Unit 2
Physical Quantities
&
Measuring Length

Lesson Objectives

- Show understanding that all physical quantities consist of a numerical magnitude and a unit
- Recall the following base quantities and their units: mass (kg), length (m), time (s), current (A) and temperature (K)
- use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M)
- show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth
- describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary

1.1 Physical Quantities

- A physical quantity is a quantity which can be measured. It is a number with a unit.

- **Examples of physical quantities are:**
- **Length**
- **Volume**
- **Time**
- **Temperature**
- **Mass**

Physical Quantities

Accurate measurement of physical quantities can be done by accurate and universal instruments.

- Length-metre rule
- Volume-measuring cylinder
- Time-electronic stopwatch
- Temperature-thermometer
- Mass-electronic balance

1.2 S.I. Units

- Since 1960, scientists all over the world have agreed to adopt a single system of units
    - SI Units (Système International d'Unités)

- An adaptation of the metric system

S.I. Units

Physical quantity	SI unit	Symbol for unit
Length, l	metre	m
Mass, m	kilogram	kg
Time, t	second	s
Temperature, T	kelvin	K
Electric current, I	ampere	A

1.3 Prefixes

- There is a need to use a prefix when the numbers get unusually large or small.
  E.g. 1 000 000 m

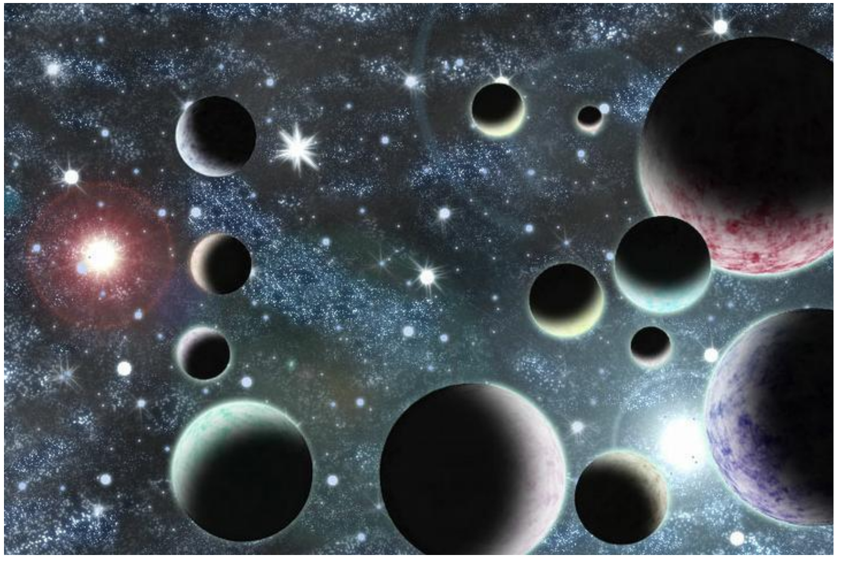
- So we can convert this value to 1000km, which is shorter to write.

- This will make things more meaningful.

Prefixes

The Use of Prefixes in Our Daily Lives

- Nanotechnology equipments:
  - ✓ Computer circuit boards
  - ✓ Mobile phones
  - ✓ Enhancing car car bumpers.
- Astrology
  - ✓ Travelling in light years



1.3 Prefixes

Prefix	Symbol	Meaning
tera	T	trillion
giga	G	billion
mega	M	million
kilo	k	thousand
hecto	h	hundred
deca	da	ten
deci	d	tenth
centi	c	hundredth
milli	m	thousandth
micro	μ	millionth
nano	n	billionth
pico	p	trillionth

Prefixes

Prefix	Symbol	Value
tera	**T**	10^{12}
giga	**G**	10^{9}
mega	**M**	10^{6}
kilo	**k**	10^{3}
hecto	**h**	10^{2}
deca	**da**	10
deci	**d**	10^{-1}
centi	**c**	10^{-2}
milli	**m**	10^{-3}
micro	μ	10^{-6}
nano	**n**	10^{-9}
pico	**p**	10^{-12}

135 nm = 135×10^{-9} m

350 mg = 350×10^{-3} g

92 km = 92×10^{3} m

68 MW = 68×10^{6} W

Complete the table below with the correct symbol/ prefix /factor.

Symbol	**prefix**	**Factor**
M		**10^6**
	kilo	
c		
	milli	
μ		**10^{-6}**
	nano	

1.5 Standard form

- Standard form is a way of writing down very large or very small numbers easily.

For example:

i. **1**.23 x 10^6 s

ii. **6**.1 x 10 kg

iii. **5**.55 x 10^{-9} m

What do you observe?

A number in standard form is of the form A x $10^{\mathbf{n}}$, where $1 \leq A < 10$ and n is an integer.

How do you perform standard form tricks:

e.g. 1 x 10 = 10

1.1 x 10 = 11

1.1 x 100 = 110

1.1 x 1000 = 1100

What trend do you see? (Hint: look at the decimal point)

How do you perform standard form tricks:

e.g. $10 \div 10 = 1$

$1.1 \div 10 = 0.11$

$1.1 \div 100 = 0.011$

$1.1 \div 1000 = 0.0011$

So what is your conclusion?

Try it yourself!

Convert the following into standard form in S.I. units:

10^{-9}

135 nm = **1.35×10^2** nm = **1.35×10^{-7}** m

350 mg = ____________ mg = ____________ g

92 km = ____________ km = ____________ m

68 MW = ____________ MW = ____________ W

1.6 Measuring length

The accuracy of an instrument is the degree to which the results of readings of an instrument approach the true value of the calculated or measured quantities.

Usually, we take the accuracy of an instrument as the smallest division on the scale of the instrument.

Instruments for measuring length:

- Measuring tape
- Metre rule
- Vernier calipers
- Micrometer screw gauge

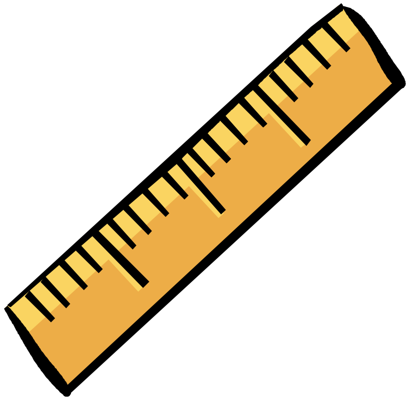
Measuring length

Accuracy of a measuring tape

→0.1cm or 1mm

Accuracy of a ruler

→0.1cm or 1mm



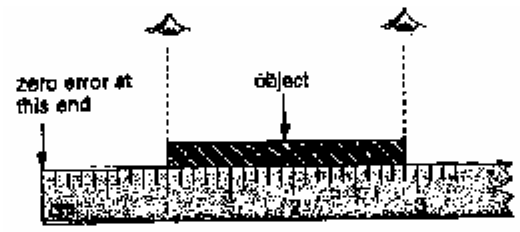
Measurement of length

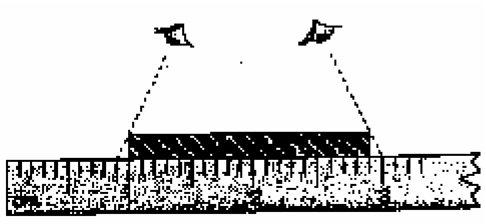
Metre rule:

- For length from several cm to 1 m.
- Accuracy to 0.1 cm or 1 mm
- Precaution: Avoid parallax error

Parallax error:

Error arises due to a relative movement between the scale when an observer's eye is moved from side to side.





Test yourself

Complete the following conversion

1 km = ______m = _______cm = ______mm

______km = 1 m = ______cm = _______ mm

______km = ______ m = 1 cm = _______mm

______km = ______ m = ______ cm = 1 mm

Test yourself: Answers

Complete the following conversion

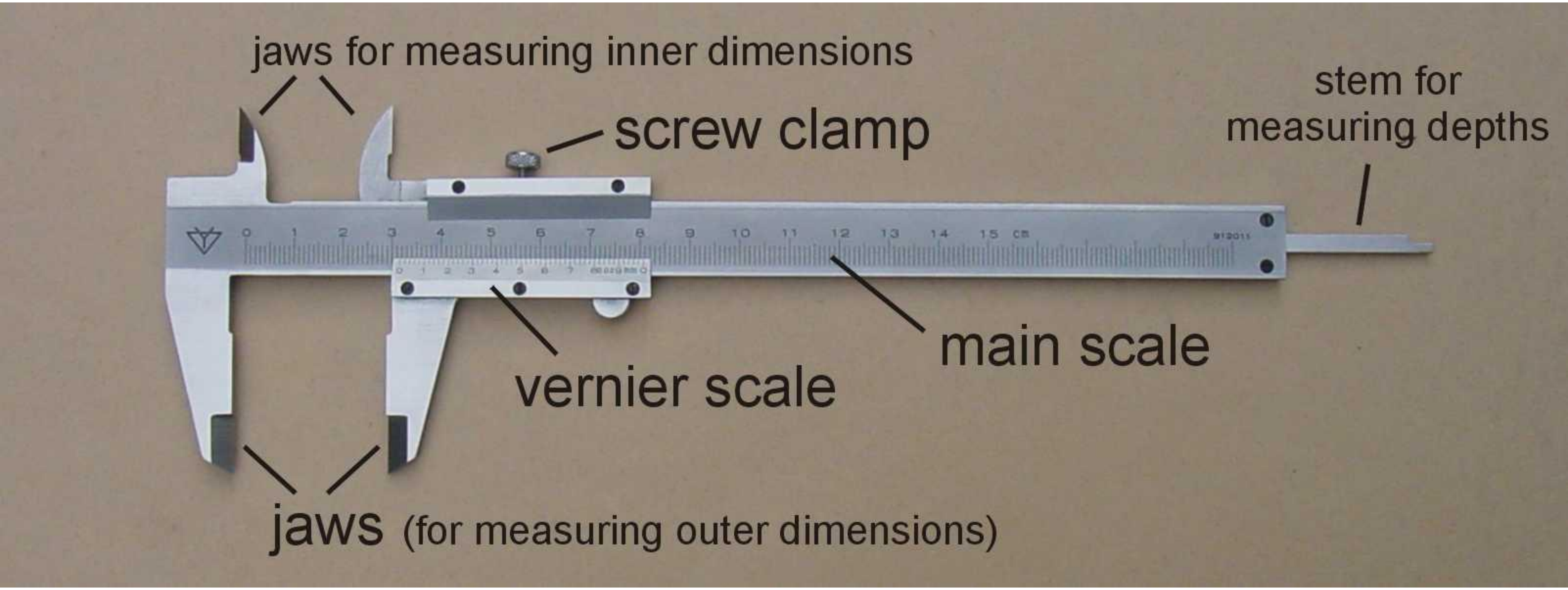
1 km = <u>1000</u> m = <u>100 000</u> cm = <u>1 000 000</u> mm

<u>0.001</u> km = 1 m = <u>100</u> cm = <u>1000</u> mm

<u>0.000 01</u> km = <u>0.01</u> m = 1 cm = <u>10</u> mm

<u>0.000 001</u> km = <u>0.001</u> m = <u>0.1</u> cm = 1 mm

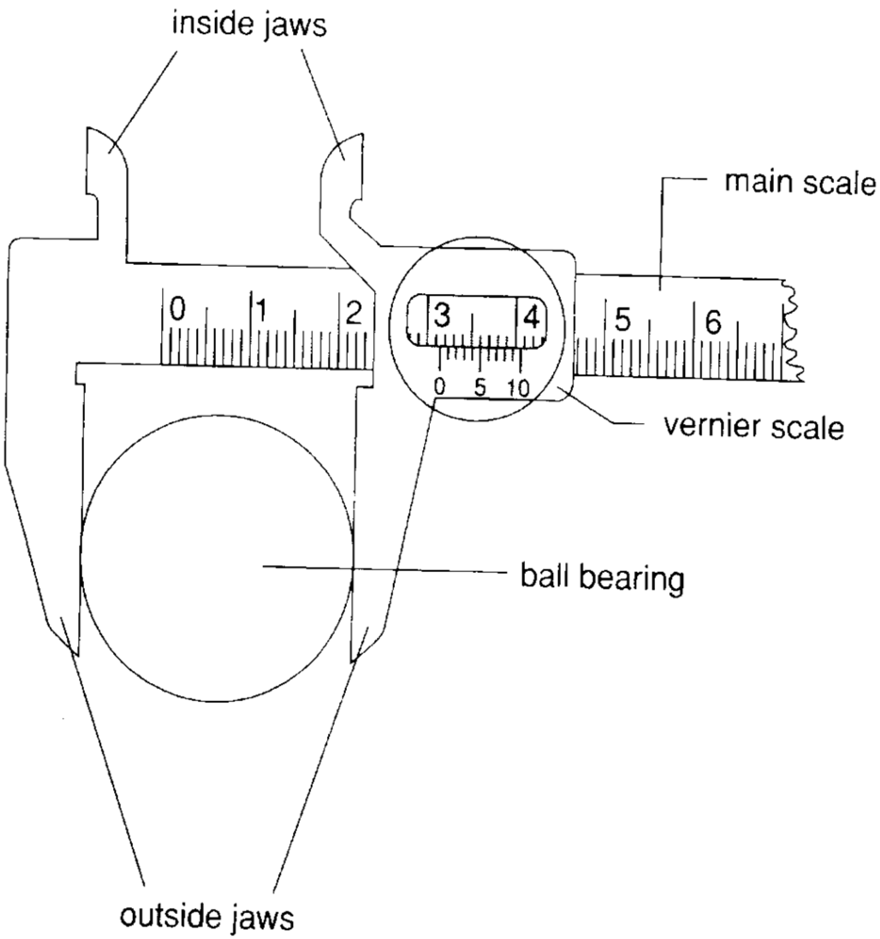
Vernier Calipers

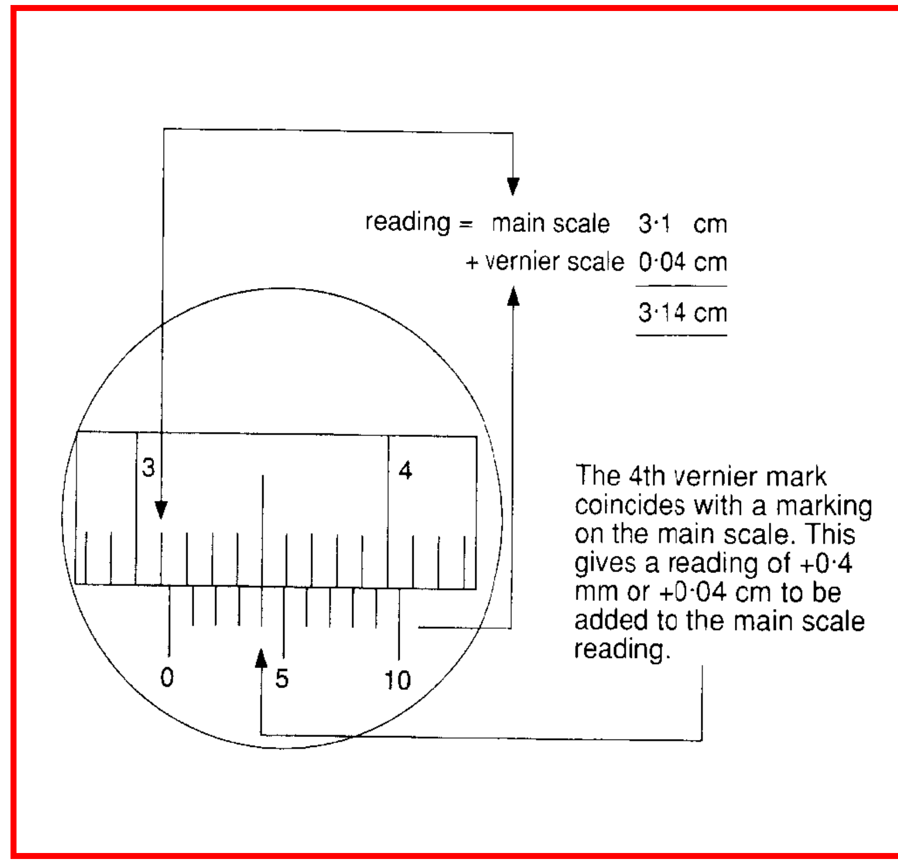


This instrument measures short LENGTH especially suitable for measuring diameters or radii of circular objects.

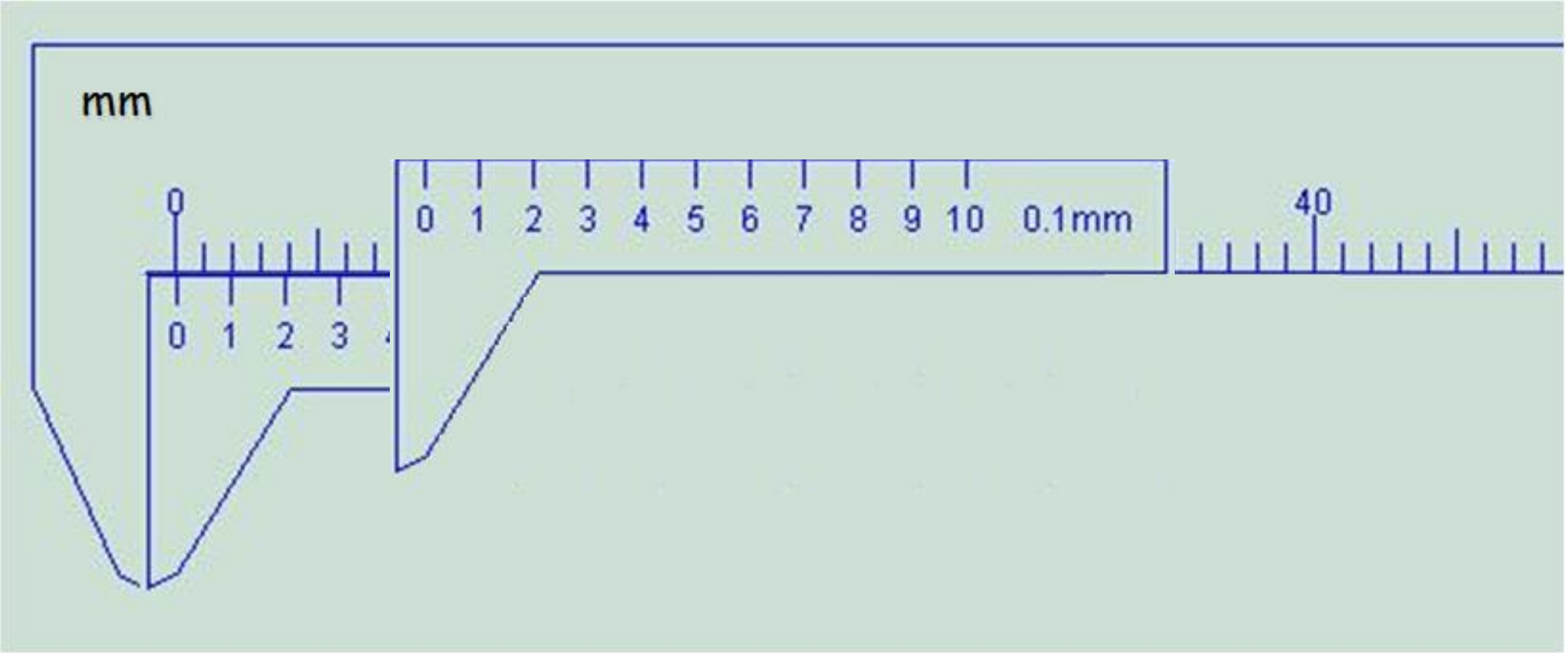
Accuracy of a vernier calipers is 0.01cm or 0.1mm

How to read the Vernier Calipers?

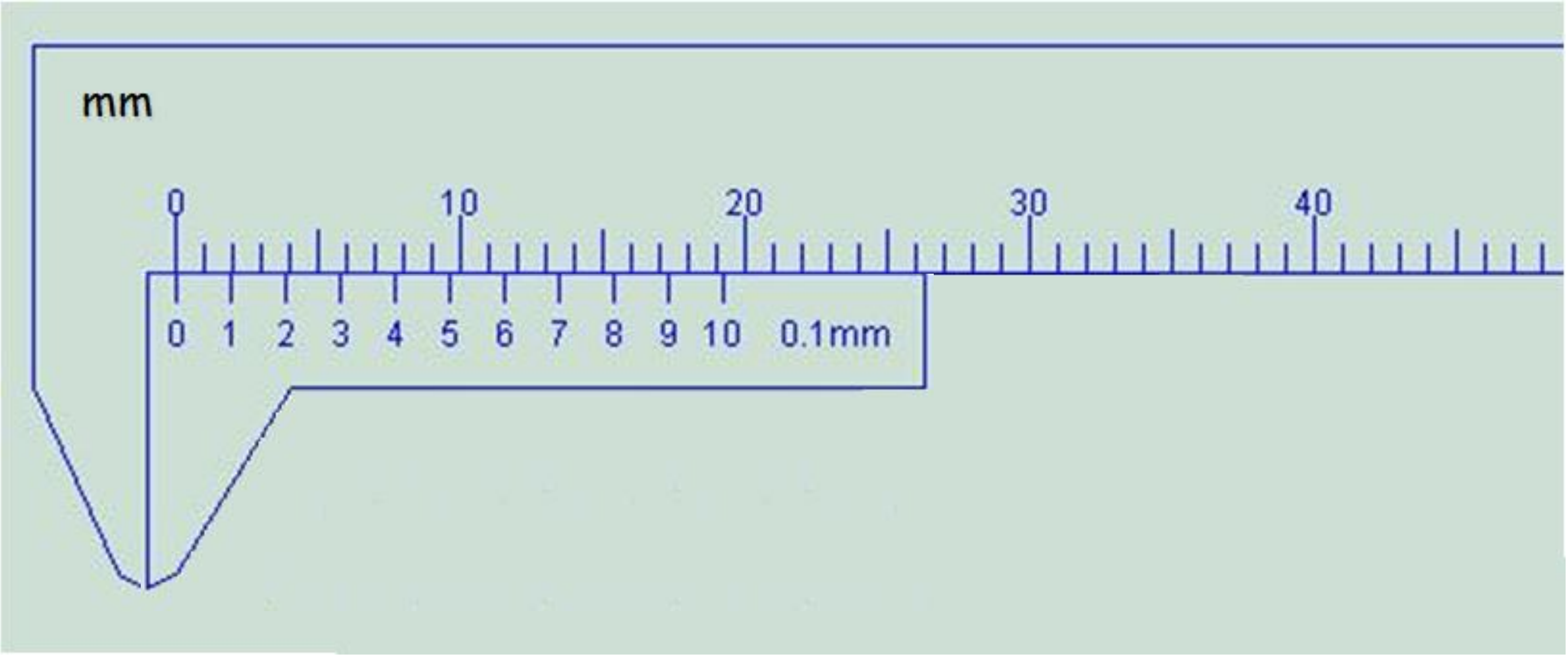




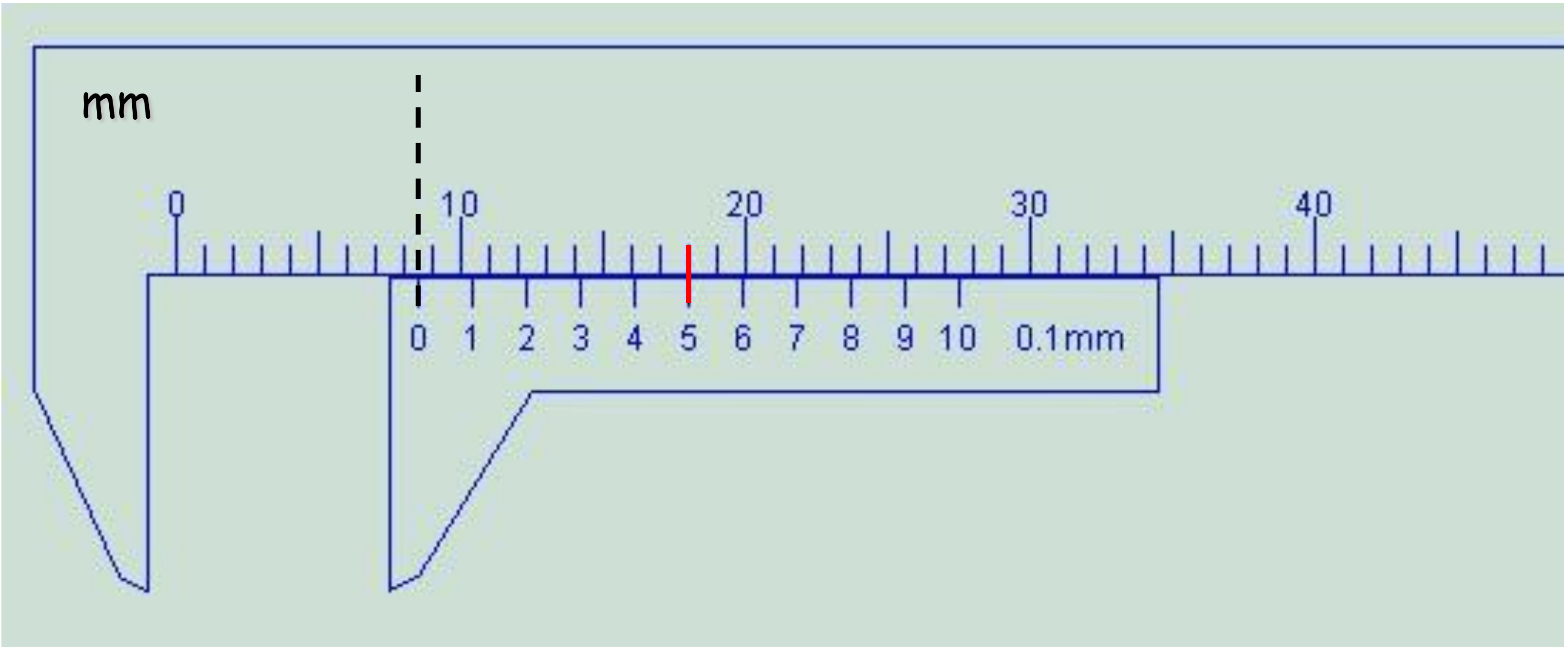
How to read the Vernier Scale?



How to read the Vernier Scale?



How to read the Vernier Scale?

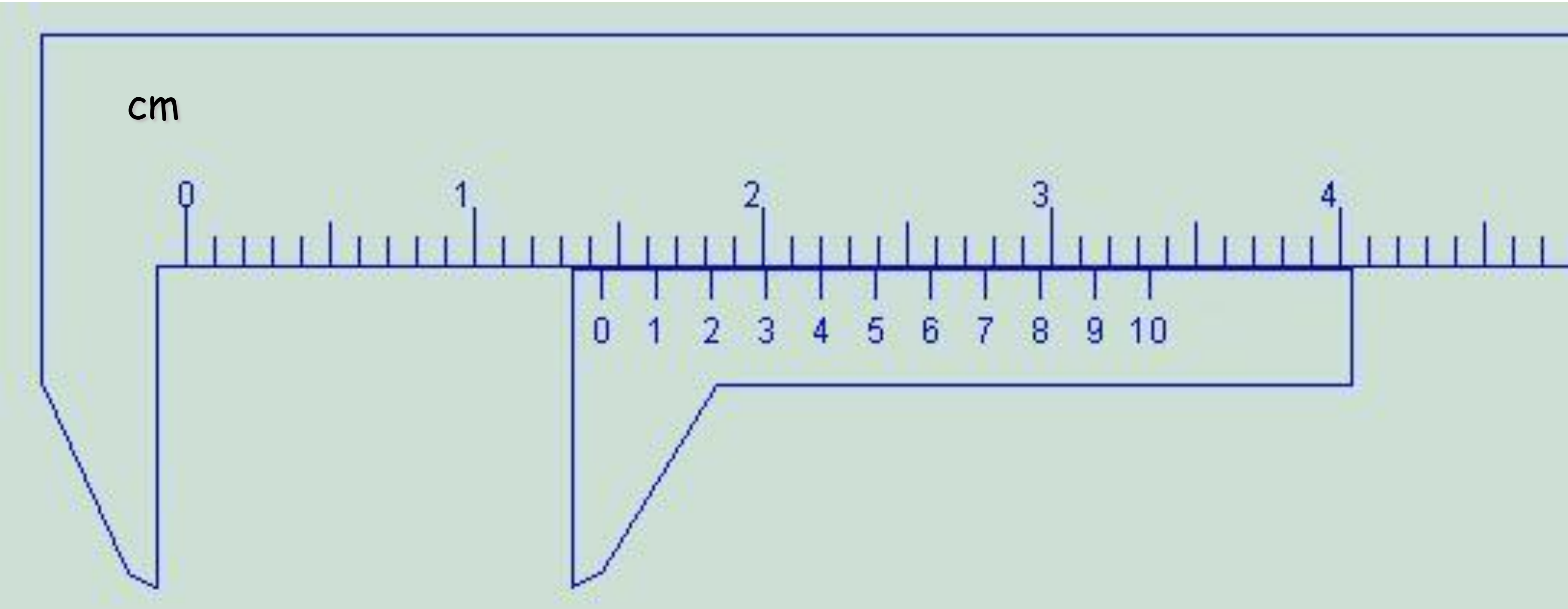


Main scale reading = 0.8cm

Vernier scale reading = 0.05cm

Measured length = 0.8cm + 0.05cm = 0.85cm

Reading the vernier scale

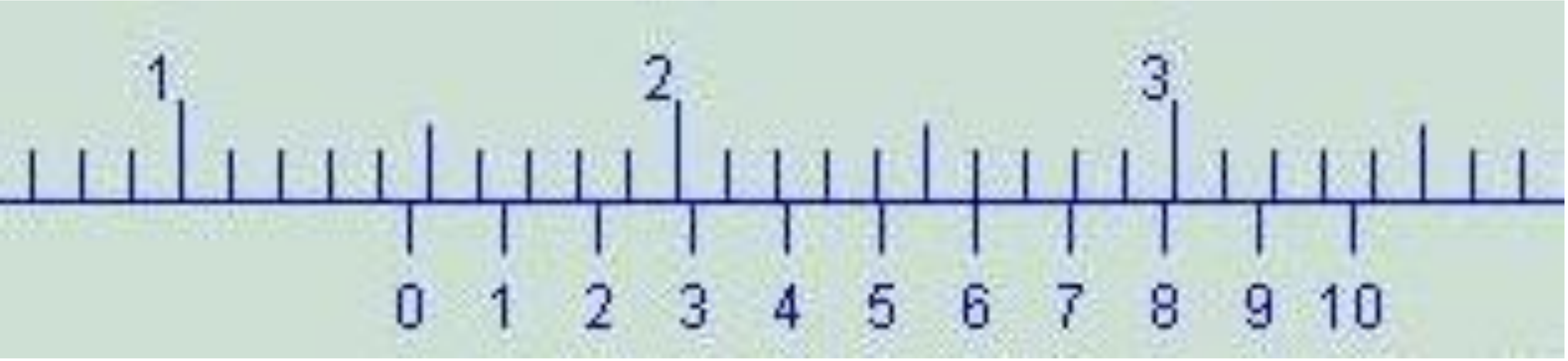


Main scale reading = 1.4cm

Vernier scale reading = 0.04cm

Measured length = 1.4cm + 0.04cm = 1.44cm

Test yourself!

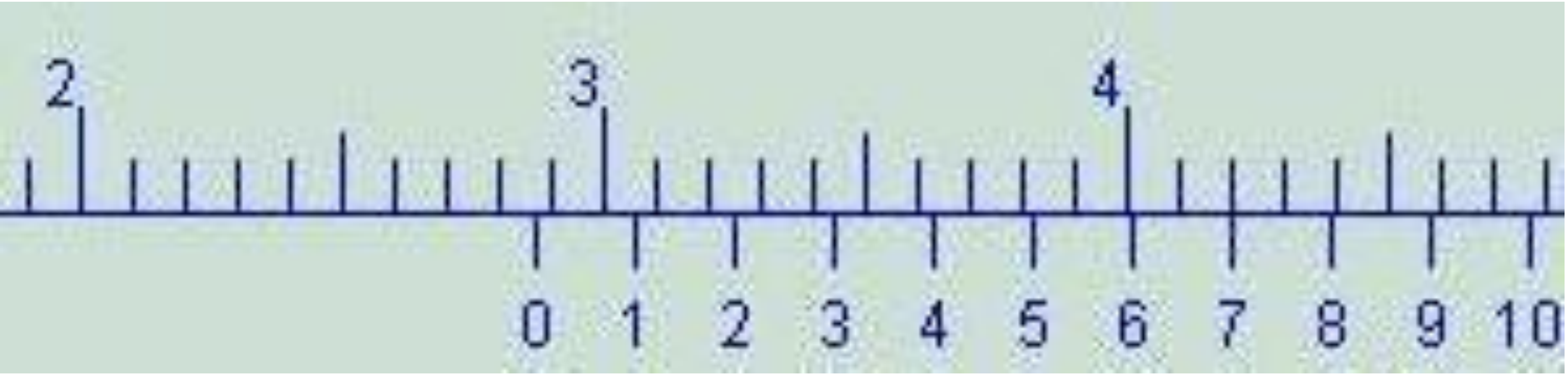


Main scale reading = 1.4cm

Vernier scale reading = 0.06cm

Measured length = 1.4cm + 0.06cm = 1.46cm

Test yourself!

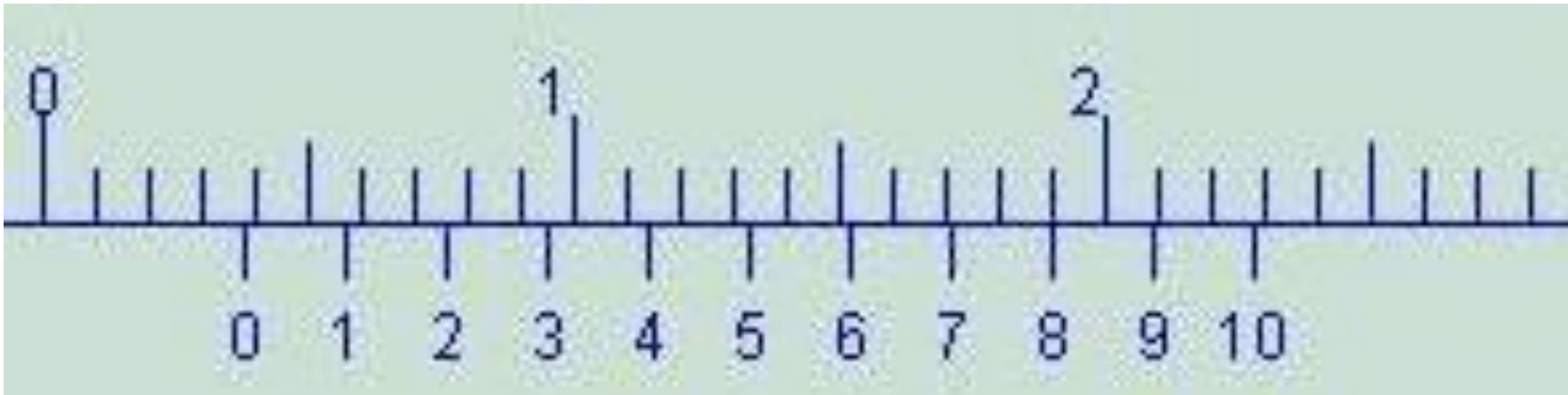


Main scale reading = 2.8cm

Vernier scale reading = 0.07cm

Measured length = 2.8cm + 0.07cm = 2.87cm

Test yourself!

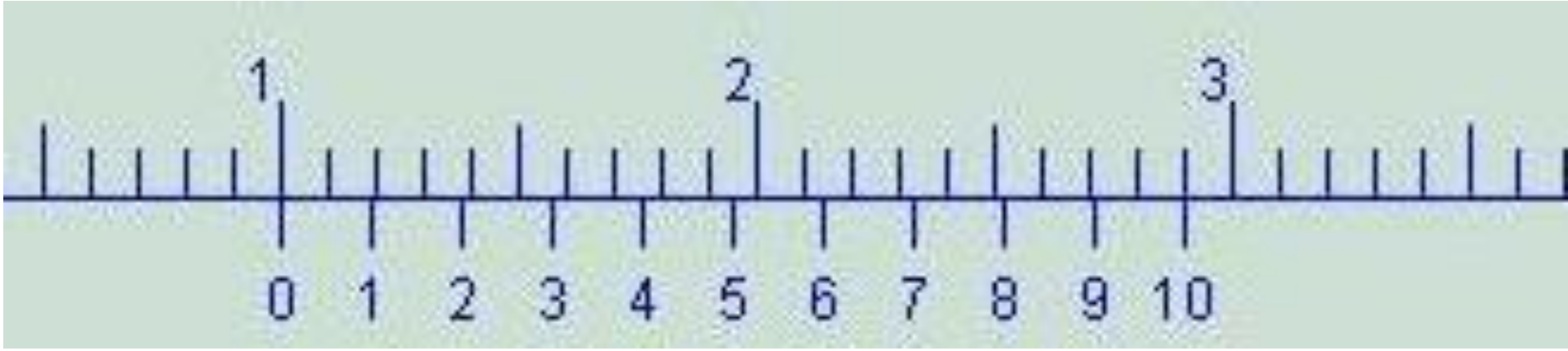


Main scale reading = 0.3cm

Vernier scale reading = 0.08cm

Measured length = 0.3cm + 0.08cm = 0.38cm

Test yourself!



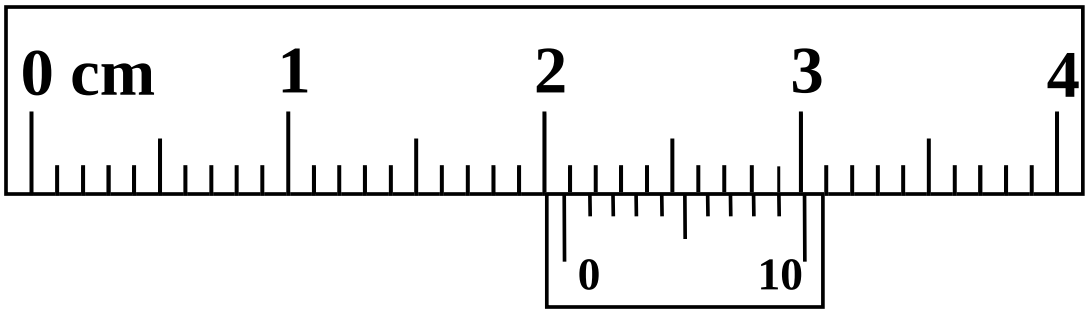
Main scale reading = 1.0cm

Vernier scale reading = 0.00cm

Measured length = 1.0cm + 0.00cm = 1.00cm

Test yourself!

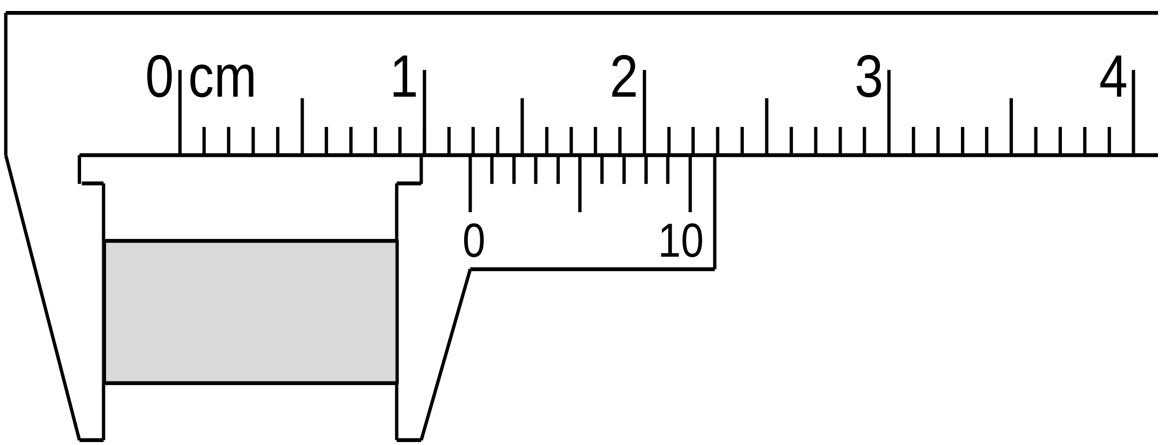
What readings are shown on the following scales?



Main scale: 2.0

Vernier scale: 0.09

Reading: 2.09cm



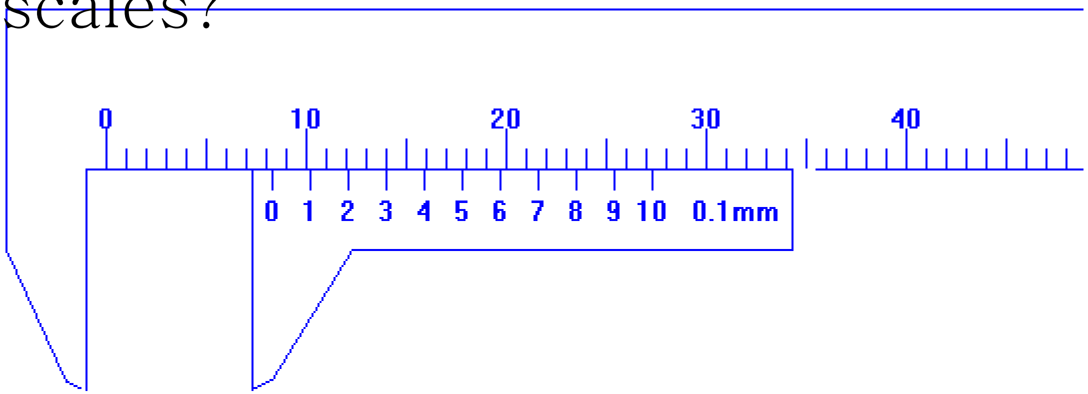
Main scale: 1.1

Vernier scale: 0.09

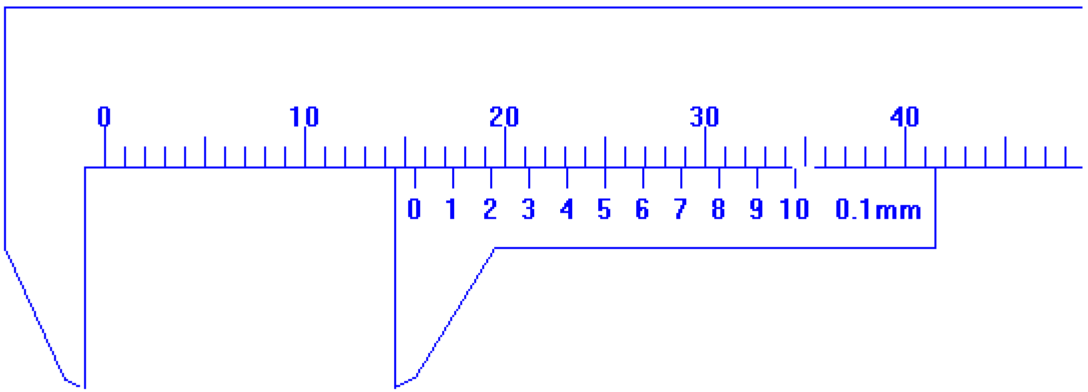
Reading: 1.19 cm

Test yourself!

What readings are shown on the following scales?



Reading: 0.83 cm



Reading: 1.55 cm

http://members.shaw.ca/ron.blond/Vern.APPLET/

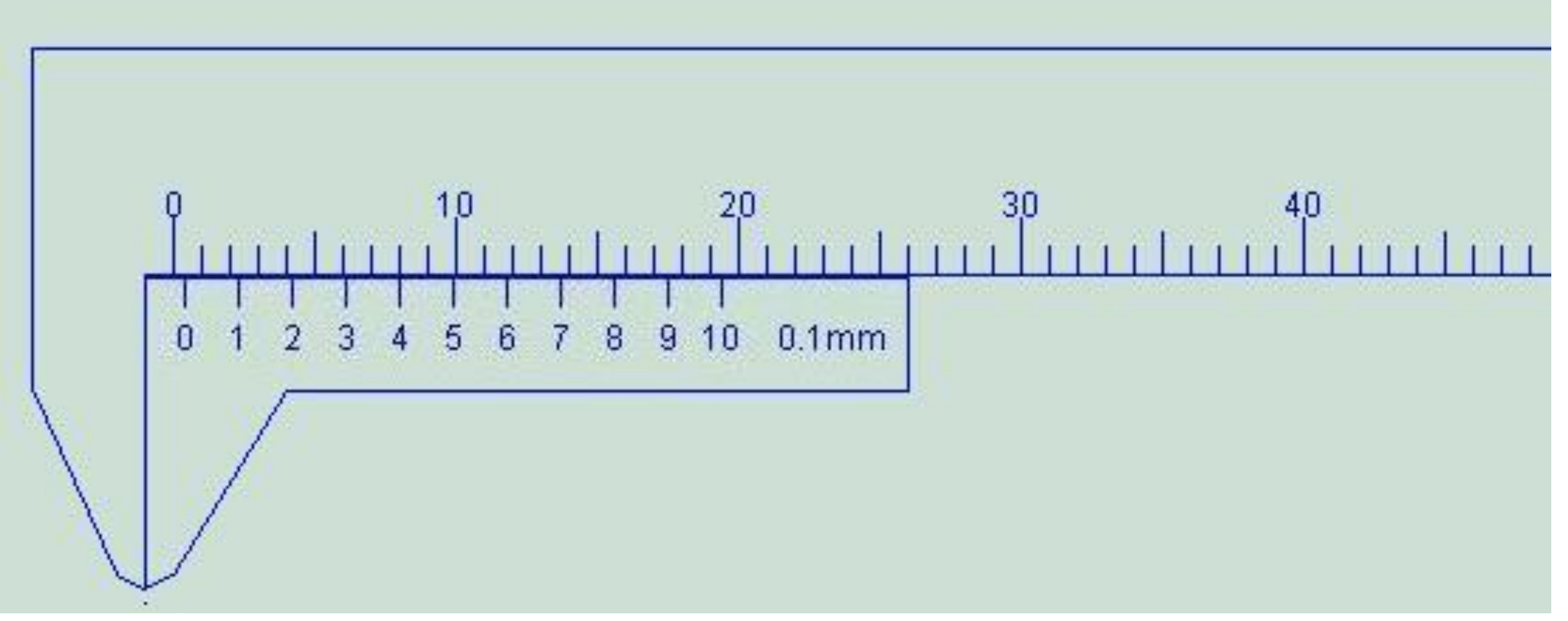
http://www.phys.hawaii.edu/%7Eteb/java/ntnujava/ruler/vernier.html

When a measuring instrument shows a reading when there actually should be none (i.e the reading should be zero), there is an error.

What is this error called?

Zero Error

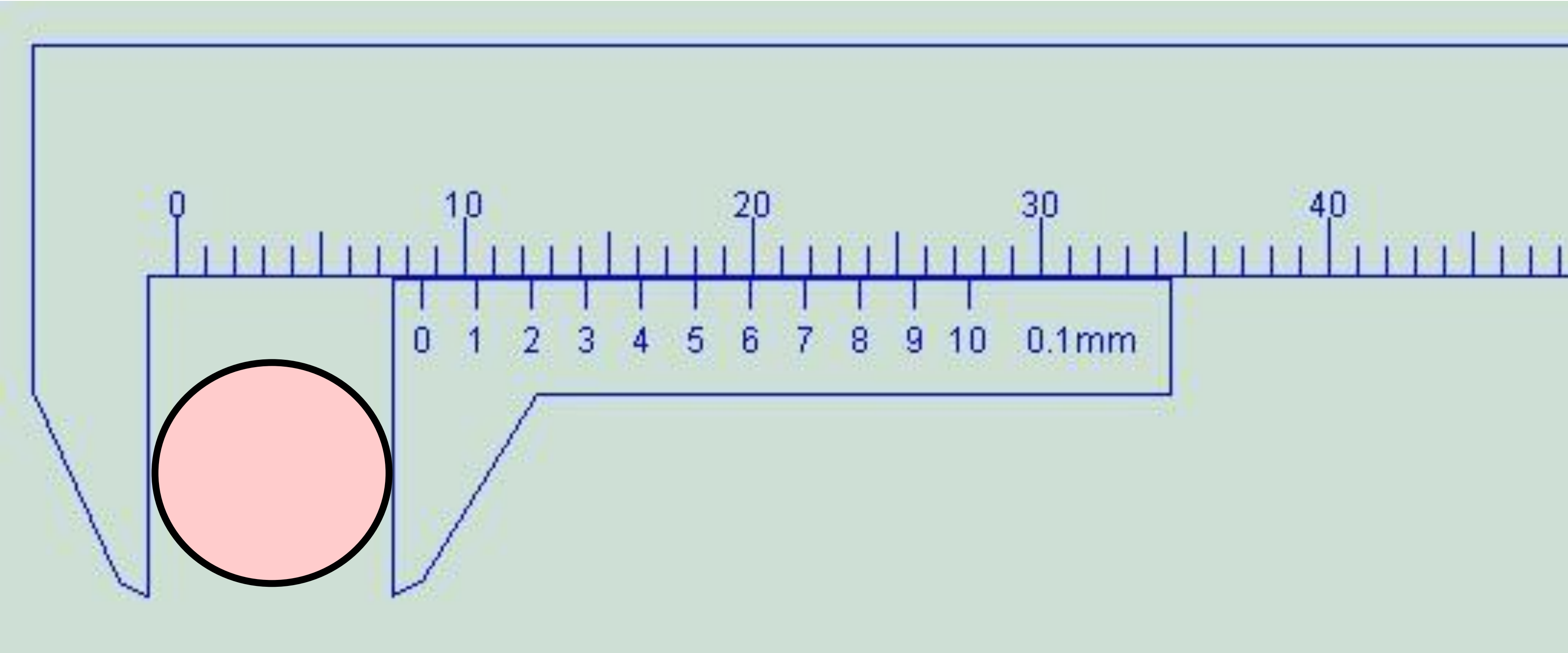
Zero error: -ve error



Zero Error = **0.04cm**

The subsequent readings taken with this instrument is to be decreased by this error.

Zero error-example 1

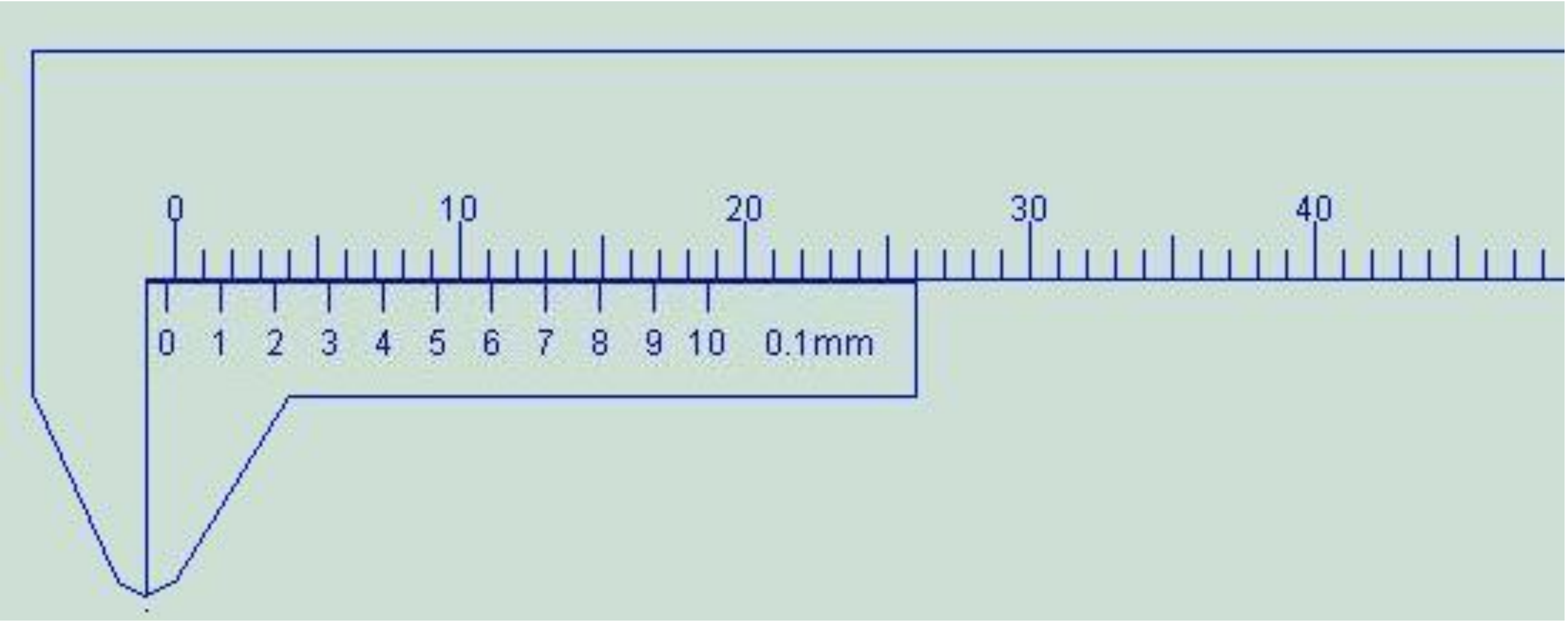


Observed reading = **0.85cm**

Actual diameter = **0.85 – 0.04 = 0.81cm**

In this example, the zero error is to be reduced from the OBSERVED reading to get the ACTUAL measurement.

Zero error: +ve error

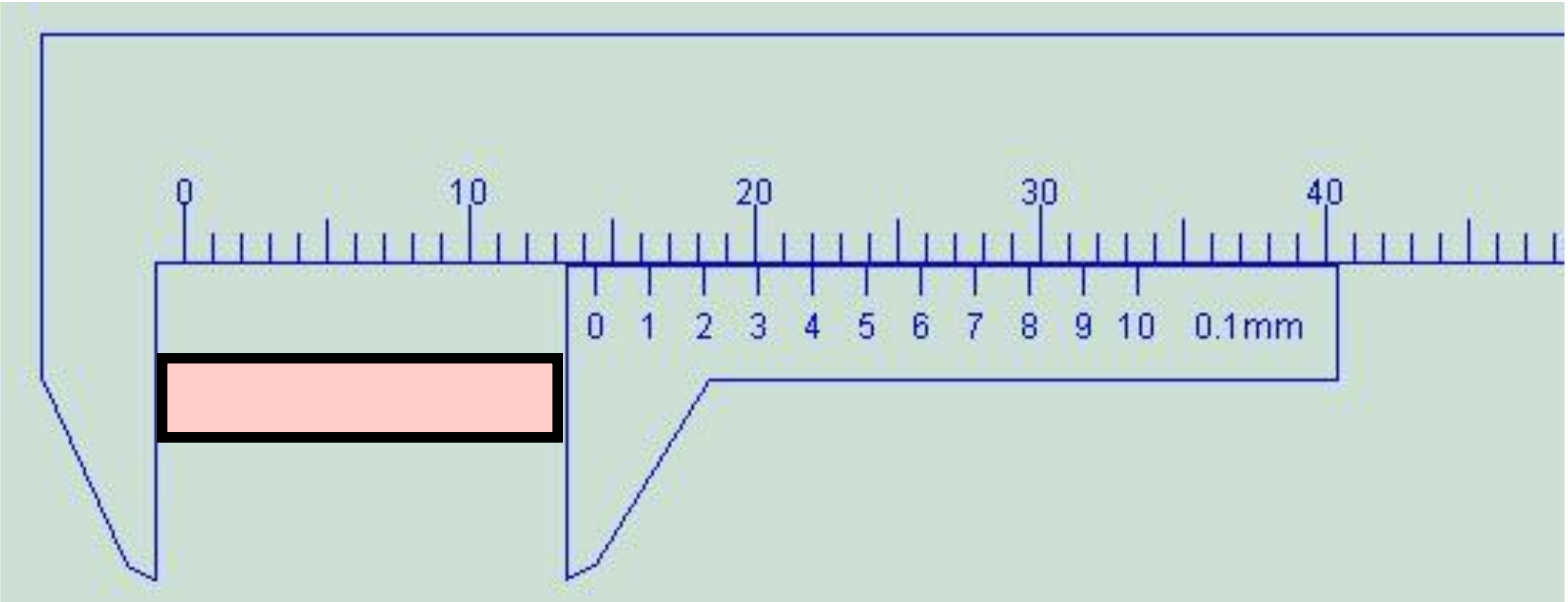


Zero Error = **0.03 cm !!!!!!**

NOT 0.07 cm!

The subsequent readings taken with this instrument is to be increased by this error.

Zero error-example 2



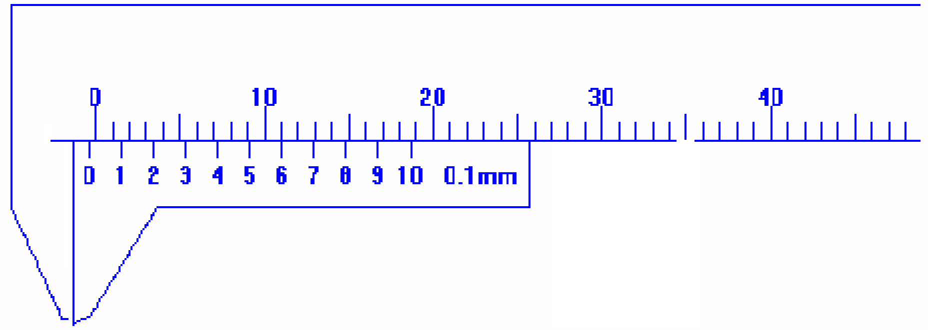
Observed reading = **1.44 cm**

Actual length = **1.44 + 0.03 = 1.47 cm**

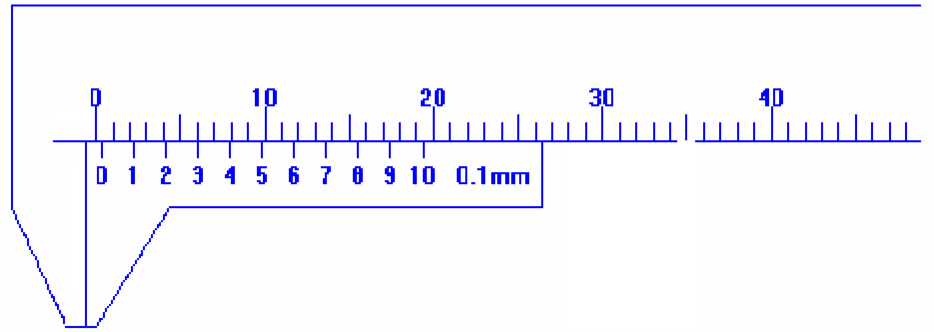
In this example, the zero error is ADDED to the OBSERVED reading to get the ACTUAL measurement.

Test yourself!

What zero errors are shown on the following scales?



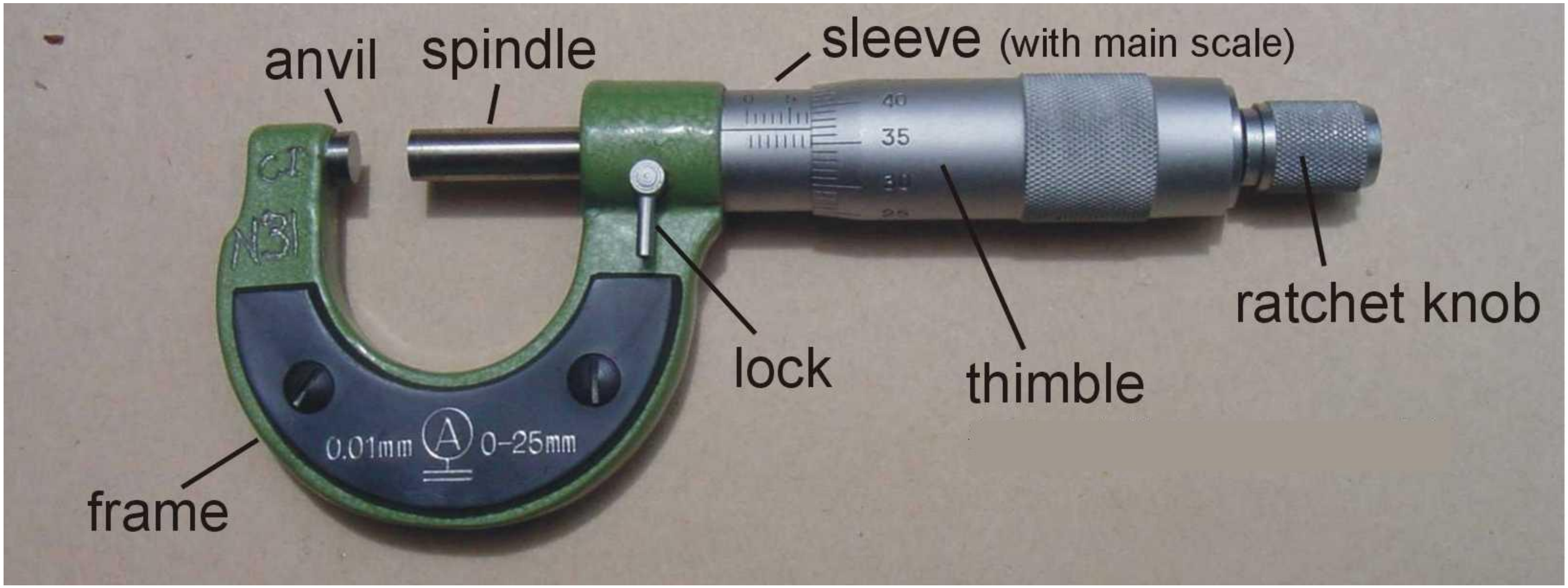
Zero error = 0.04 cm



Zero error = 0.03 cm

1.6 Measuring length

Micrometer screw gauge



This instrument measures very short LENGTH especially suitable for measuring diameters or radii of wires.

http://www.upscale.utoronto.ca/PVB/Harrison/Micrometer/Micrometer.html

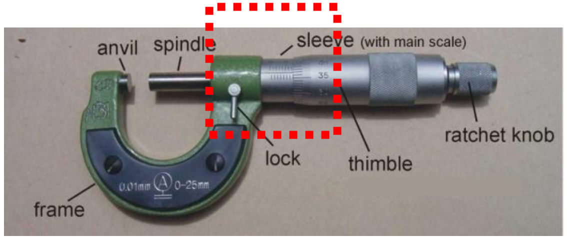
Micrometer screw gauge

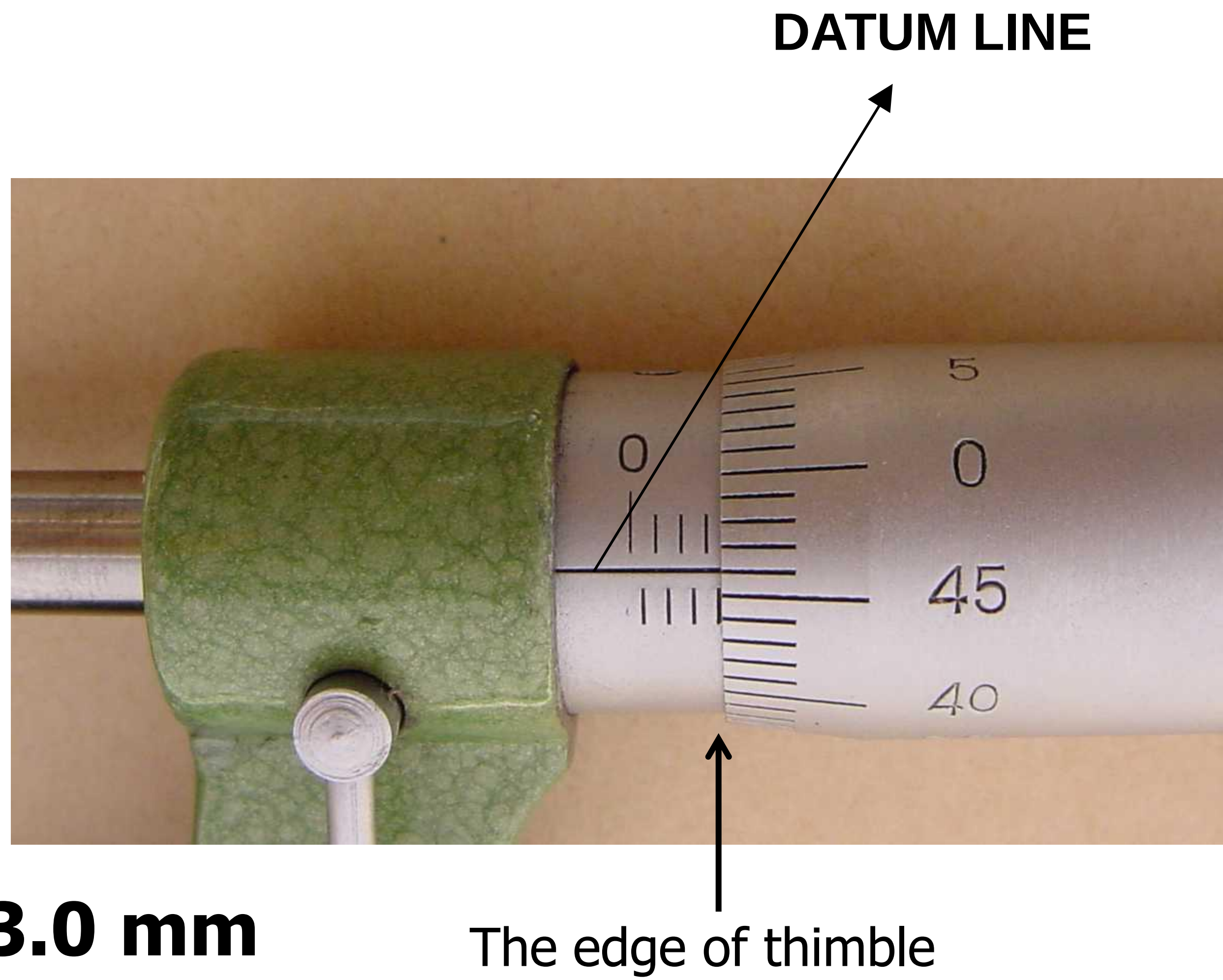
- Measure up to 25 mm
- Accuracy to 0.001 cm or 0.01 mm

Precautions:

- Zero error should be noted and corrected.
- The ratchet must be used to avoid over tightening.
- Several readings should be taken and the average value is taken.

How to read the micrometer screw gauge?





Main scale = 3.0 mm
Thim. scale = 0.46 mm
reading = 3.46 mm

EXAMPLE 1

Main scale reading= 7.5mm

Thimble scale reading= 0.22mm

Measured length= 7.5 + 0.22 = 7.72mm

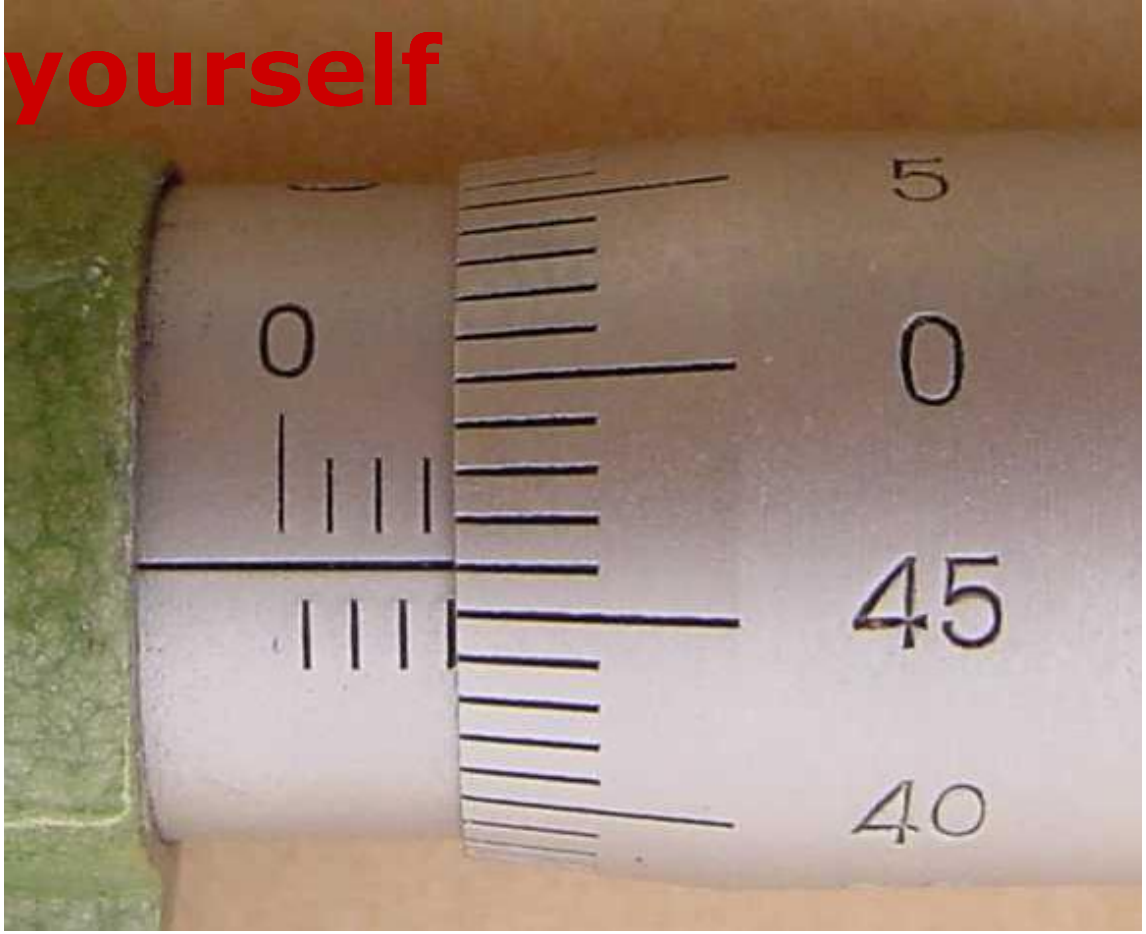
EXAMPLE 2

Main scale reading= 7.0mm

Thimble scale reading= 0.38mm

Measured length= 7.0 + 0.38 = 7.38mm

Test yourself



Main scale reading= 3.0mm

Thimble scale reading= 0.46mm

Measured length= 3.0 + 0.46 = 3.46mm

http://www.upscale.utoronto.ca/PVB/Harrison/Micrometer/Flash/MicSimulation.html

Test yourself

Main scale reading= 3.5mm

Thimble scale reading= 0.06mm

Measured length= 3.5 + 0.06 = 3.56mm

Test yourself

Main scale reading= 5.5 mm

Thimble scale reading= 0.30mm

Measured length= 5.5 + 0.30 = 5.80mm

Micrometer Screw Gauge

- Similar to the usage of the vernier calipers, the micrometer must be checked for zero error before the measurement is taken.
- The error is then added or subtracted from the observed reading to get the actual reading.

Zero error: -ve error

Zero error

= - 0.06mm

This zero error should be REDUCED from the observed reading.

This -ve error means reduce the final reading by this amount.

Zero error: +ve error

Zero error

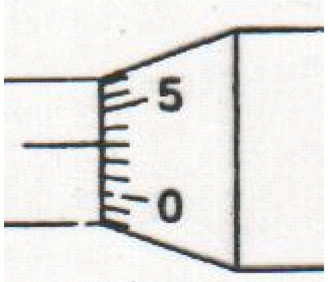
= 0.04 mm

This zero error should be added to the observed reading.

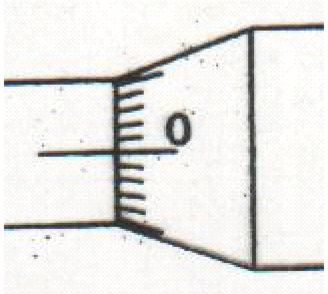
This +ve error means to increase the final reading by this amount.

Test yourself

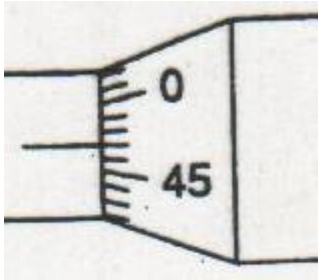
Read the zero errors shown below:



All measurements should be reduced by 0.03 mm (-0.03 mm)



Zero error = 0.00



All measurements should be increased by 0.03 mm (+0.03 mm)