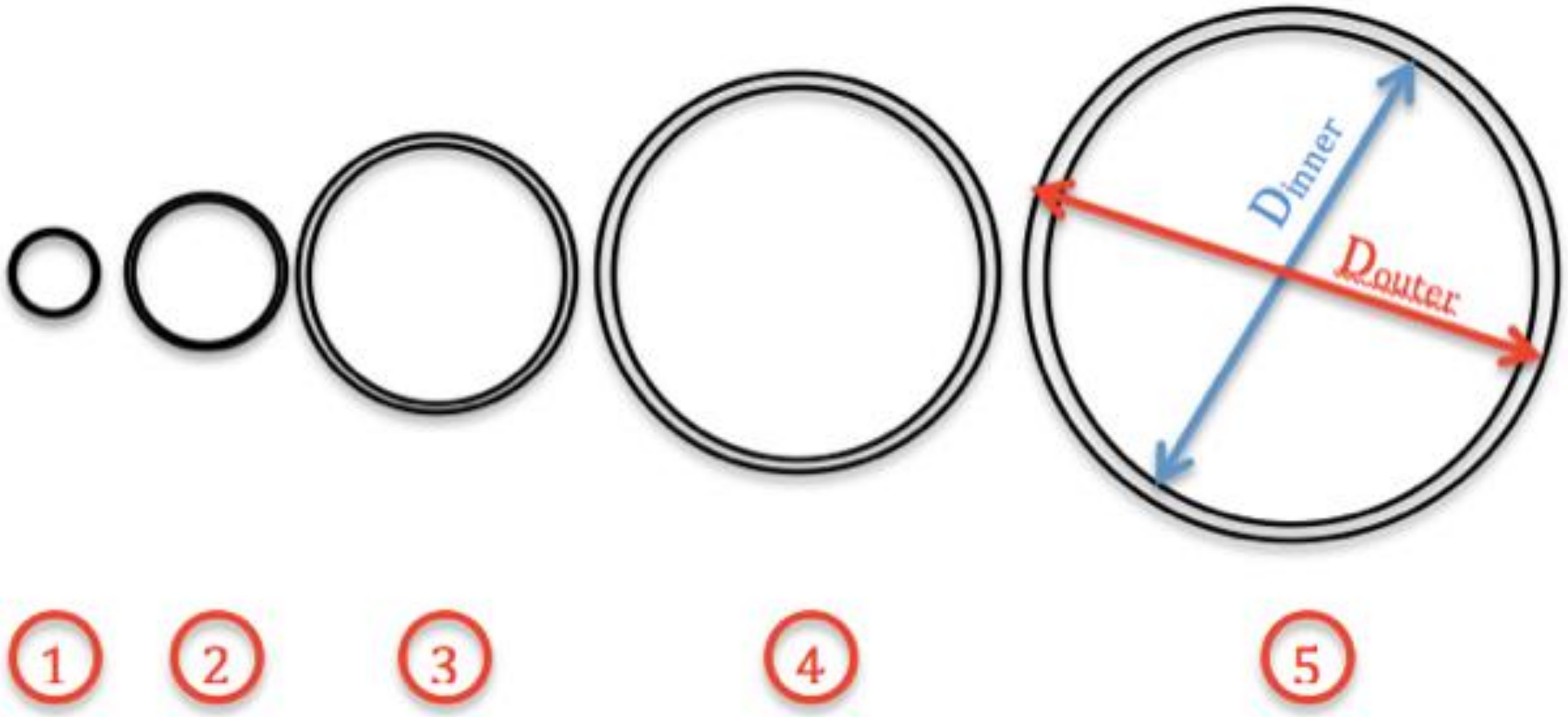
***A,n:* Physical constants to be determined**



APPARATUS

Apparatus:

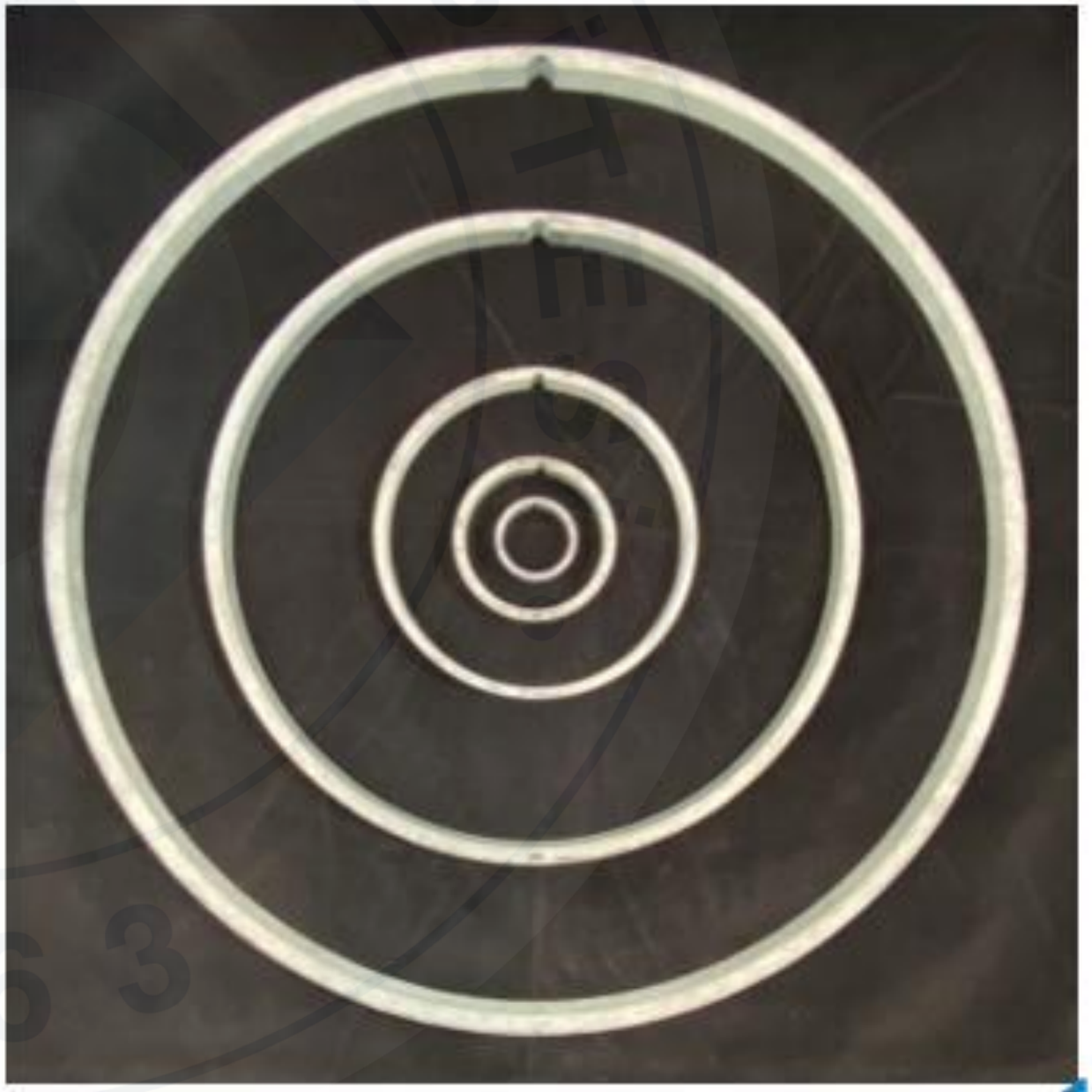
There are 5 rings made of same material with different diameters. Since the rings have thickness, both inner and outer diameter must be measured as shown below.



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

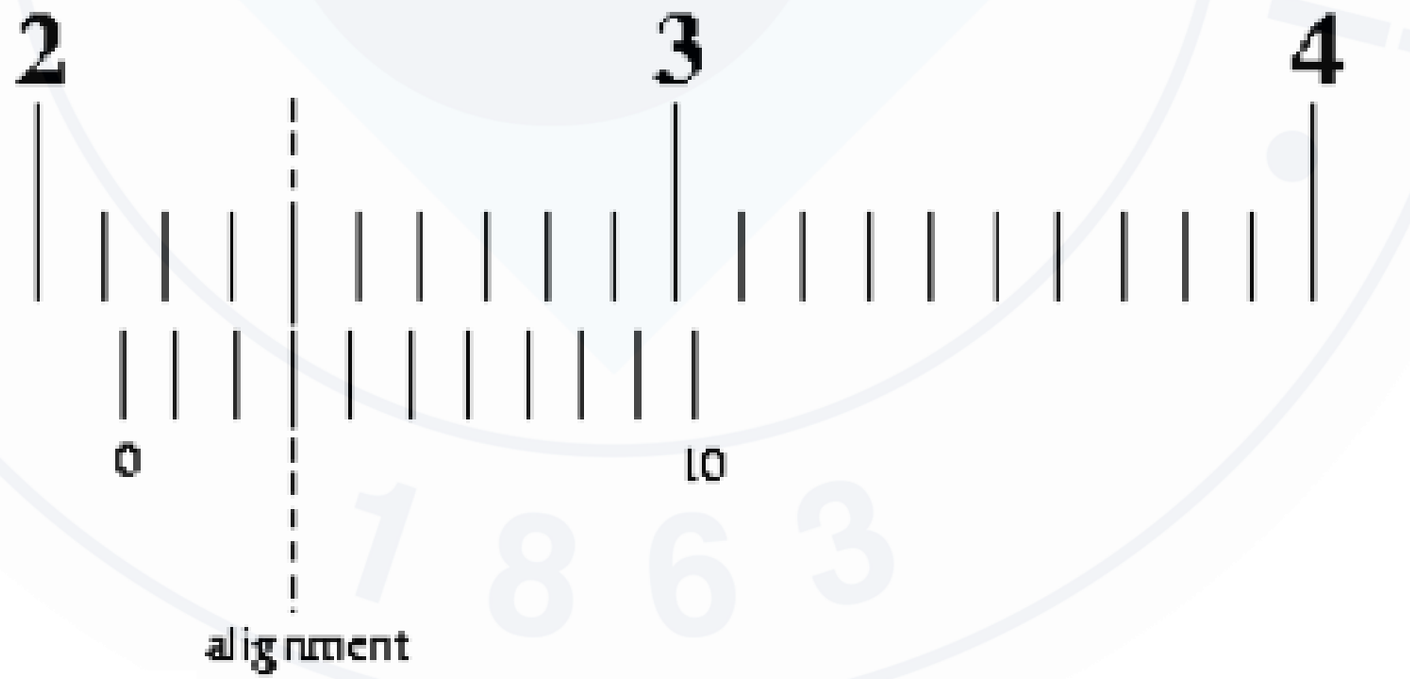




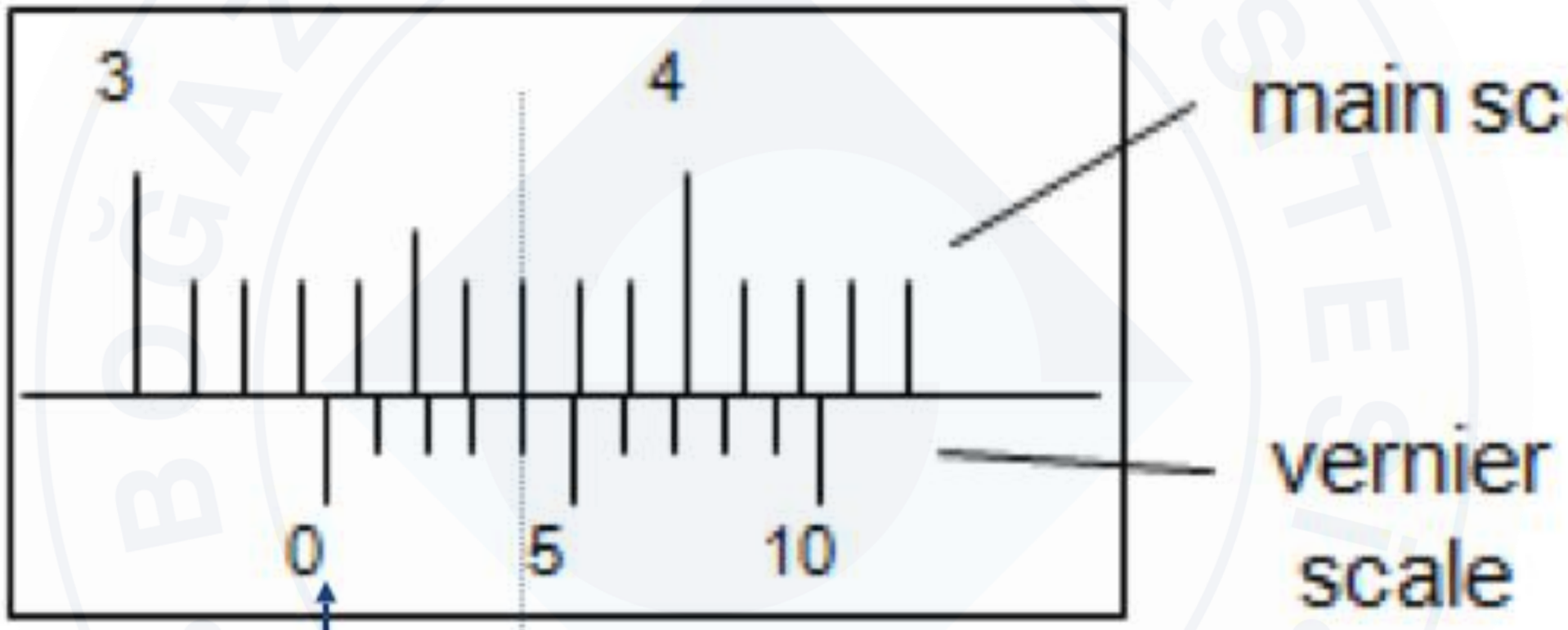
How to measure with vernier calipers:

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:

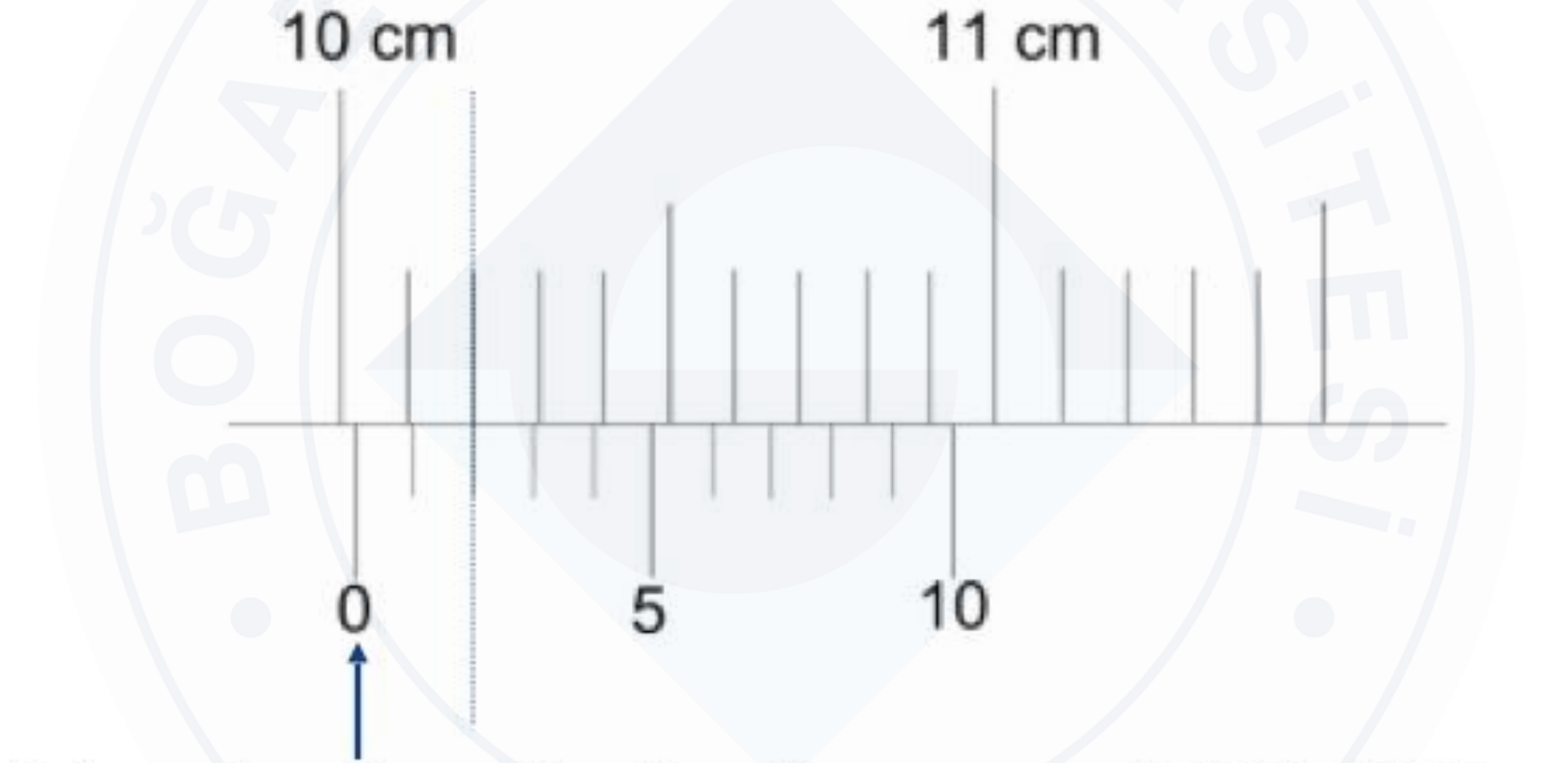


Main number: 3
One decimal: 3
3.3

The aligned line corresponds to 4.
0.04

RESULT: 3.34 cm

Example:

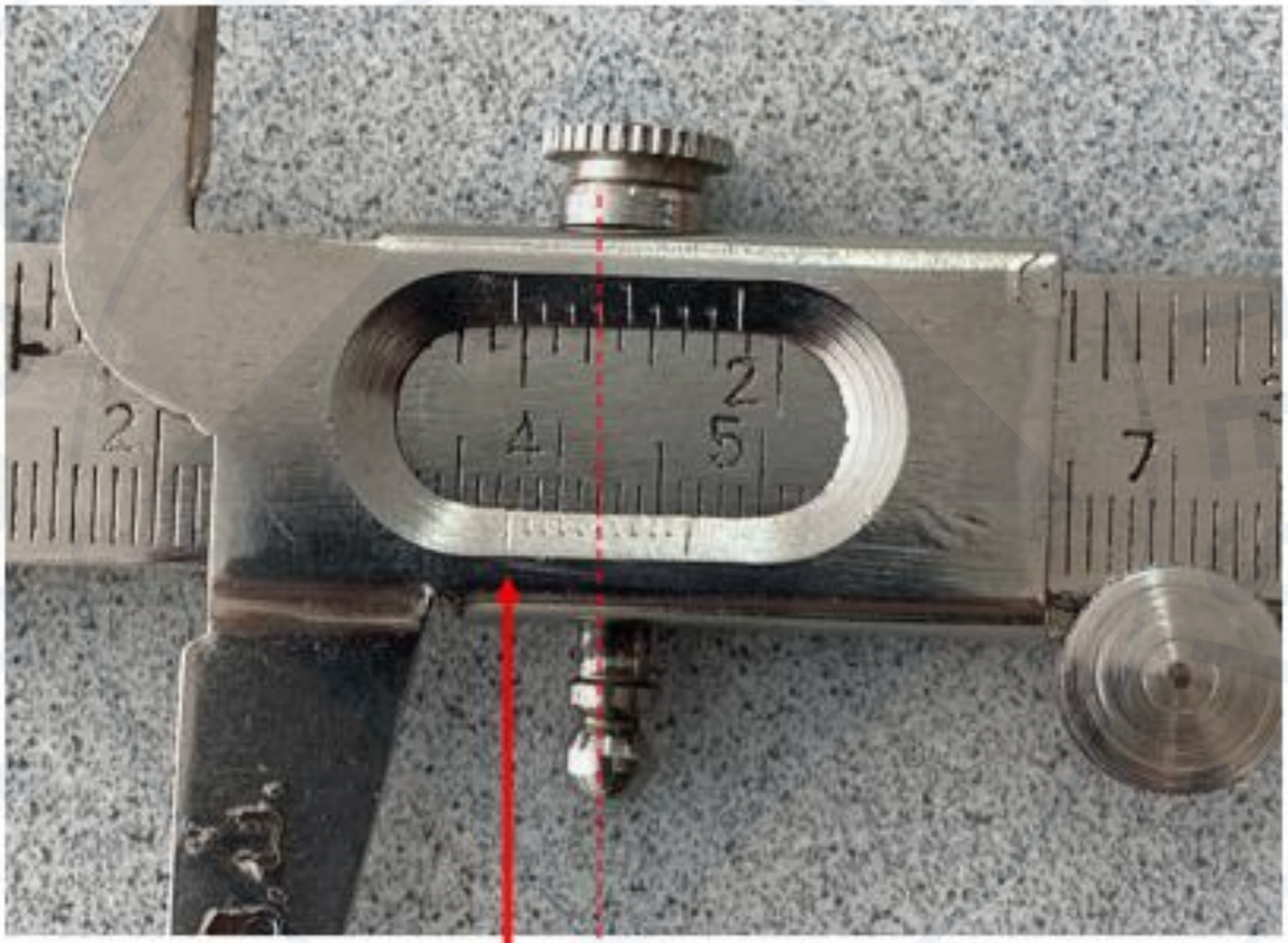


Main number: 10
One decimal: 0
10.0

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

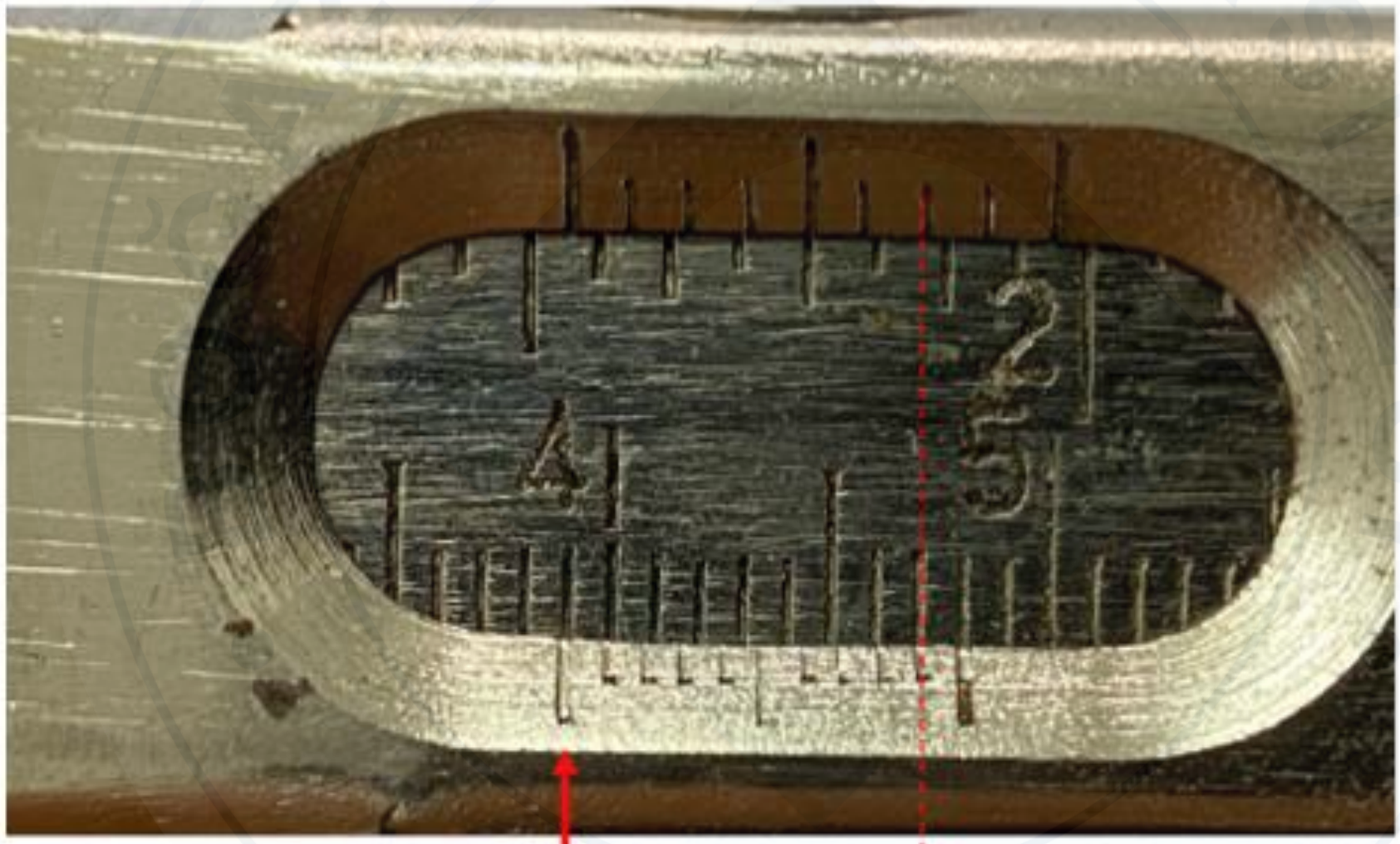
The aligned line corresponds to 5.
0.05

RESULT: 3.75 cm

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Special Case:

Reading of 3.89 cm, 3.90 cm and 3.91cm.



Main number: 3
One decimal: 8
3.8

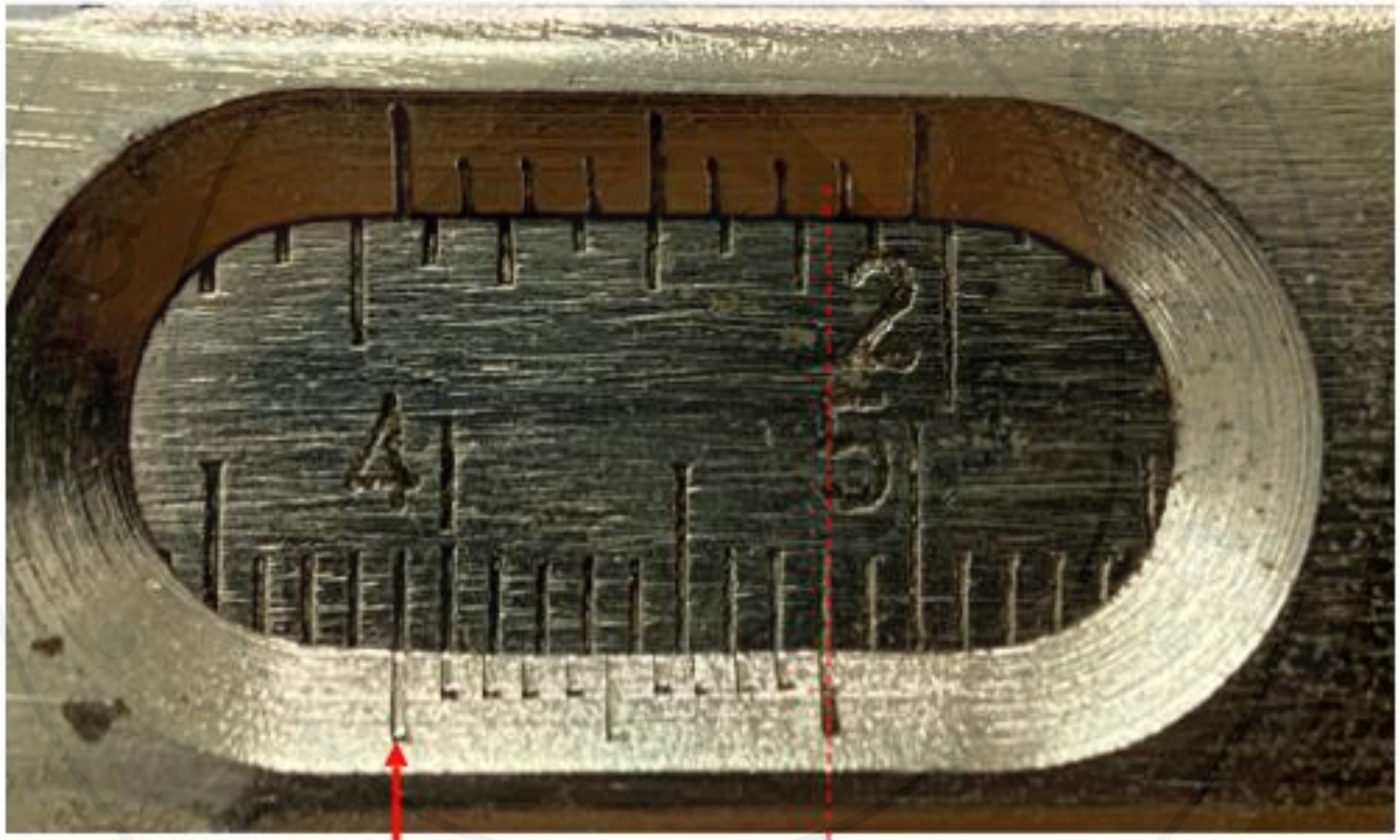
The aligned line corresponds to 9.
0.09

RESULT: 3.89 cm

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Special Case:

Reading of 3.89 cm, 3.90 cm and 3.91cm.



Main number: 3
One decimal: 9
3.9

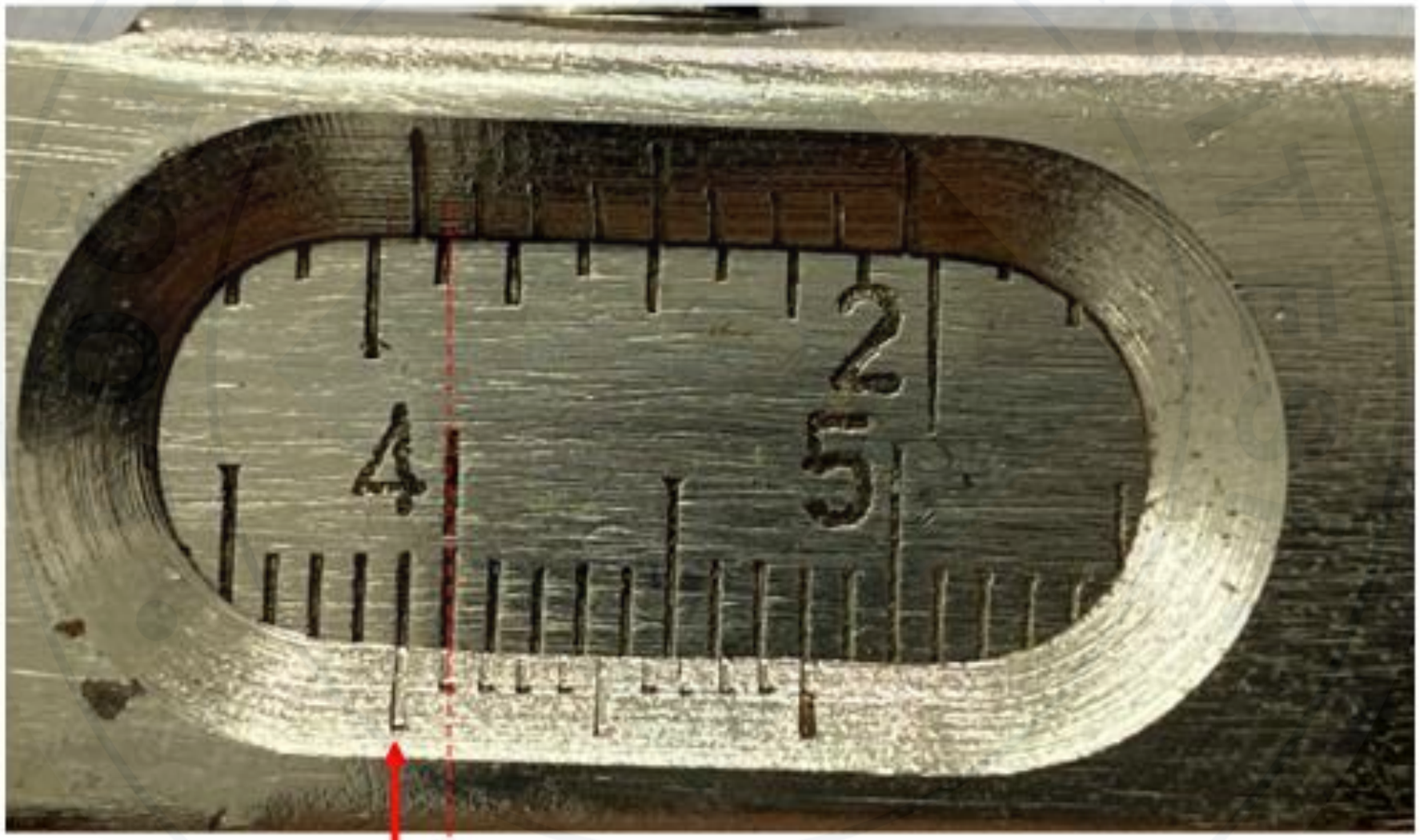
The aligned line corresponds to 10.
0.00

RESULT: 3.90 cm

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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

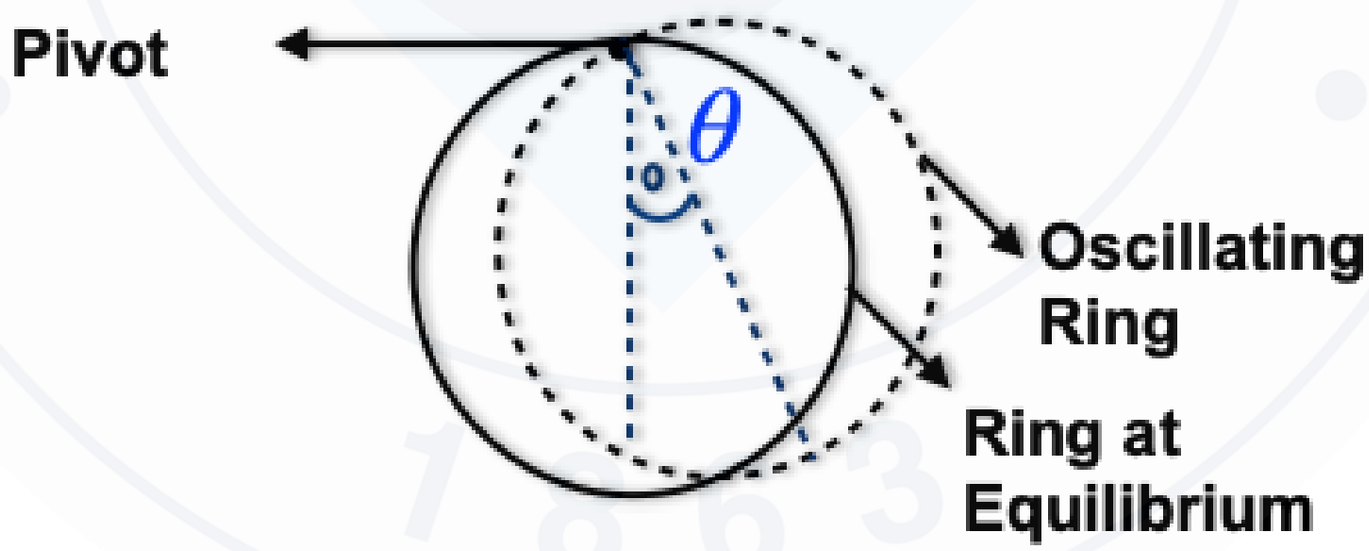
EXPERIMENT

EMPIRICAL EQUATIONS

- 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



Procedure: Data Taking

- You will have 3 rings with different diameters.
- For each of them measure the inner and the outer diameter.
- Use the vernier when needed!
- Then hang them on the wall and let them oscillate.
- Use stopwatch to measure the time for 5 oscillations!
- Record your results in Table 1.
- Be careful about Significant Figures and Units while taking data!
- Try to be precise, accuracy of the result depends on the carefulness when performing experiment.
- Accuracy of the final result will affect your grade!

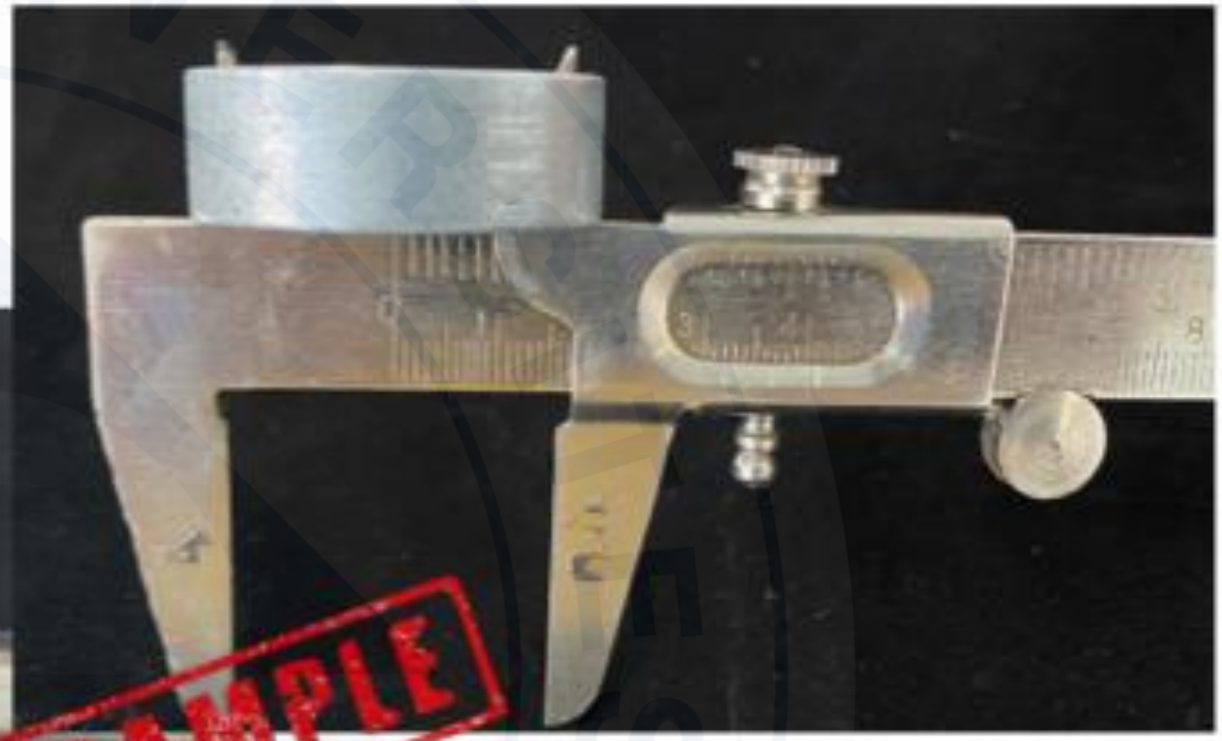
DATA-TAKING

Description	Symbol (unit)	RING NUMBER		
		- 1 -	- 2 -	- 3 -
Inner Diameter	D_i ( )			
Outer Diameter	D_o ( )			
5 Periods	t ( )			

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How to Measure the Inner Diameter of Small Rings





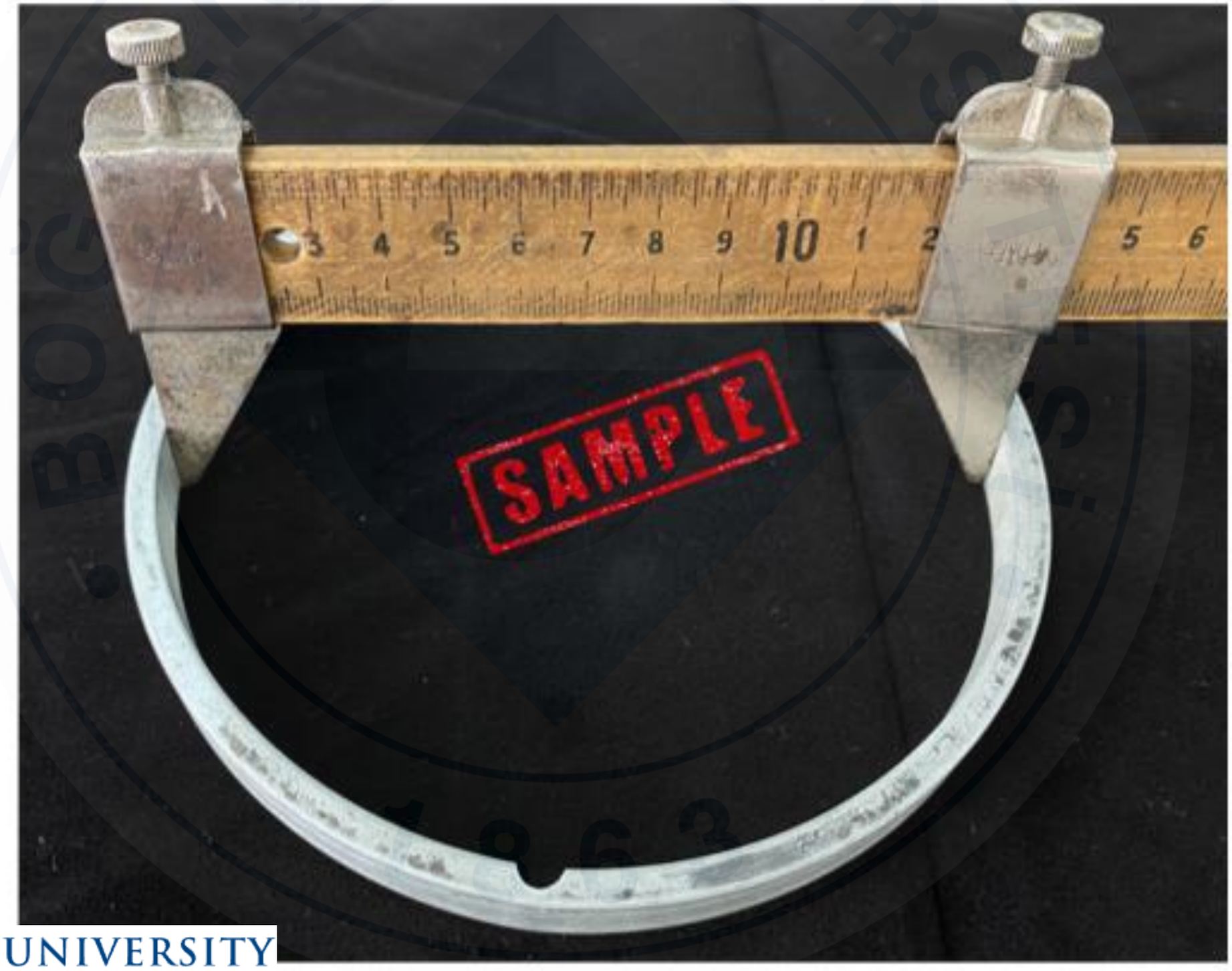
Phys Labs

How to Measure the Outer Diameter of Small Rings

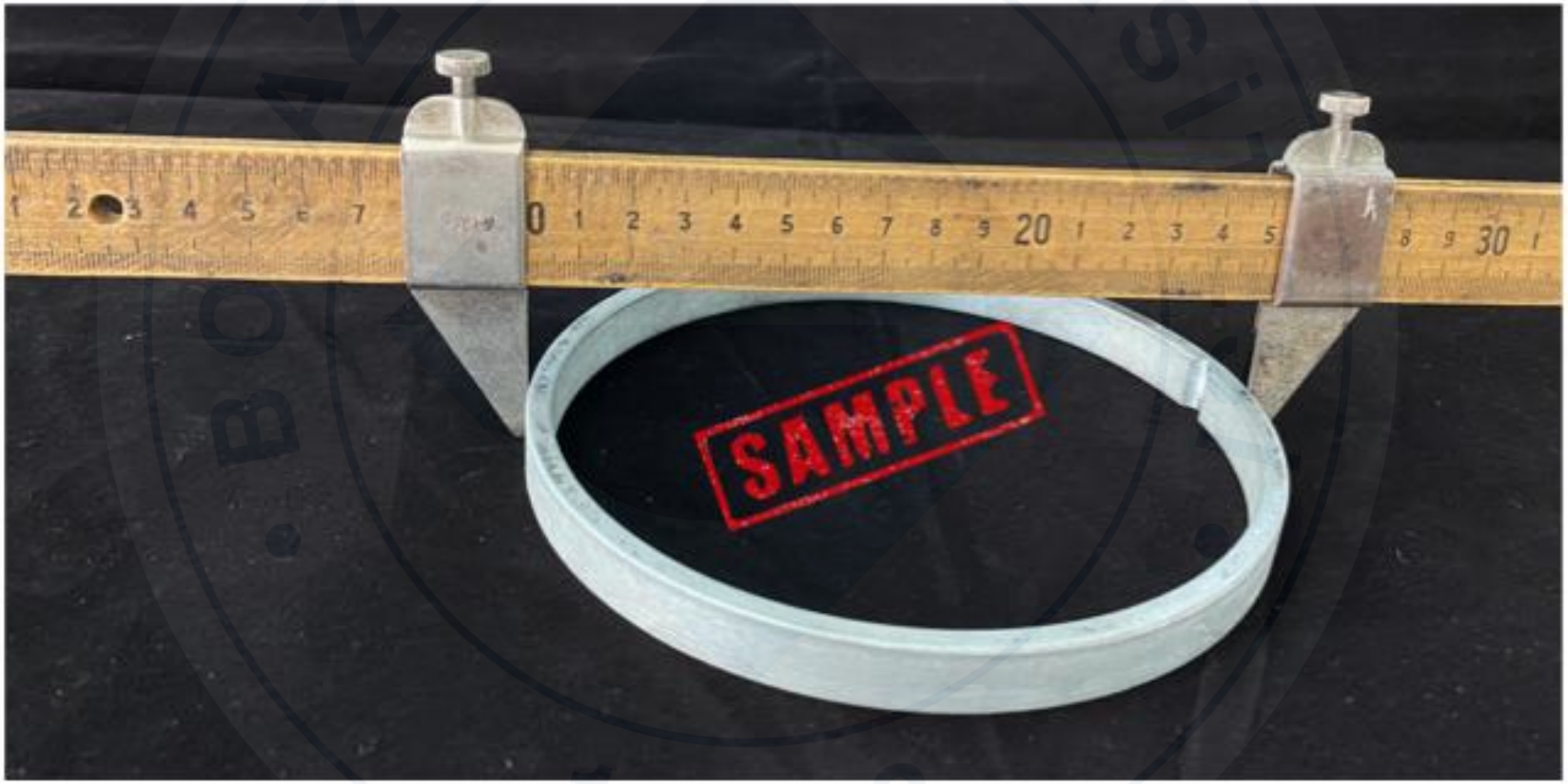




How to Measure the Inner Diameter of Large Rings



How to Measure the Outer Diameter of Large Rings



Procedure - Calculations

- Calculate average diameter (using inner and the outer).
- Calculate one period by dividing t by 5.
- Then take the logarithm of both so as to plot Log T vs Log D on a regular graph paper.
- Record your results in Table 2.
- Be careful about Significant Figures and Units in your calculations. Remember the rule of significant figures for logarithms!

CALCULATIONS

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

Plot on a regular graph paper

Plotting of $logD$ vs $logT$ on a regular graph paper.

***A* and *n* are to be calculated from the graph.**

EMPIRICAL EQUATIONS

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.

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

Place your data points, i.e. Logarithms of T and D, on the regular graph paper.

Calculation of slope

- **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 y-intercept and calculate A

Things to pay attention

- Give coordinates of the two SLOPE POINTS chosen on the graph.
- Read the y-intercept of the line from the graph, where the best line intersects the y-axis.

- Linearize the equation $\boldsymbol{T = AD^n}$ (You shall show your algebra inside the big red box).
- Express the constants “n” and “A” (in terms of slope, i.e. SP1 and SP2 and y-intercept.)
- Calculate n and A by inserting slope points and y-intercept values.
- Give dimensions of n and A! Be careful, dimensions may or may not depend on the value of n and A.
- Accuracy of n is important, you may remember its numerical value from Experiment 2.
- Calculate D for T=1.0 seconds. Use the linearized or nonlinearized form of the original equation.

- Significant figures and units are very important in the applied exam. If you do not pay attention to them, you will loose significant amount of points!

- Learn how to plot a best line. Pay attention to axis, units, scale, linearity and fit of the best line.
- Placing data points precisely and accurately, reading slope points and the intercept precisely are very important.
- One mistake in significant figures or misreading may propagate through the following steps which will cost you many points!

READ LAB WEBSITE FOR THE EXAM RULES!

DO NOT FORGET TO BRING A SCIENTIFIC CALCULATOR AND a printed copy of THE APPLIED EXAM SHEET (as BLANK!)

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Physics Department

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Applied Exam Rules

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6. Applied Exam Rules

6.1 The Applied Exam: