Boğaziçi University

Introductory Phys Labs

CENTRIPETAL FORCE

PHYL 101

THEORY

CENTRIPETAL FORCE

Centripetal force is a net force that acts on an object to keep it moving along a circular path.

Figure 1:Solar System

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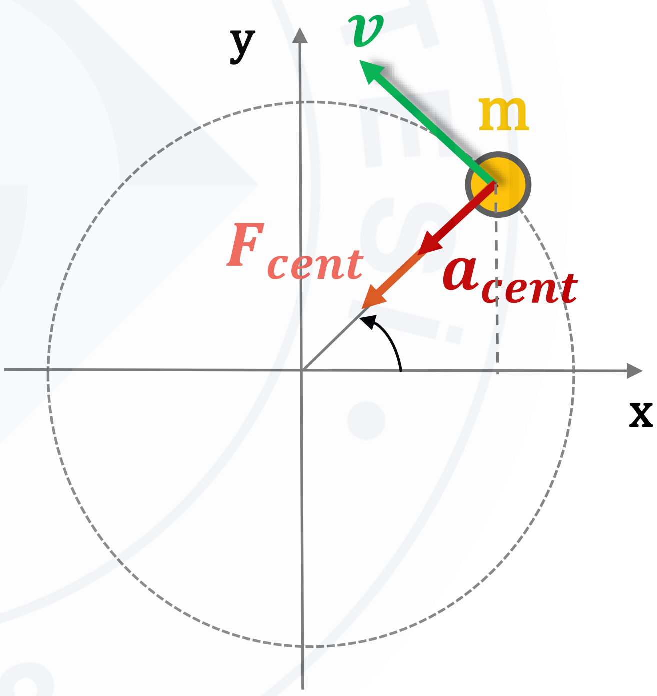
CENTRIPETAL FORCE

Centripetal acceleration and centripetal force

Centripetal acceleration is the acceleration of an object which does a circular motion. It's directed towards the center of rotation at all times.

$$a_{cent} = \frac{v^2}{R}$$



Centripetal force is the net force causing uniform circular motion.

$$F_{cent} = ma_{cent} = \frac{mv^2}{R}$$

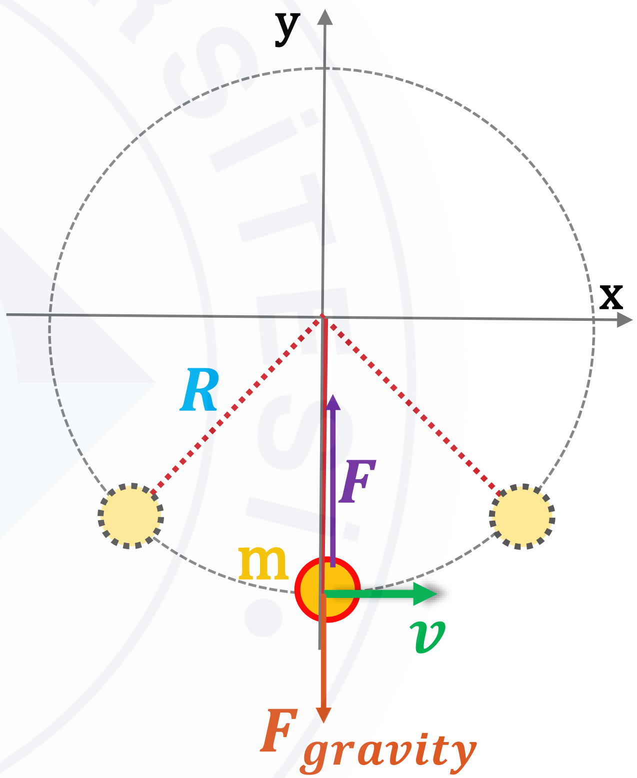
F_{cent}

CENTRIPETAL FORCE

Forces acting on simple pendulum at equilibrium position

$$F - F_{gravity} = ma_{cent}$$

$$\rightarrow F = mg + \frac{mv^2}{R}$$



equilibrium position

v: Speed of the bob at equilibrium position.

F: Pulling force of the pendulum's rope.

R: Length of pendulum.

CENTRIPETAL FORCE

Centripetal force with respect to initial potential energy of pendulum

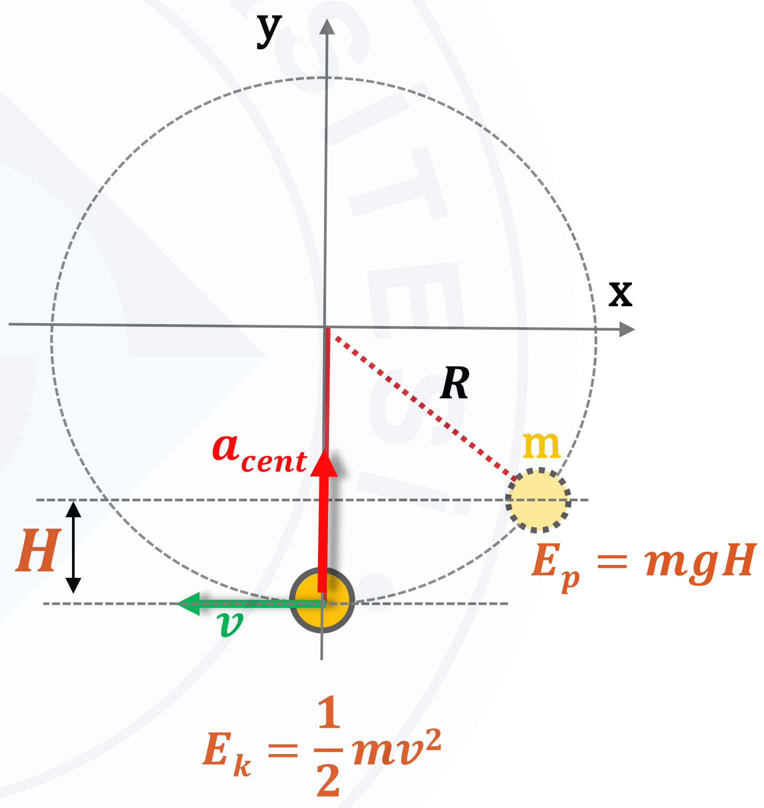
From the conservation of energy, $E_p = E_k$;

$$\frac{1}{2}mv^2 = mgH \quad \rightarrow \quad v^2 = 2gH$$

F_{cent} in terms of initial Potential Energy or H;

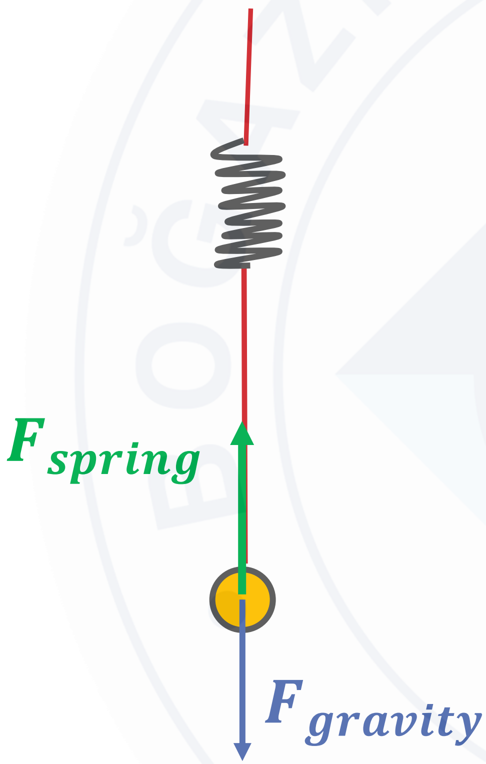
$$F_{cent} = ma_{cent} = \frac{mv^2}{R} = \frac{2mgH}{R}$$

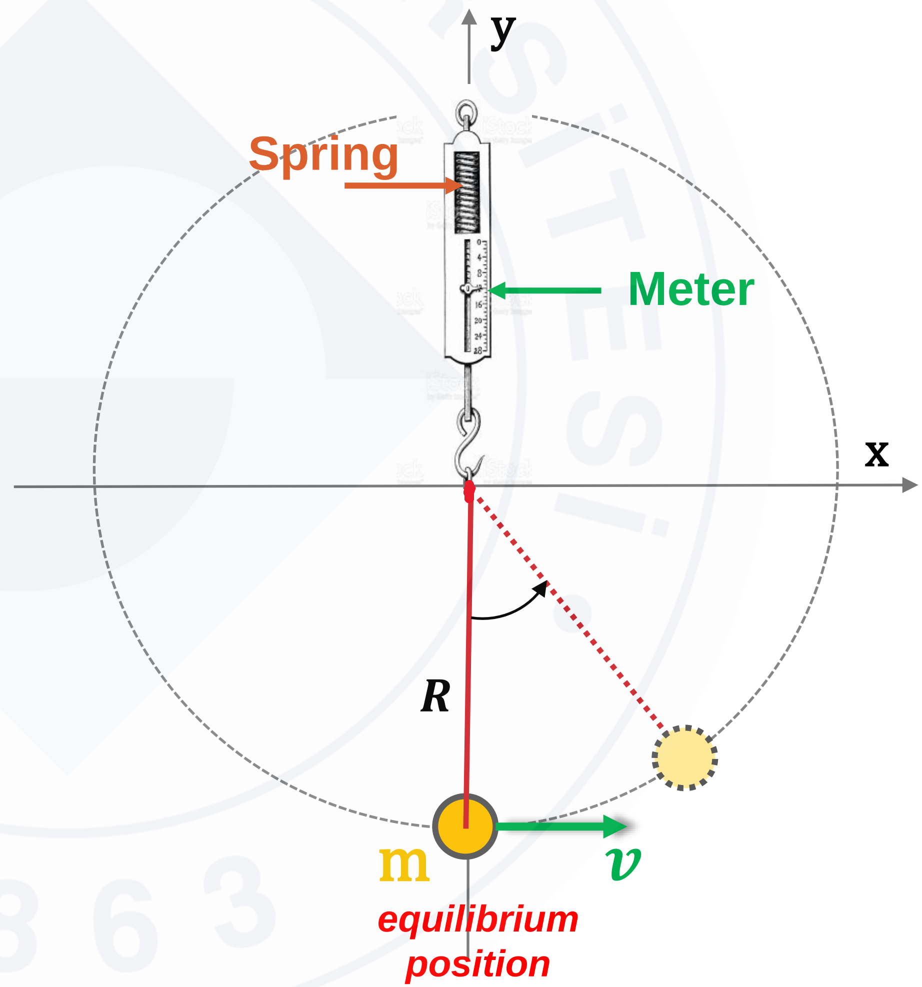
H: height of the bob from the equilibrium position.



CENTRIPETAL FORCE

Net (centripetal) force at the equilibrium position can be measured by using a dynamometer





$$F_{cent} = F_{spring} - F_{gravity}$$

*Changes in dynamometer length is neglected.

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CENTRIPETAL FORCE

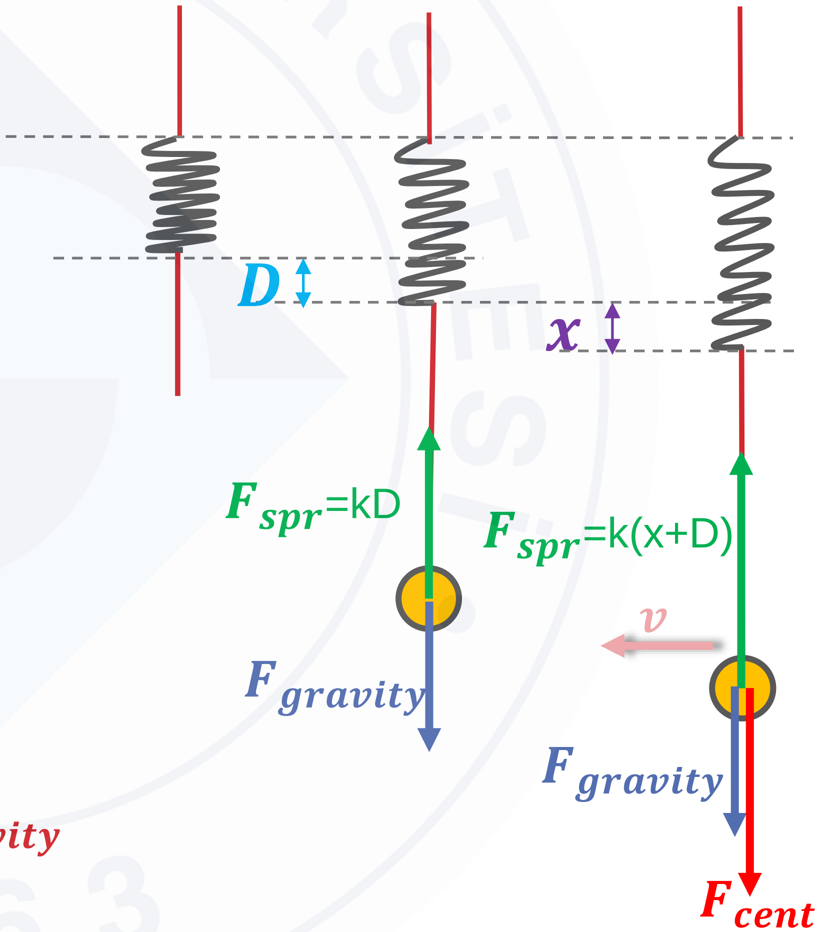
Initial height – spring extension relation

$$kD = mg \quad \rightarrow \quad k = \frac{mg}{D}$$

$$F_{spr} = F_{cent}$$

$$kx = \frac{mv^2}{R} \qquad v^2 = 2gH$$

$$\frac{mg}{D}x = \frac{2mgH}{R} \quad \rightarrow \quad H = \frac{R}{2D}x$$



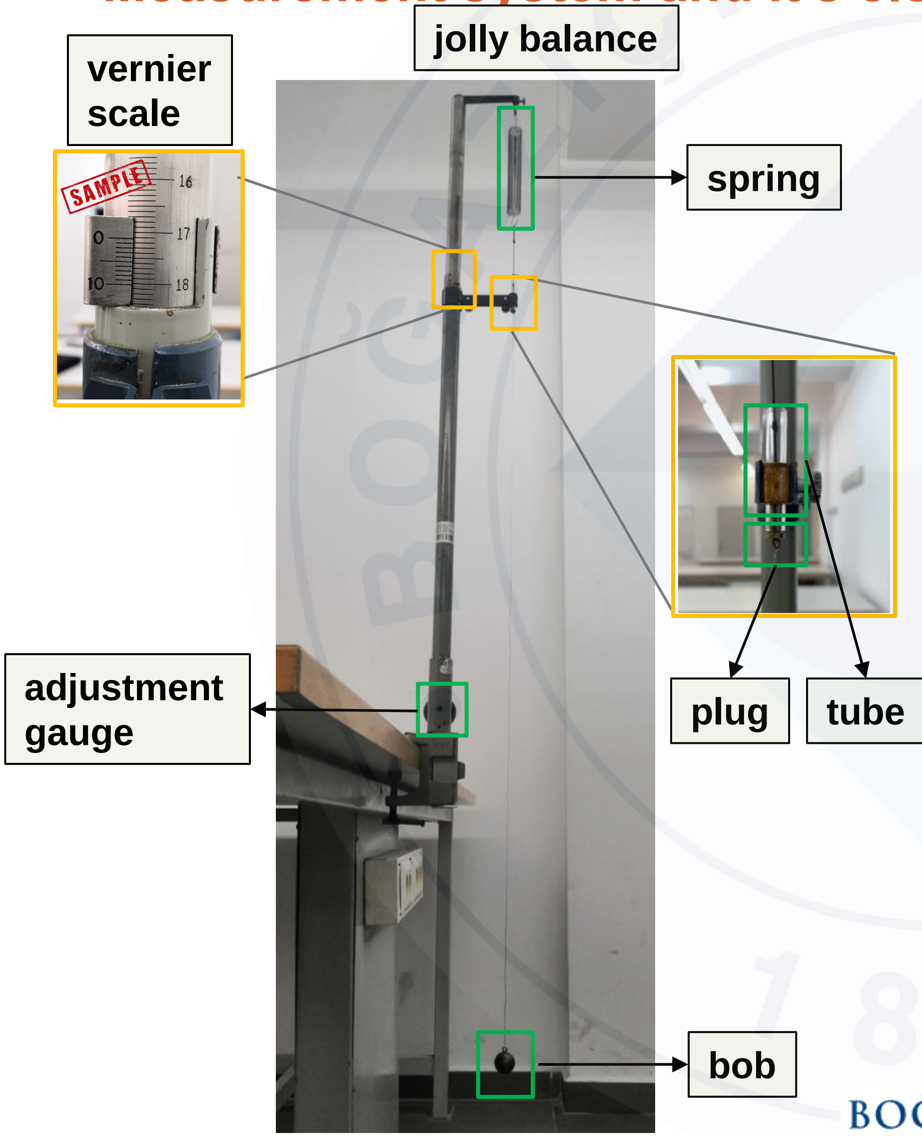
k: Spring constant.
D: Extension of the spring due to $F_{gravity}$
x: Extension of the spring due to F_{cent}.

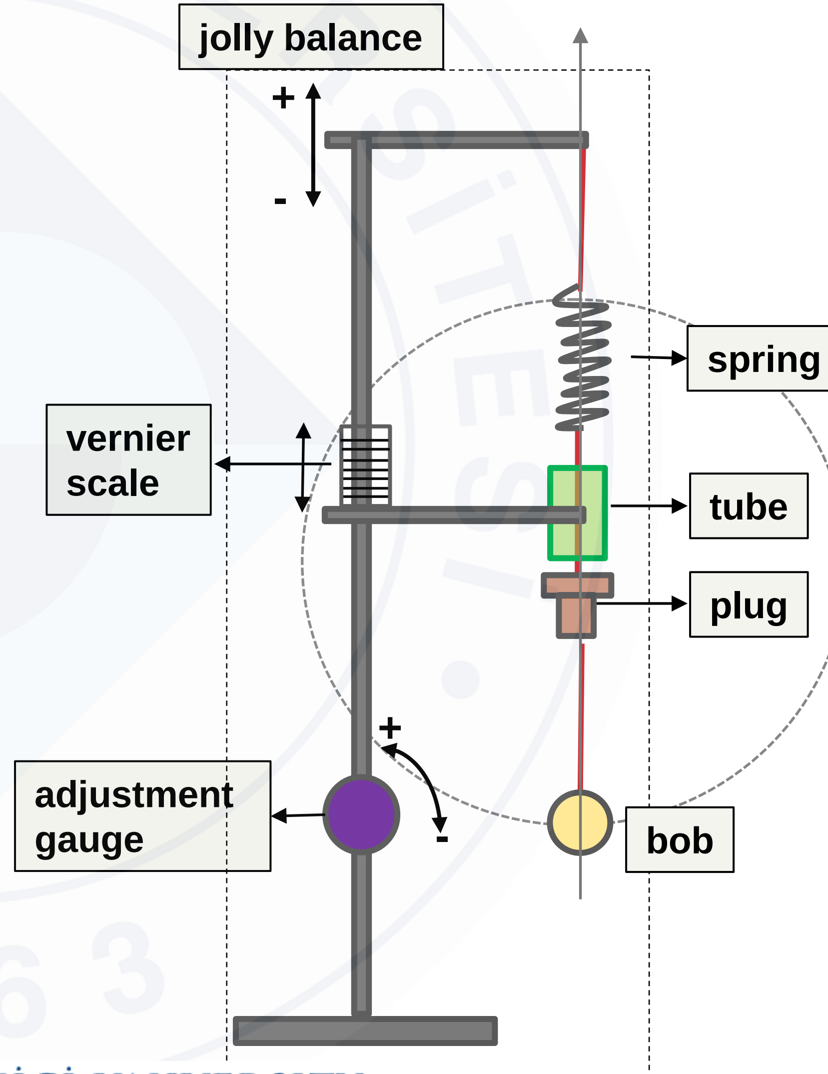
H is proportional to x.

SETUP

CENTRIPETAL FORCE

Measurement system and it’s elements

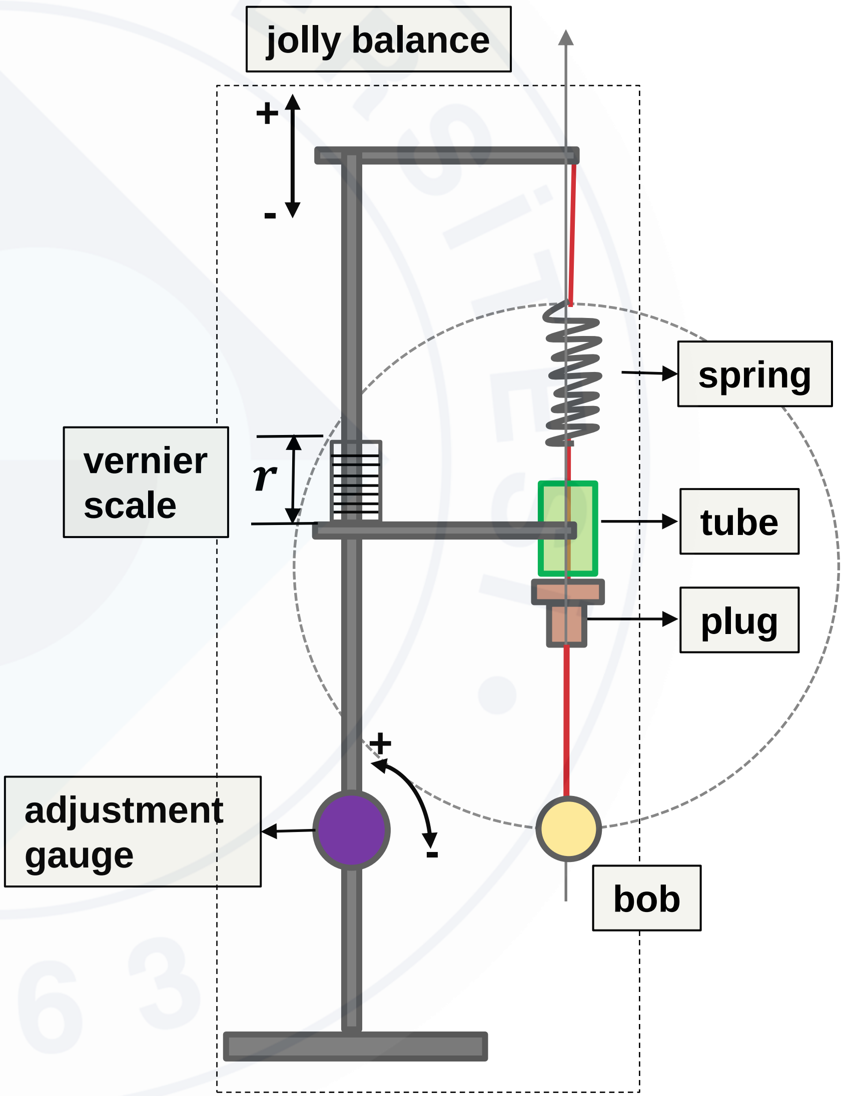




CENTRIPETAL FORCE

Measurement system and it's elements

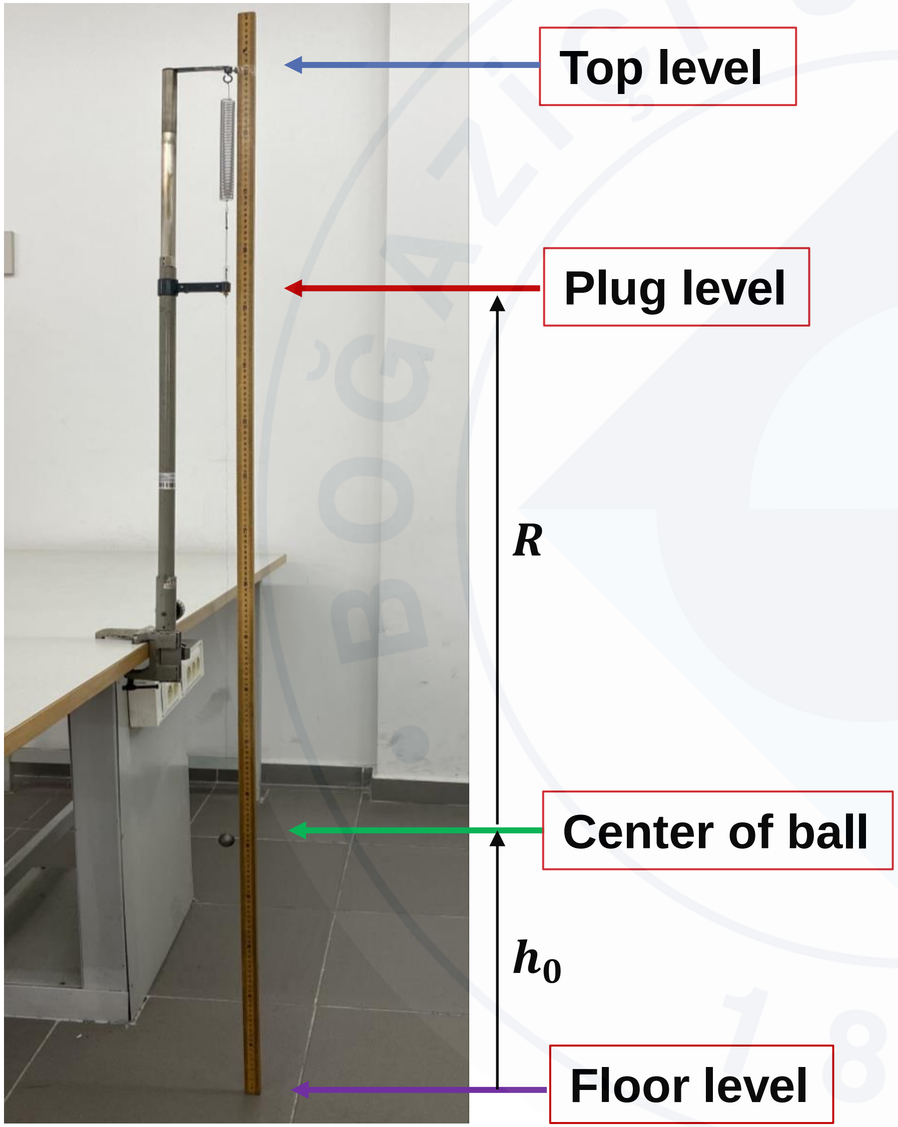
- **Spring** is used to measure force(as a dynamometer).
- **Vernier scale** is used to measure how much jolly balance moved up/down (denoted as r).
- **Adjustment gauge** is used to move jolly balance up/down.
- **Tube and plug** is used to limit spring lower end's upwards and sideway motion.
- **Bob** is the ball off simple pendulum that is doing centripetal motion.

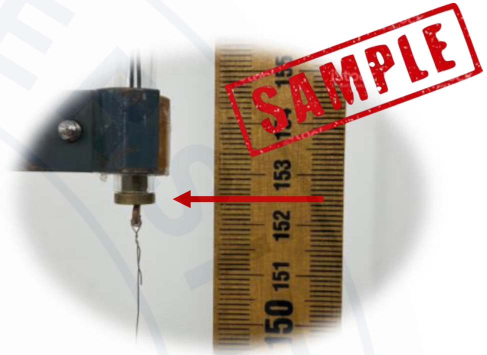


EXPERIMENT

CENTRIPETAL FORCE

Measuring lengths





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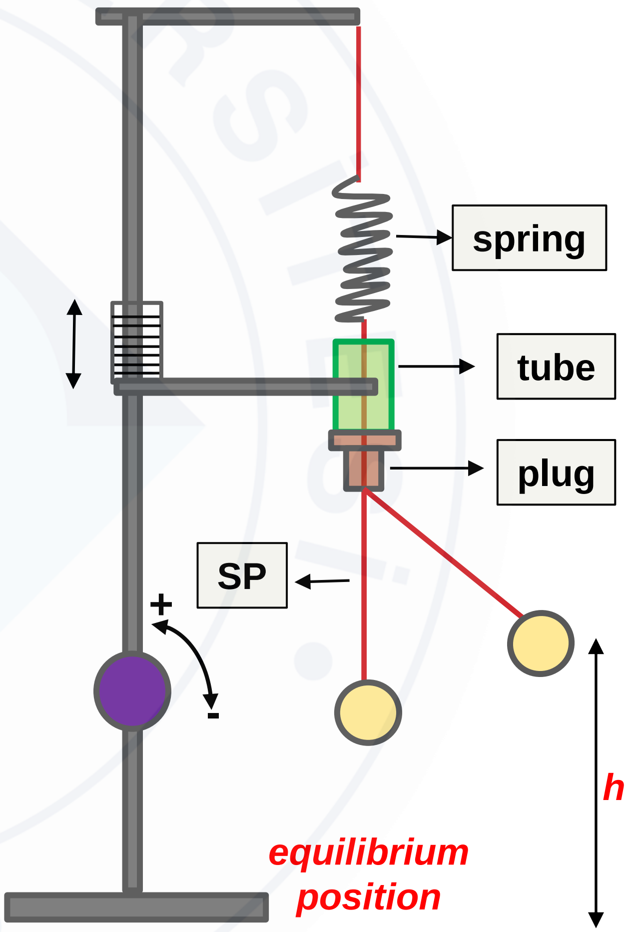
A simple pendulum is attached to the one end of a spring.

The upward and sideway motions of SP- spring connection are limited by a plug and a tube.

First determine how much extension (D) occurs due to the mass of simple pendulum bob.

Then spring force increased to 2k.

In order to generate a force exactly equal to F_{spring}=2k, pendulum is released from a certain height h to create necessary acceleration at equilibrium position.



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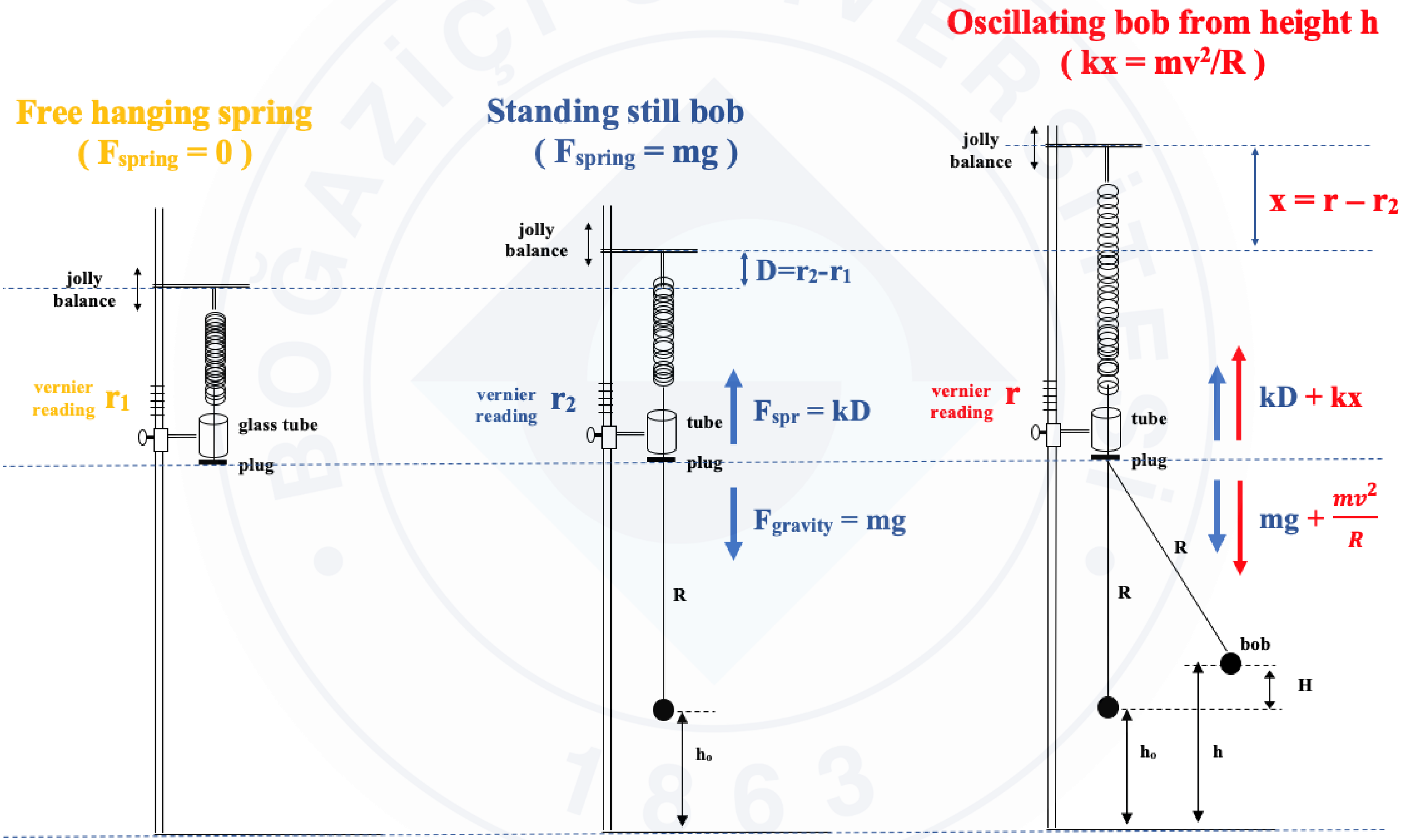

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CENTRIPETAL FORCE

- **What to measure :** Heights of the ball, h_0, h, r_1, r_2

  Length of the pendulum, R_{TV}

- **What to calculate:** Total extension of the spring, x

  $D = r_2 - r_1$

  Slope of $\frac{H}{x}$

- **Experimental findings:** Length of the pendulum, R_{EV}

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Measurement for the free spring case ($F_{spring} = 0$)

I. Put the bob above the table.

II. Adjust the jolly balance such that the plug barely touches to the tube.

III. Read the vernier of the jolly balance, note the value as r_1.

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Read r_1

In this example it's 12.40 cm.

CENTRIPETAL FORCE

For the loaded spring, bob is standing still ($F_{spring} = \mathrm{mg}$).

I. Load the spring with the bob by putting it off the table.

II. Adjust the jolly balance such that the plug barely touches to the tube.

III. Read the vernier of the jolly balance, note the value as r_2.

Read r_2

In this example it's 17.13 cm.

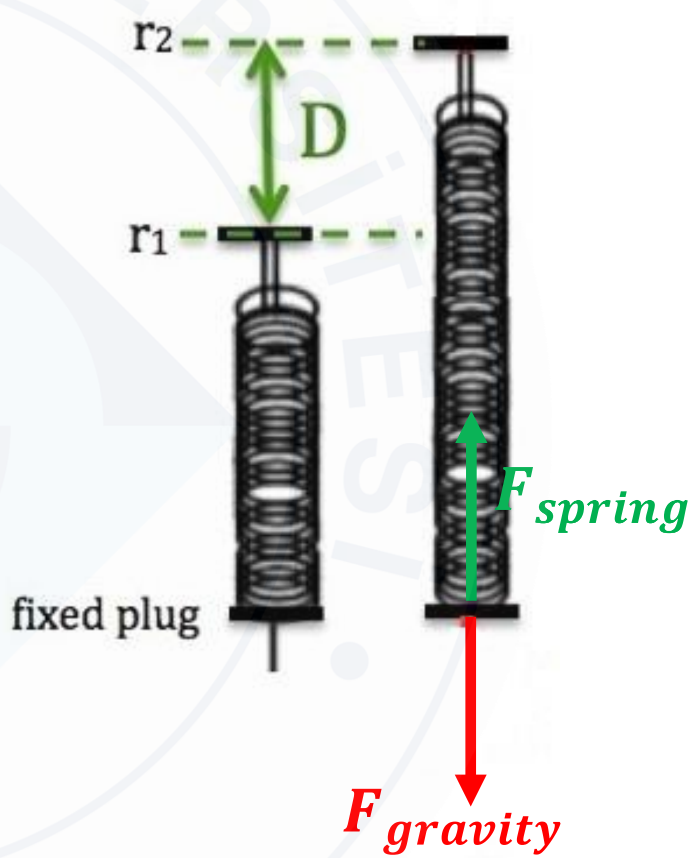
- Difference between r_1 and r_2 gives the extension of the spring, D, due to mass of the bob.

$$D = r_2 - r_1$$

- Now, the tension of the spring balances the mass of the bob.

$$F_{spring} = F_{gravity}$$

$$\rightarrow kD = mg \rightarrow k = \frac{mg}{D}$$



CENTRIPETAL FORCE

Measurements for the oscillating bob

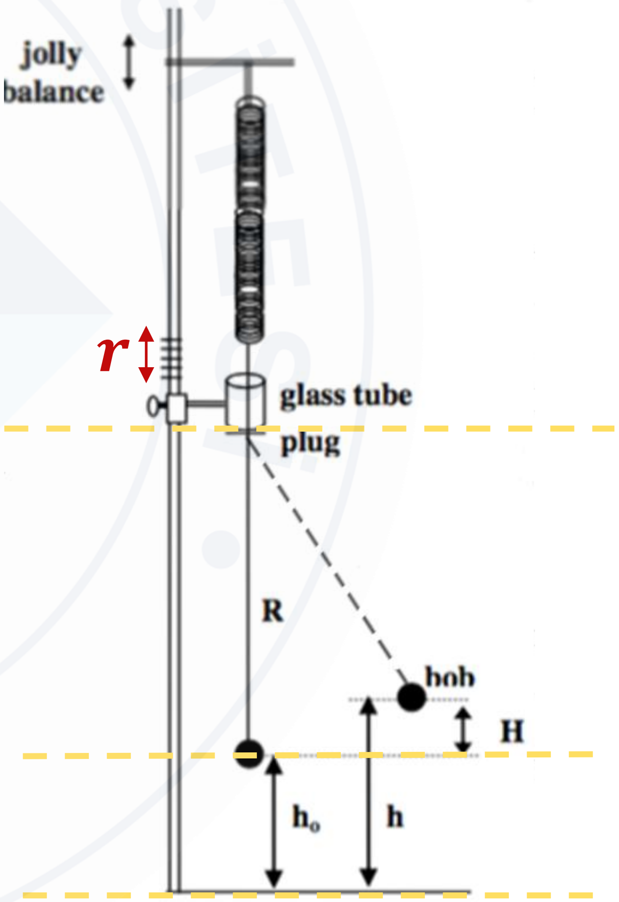
We will give different extensions to the spring by moving jolly balance up.

(That means the spring is fixed from lower end and the position of plug and glass tube is unchanged.)

Then we will try to find the heights (h) to release the bob to make the centripetal force close to the restoring force (F_{cent}~F_{rest}).

(When $F_{cent}=F_{rest}$ we cannot observe anything. Try to observe when F_{cent} is slightly bigger than F_{spring})

The relationship between H and x (spring extension) is observed.



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CENTRIPETAL FORCE

For the loaded spring, bob is oscillating

I. For the first measurement, extend the spring by 1.90cm which is shown in your data video.

II. Find the height h, so that the plug will be separated from the tube by approximately 0.10cm while the bob is passing through equilibrium position. This corresponds the point where $F_{cent} > F_{rest}$ (spring force)

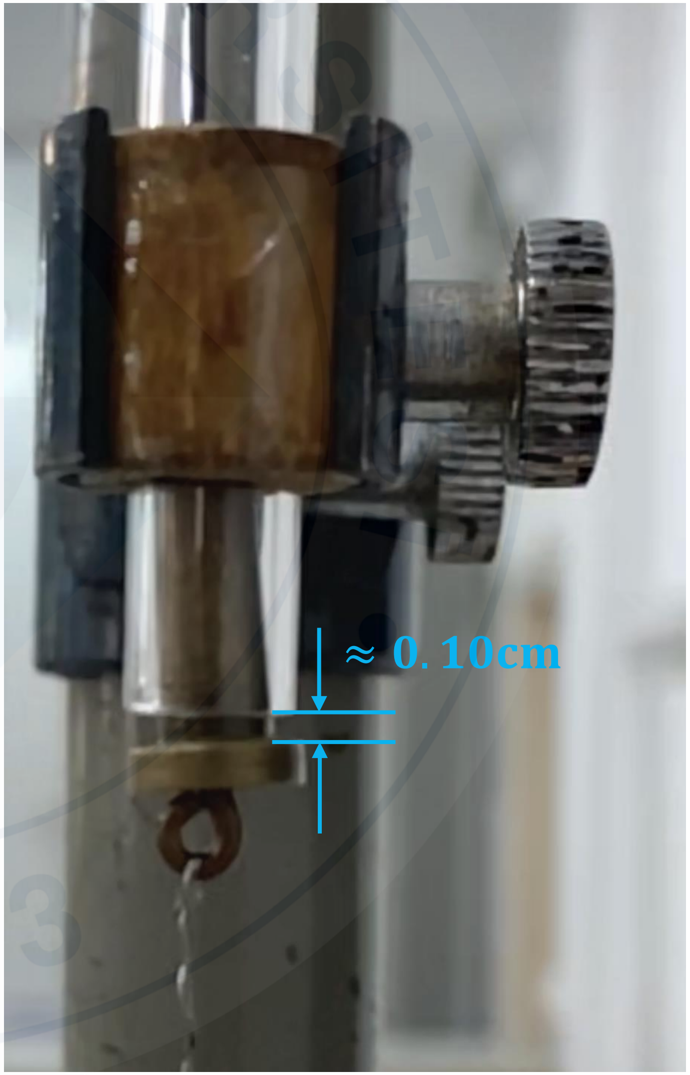
III. Since the elongation due to the centripetal force is ≈ 0.10cm, total spring extension,

$$x = 1.90 \text{ cm} + 0.10 \text{ cm} = 2.00 \text{ cm}$$

$$F_{spring} = 2.00 \times k$$

III. Read the vernier of the jolly balance, note the value as r.

IV. If you need to take more datapoints, extend the spring by a distance which is shown in your data video. And go to step II. If you have taken all datapoints, measurements are completed!



CENTRIPETAL FORCE

Maximum seperation is too much (>> 0.10cm)

$$F_{cent} = \frac{mv^2}{R} = \frac{2mgH}{R} > \mathrm{kx}$$

- Release the mass from lower height in order to <u>decrease</u> centripetal force F_{cent}.

CENTRIPETAL FORCE

Maximum seperation is too low (<< 0.10cm)

$$F_{cent} = \frac{mv^2}{R} = \frac{2mgH}{R} < kx$$

- Release the mass from lower height in order to <u>increase</u> centripetal force F_{cent}.

CENTRIPETAL FORCE

Maximum seperation is too low (~0.10cm)

$$F_{cent} = \frac{mv^2}{R} = \frac{2mgH}{R} \sim \mathrm{kx}$$

- Forces are balanced. Now you can enter the measured bob height h into your report.

Change total extension in the spring with the increments given in the DataVideo.

Measure h, height of the bob from the floor for each extension given to the spring.

Data should be written with the correct number of significant figures.

Spring extension is $x = r - r_2 + 0.10$ cm.
r_2 reading was 17.13 cm

Note: Elongation 0.10 is only added at first step.

SAMPLE

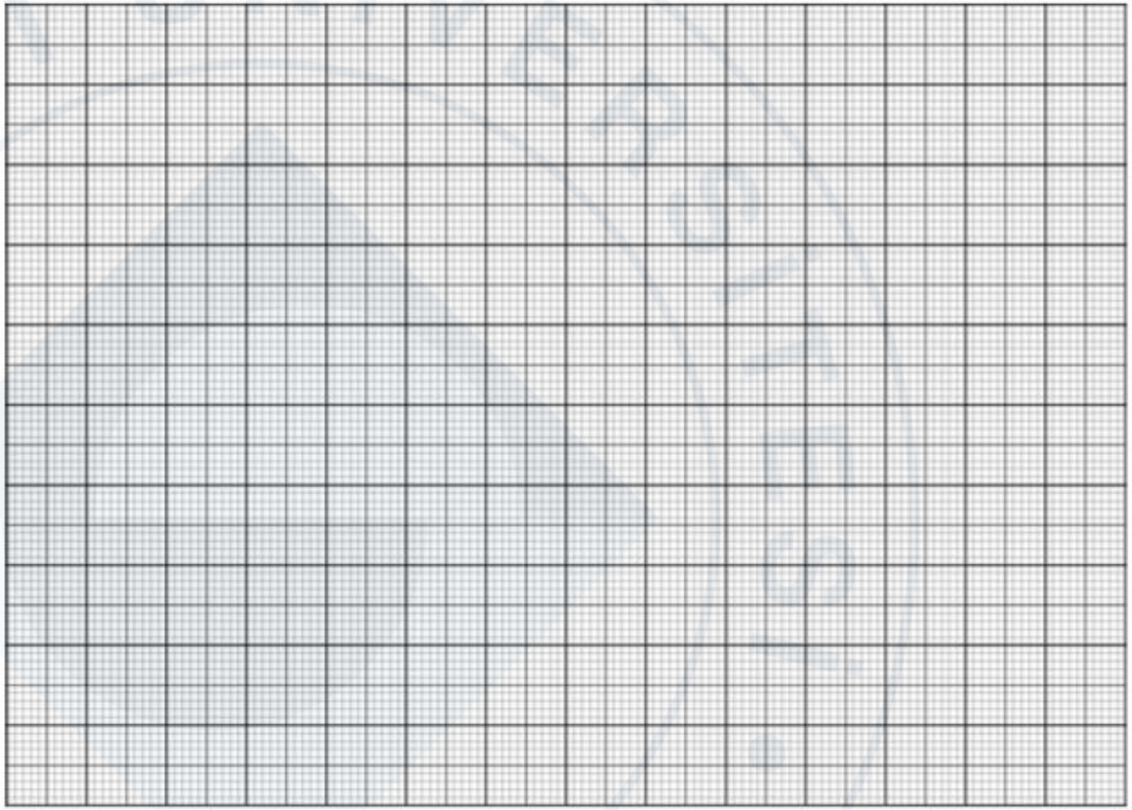
increment in vernier	Reading in vernier r (unit)	Total Extension in the spring x (unit)	Height of the bob from floor h (unit)	$H = h - h_o$ (unit)
1.90	19.03	2.00 (1.90 + 0.10)	68.2	17.2 (68.2-50.9)

From DataVideo, you will read 2nd and 3rd column of the table. Rest will be filled accordingly.

CENTRIPETAL FORCE

Hence, recording the height from which we release the bob and the corresponding extension of the spring, we can determine the slope by plotting the data.

Then, we can calculate the length of the pendulum R and compare it with the measured value.



From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

Fill in the empty spaces accordingly!

$H = (R/2D)\ x$

What is the physical correspondence of the slope of H vs. x graph?

$R = R_{EV}$

Here EV means Experimental Value.

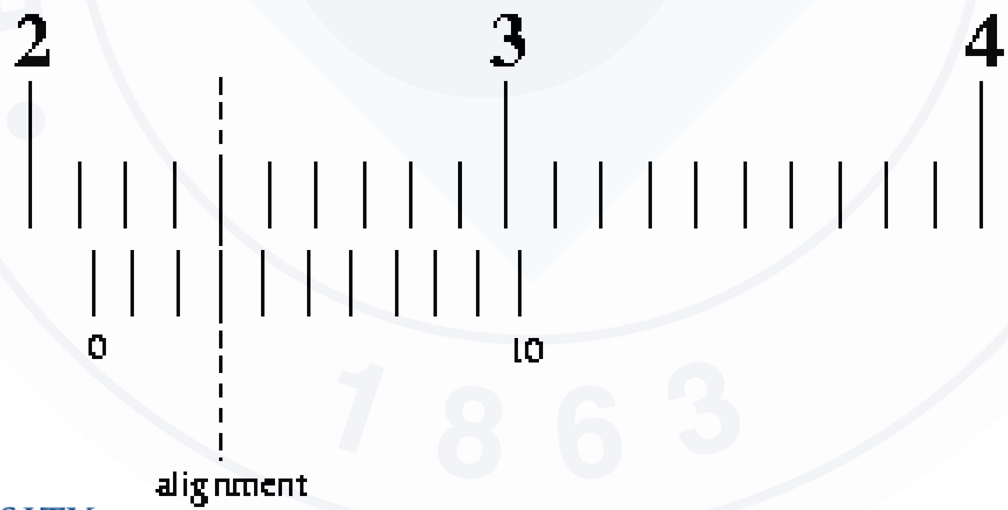
Symbol		Calculation (show each step)	Result	Dimension
Slope	=	....	....	....
		....		
$R/2D$	=	....	....	....
		....		
R_{EV}	=	....	....	....
		....		

% Error for the Length of the Pendulum, R: ....

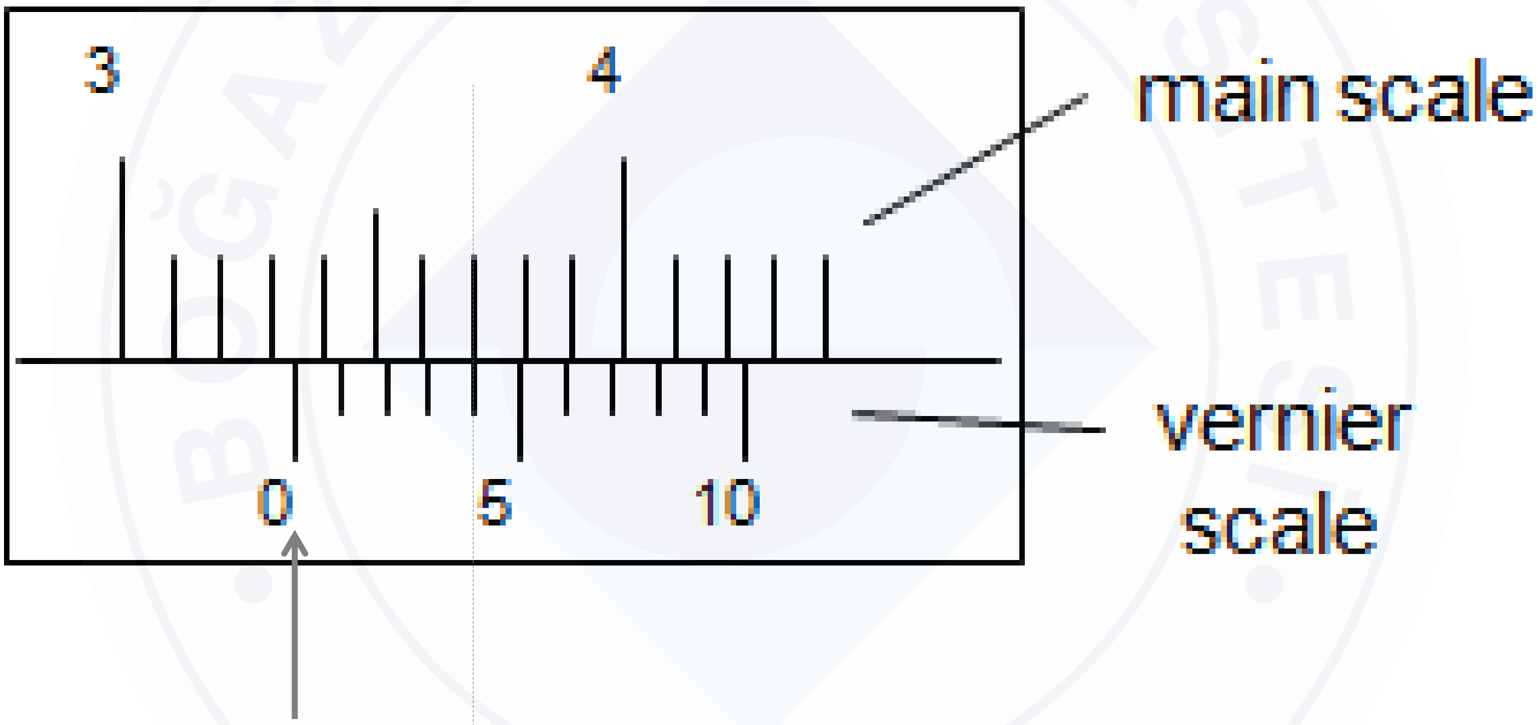
How to measure with vernier calipers:

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:

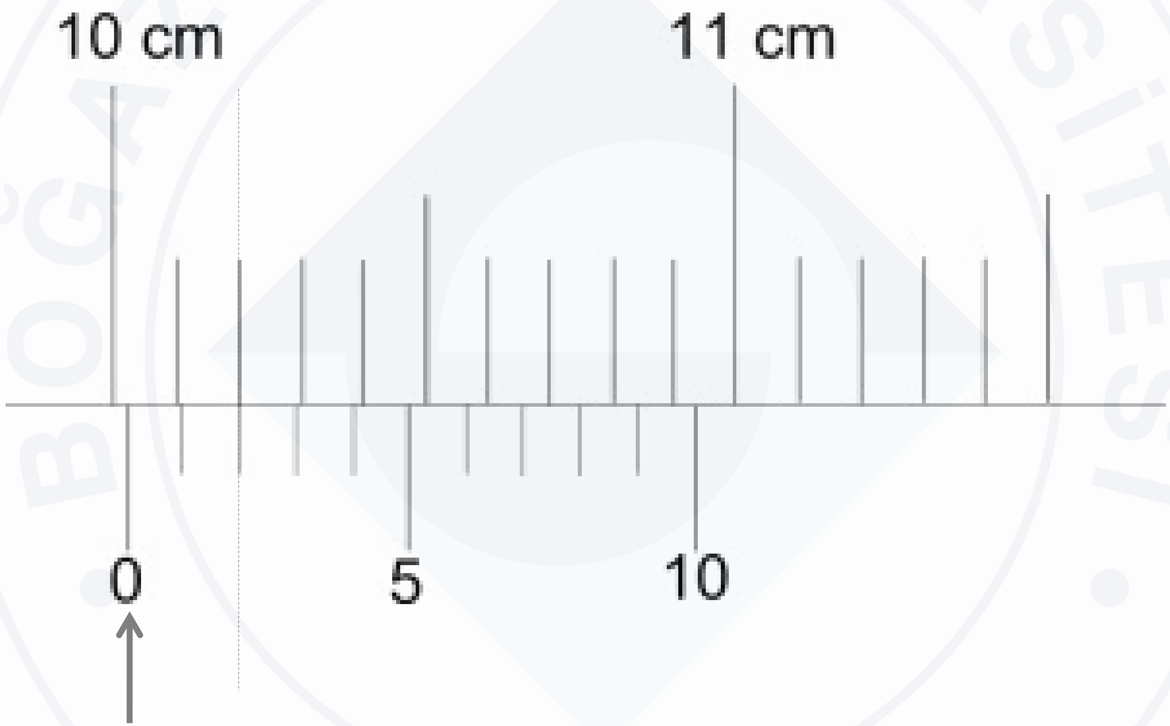


Main number: 3
One decimal: 3
3.3

The aligned line corresponds to 4.
0.04

RESULT: 3.34 cm

Example:

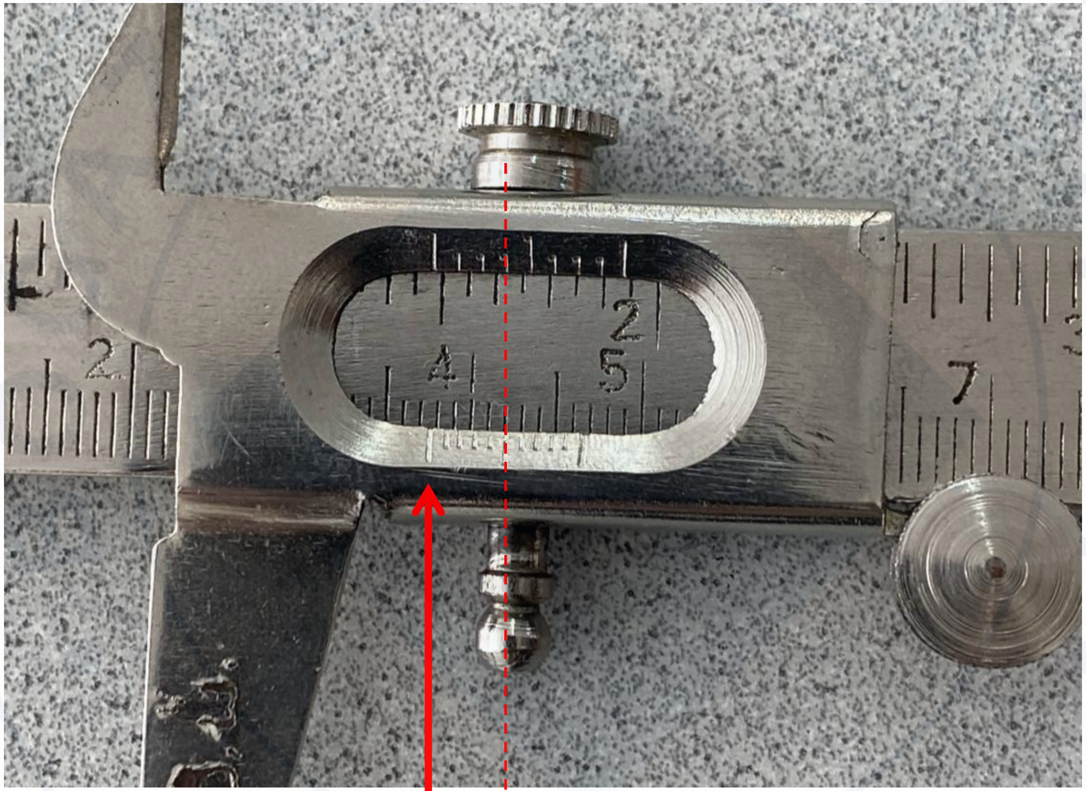


Main number: 10
One decimal: 0
10.0

The aligned line corresponds to 2.
0.02

RESULT: 10.02 cm

Example: by using a real vernier calipers

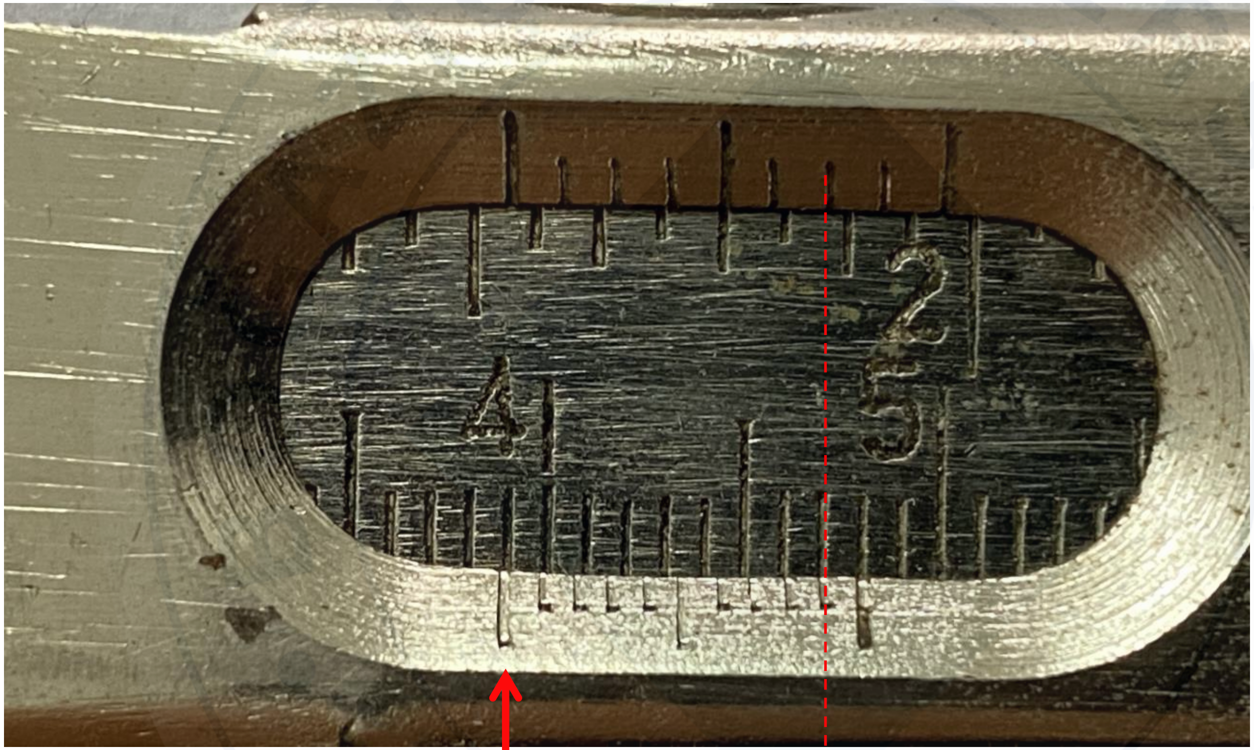


Main number: 3
One decimal: 7
3.7

The aligned line corresponds to 5.
0.05

RESULT: 3.75 cm

Special Case: Reading of 3.89 cm, 3.90 cm and 3.91cm.

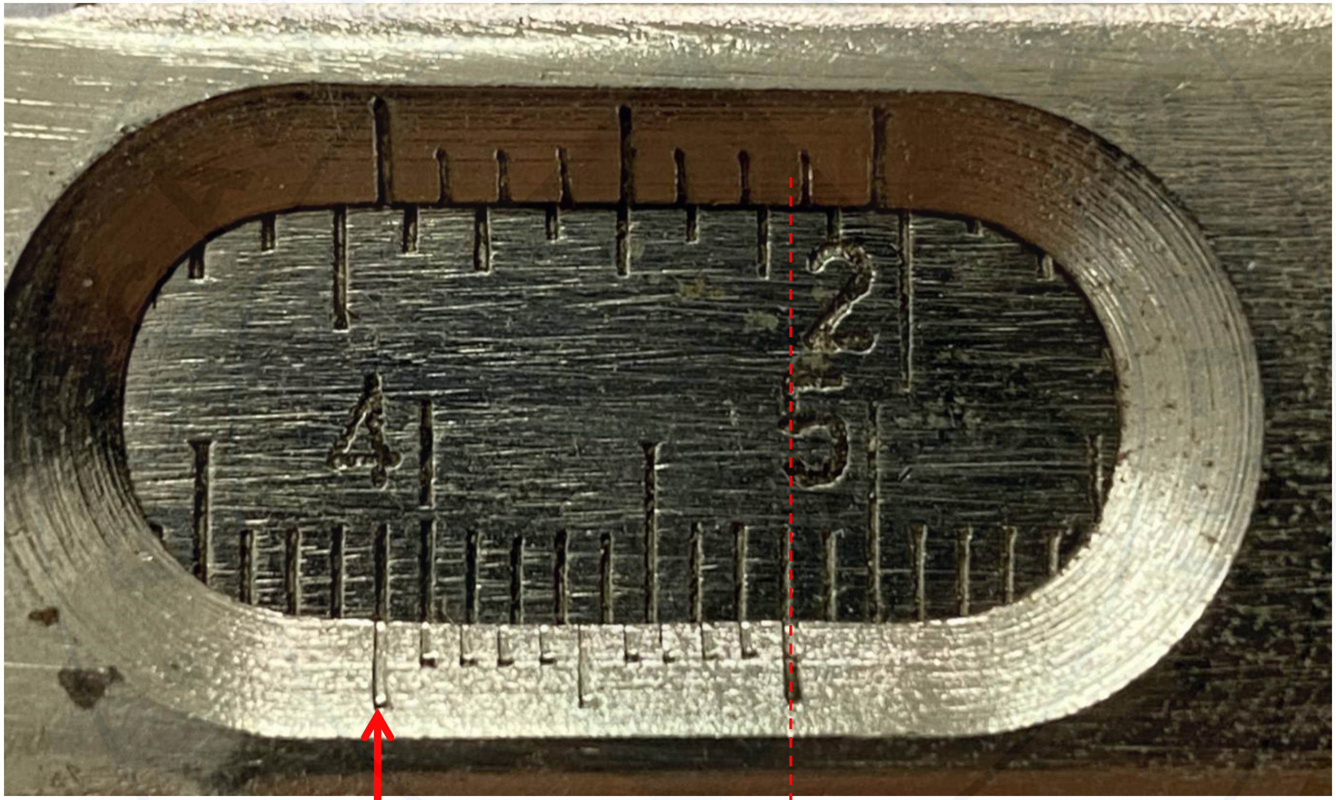


Main number: 3
One decimal: 8
3.8

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.**

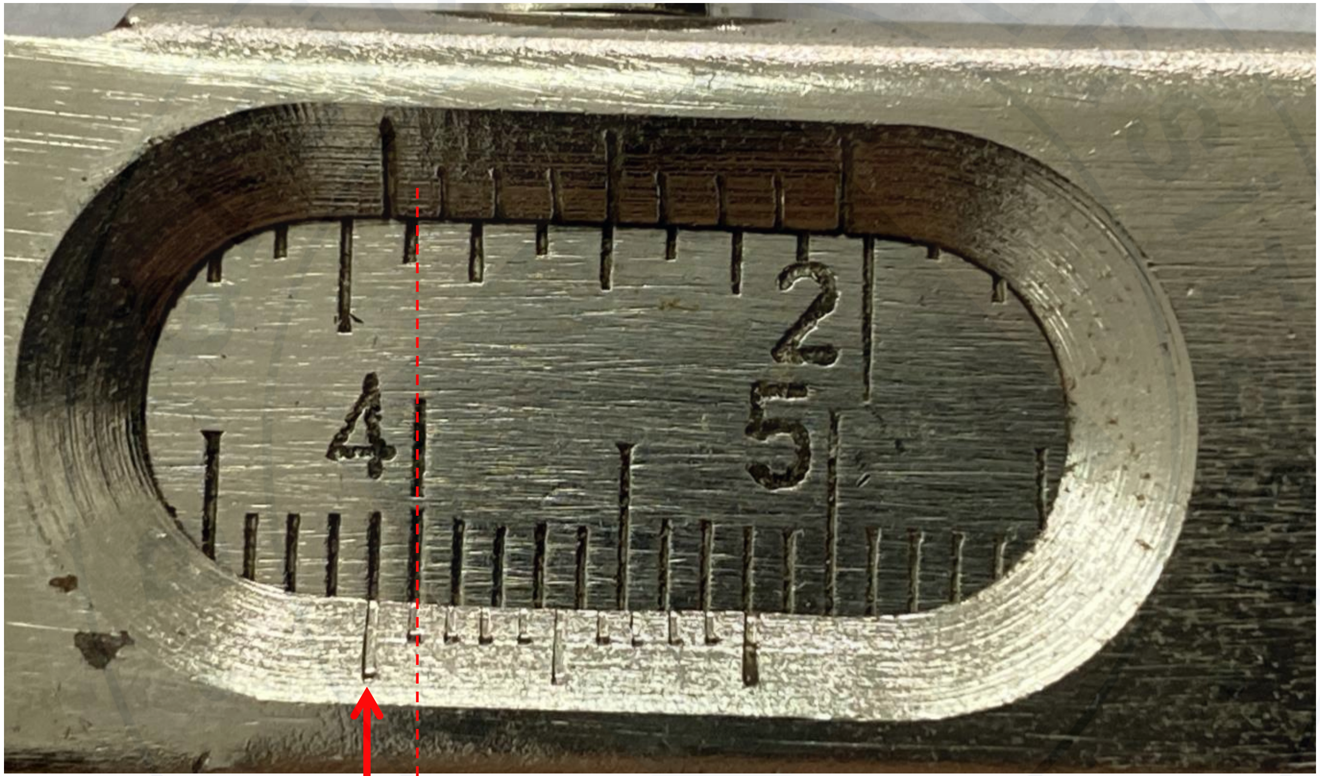


Main number: 3
One decimal: 9
3.9

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