

AE405 LAB-1 Measurement of basic constants: length, weight and time



Fig. 1: Experimental set-up: Measurement of basic constants: length, weight, and time.

PRINCIPLE AND TASK

Caliper gauges, micrometers and spherometers are used for the accurate measurement of lengths, thicknesses, diameters and curvatures. A mechanical balance is used for weight determinations, a decade counter is used for accurate time measurements. Measuring procedures, accuracy of measurement and reading accuracy are demonstrated.

Equipment

Vernier caliper

Micrometer

Spherometer

Light barrier

Digital counter, 4 decades or (Alternative) Digital counter, 6-decade

Precision balance, 2 pans, 500 g

Set of precision weights, 1 mg–200 g

Iron column

Iron cylinder

Iron wire, $d = 1.0 \text{ mm}$, 10 m

Aluminium foil, set of 4 sheets

Glass plate, 100x85x1 mm

Watch glass, dia. 80 mm

Watch glass, dia. 100 mm

Watch glass, dia. 125 mm

Glass tubes, straight, 80 mm, 10

Glass tube, d 24/21 mm, l 120 mm

Cubes, set of 8

Fish line, l 100 m

Steel ball with eyelet, d 32 mm

Rod with hook

Support rod -PASS-, square, l 630 mm

Tripod base -PASS-

Right angle clamp -PASS- (2)

Measuring tape, l = 2 m

Connecting cord, 500 mm, red (2)

Connecting cord, 500 mm, blue (2)

PROBLEMS

1. Determination of the volume of tubes with the caliper gauge.
2. Determination of the thickness of wires, cubes and plates with the micrometer.
3. Determination of the thickness of plates and the radius of curvature of watch glasses with the spherometer.
4. Determination of the weight of different articles with highest possible accuracy with a manual precision balance.
5. Determination of the frequency of the pendulum.
6. Familiarisation of the use of a digital counter in his multiple methods of use.

SETUP AND PROCEDURE

1) Vernier caliper

The caliper gauge (sliding gauge) is the best known measuring tool for rapid and relatively accurate measurement. Inside, outside and depth measurements can be made. The accuracy which can be achieved is proportional to the graduation of the vernier scale. The measuring faces which are relevant to the taking of reading may be seen in Fig. 2.

When the jaws are closed, the vernier zero mark coincides with the zero mark on the scale of the rule. The name “vernier” is given to an addition to a gauge which enables the accuracy of measurement (reading accuracy) of the gauge to be increased by 10 to 50 times. The linear vernier is a small rule which slides along a scale. This rule is provided with a small scale which is divided into m equal divisions. The overall length of these m divisions is equal to $m-1$ on the main scale. Fig. 2, enlarged, show 39 divisions extending from 28 mm to 67 mm on the graduated scale, whereas the vernier has 20 divisions (every second mark on the vernier has been omitted). The workpiece to be measured is placed between the measuring faces and the movable jaw blade is then pushed with moderate pressure up against the workpiece. When taking the reading the zero mark of the vernier is regarded as the decimal point which separates the whole numbers from the tenths. The full millimetres are read to the left of the zero mark on the main graduated scale and then, to the right of the zero mark, the vernier division mark which coincides with a division mark on the main scale is looked for. The vernier division mark indicates the tenths of a millimetre (Fig. 3).

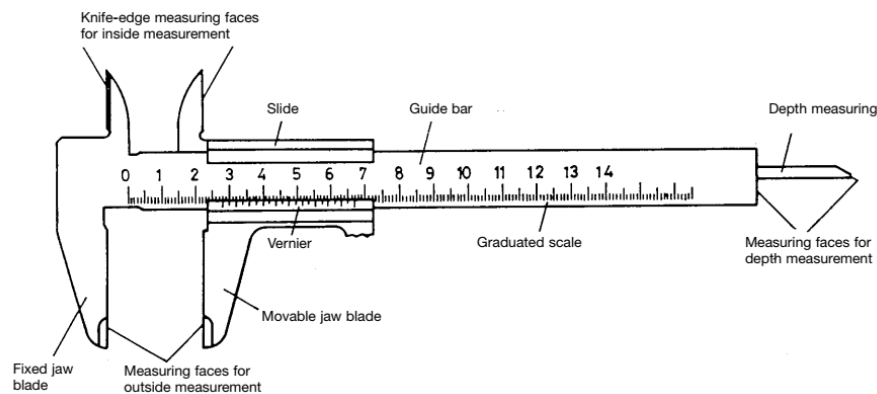


Fig. 2: Vernier caliper.

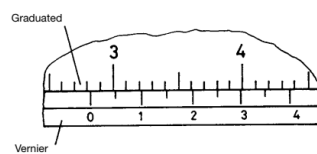


Fig. 3: Reading off 28 on the graduated scale and 25 on the Vernier scale give 28.25 mm.

2) Micrometer

With the micrometer (Fig. 4) (micrometer screw gauge) the accuracy of measurement can be increased by one order of magnitude. The workpiece to be measured is placed between the measuring faces, then the measuring spindle is brought up to the workpiece with the rapid drive (ratchet, thumb screw). When the rapid drive rotates idly, the pressure required for measurement has been reached and the value can be read off. The whole and half millimetres are read off on the scale barrel, the hundredths of millimetres on the micrometer collar. If the micrometer collar uncovers a half-millimetre, this must be added to the hundredths.

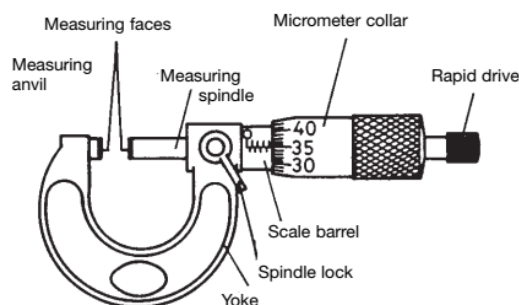


Fig. 4: Micrometer, reading off 4.35 mm.

3) Spherometer

More accurate relative measurements of parallel surfaces (plate thickness) and curvatures of spherical surfaces can be made with the spherometer. The spherometer is used for the measurement of the radius of curvature on spherical surfaces. In addition the thickness of plates and the differences in level between surfaces can be found in a convenient manner. The device has a tripod with three measuring points which form an equilateral triangle. In the centre of this triangle is located the probe of a dial gauge. The distance between the tip of the probe and the plane defined by the three measuring points can be read on the dial gauge. The measurement accuracy is better than 10^{-2} mm.

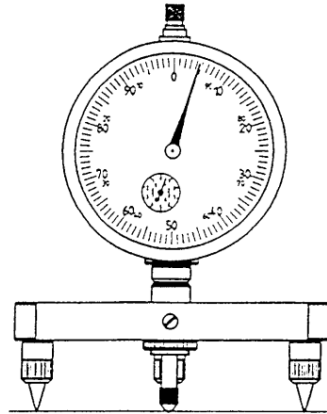


Fig. 5: Spherometer.

Operation

There are four threaded holes available on each leg of the tripod for the acceptance of the three measuring points. The points must all have the same separation from the central probe. In order to achieve a high accuracy of measurement, the points are screwed in positions as far outwards as possible. Consideration should be given to the limits set by the size of the surface to be investigated.

The dial gauge latches into the tripod at two precisely defined positions. The upper position for the dial gauge is used for measuring convex surfaces; in this case the black figures on the gauge scale are used. If the dial gauge is pushed downwards in the tripod until it latches, then concave surfaces can be measured using the red figures. It is important to check the zero-point adjustment after matching the gauge position to the measurement task in hand.

To adjust the zero point the spherometer is placed on the flat surface of the included glass plate and the scale on the dial gauge is rotated using the knurled ring so that its zero point lies below the pointer. Vertical pressure on the spherometer should be avoided during the reading.

Once this preparatory step has been completed, the device is placed on the surface to be measured and the difference in height h is measured. One revolution of the large pointer corresponds to 1 mm (1 subdivision corresponds to 10^{-2} mm). The number of revolutions is given by the small pointer. The maximum measurement displacement is 10 mm.

The radius of curvature R of a spherical surface is obtained from the measured difference in height h according to the equation

$$R = \frac{a^2 + h^2}{2h}$$

where a is the distance of the measuring points from the centre of the system. The following figures are given for the four possible positions of the measuring points from the inside towards the outside, labelled with 1 to 4:

Pos	a/mm
1	15.0
2	25.0
3	32.5
4	40.0

5) Precision balance

For didactical reasons we have not chosen a digital balance with high resolutions – which mostly is available in most laboratories. (You may use it for checking the results).

Please follow the operating instructions to determine with maximum accuracy the weight of different samples.

Note: Do not touch the precision weights with your fingers, always use the tweezers to avoid transfer of fat or dust to the weights.

6) Digital counter

Also for didactical reasons we have chosen a powerful 4 decade digital counter to learn the principles of time measurement. Please follow the detailed operating instructions to get familiar with the multiple possibilities of this equipment as a time, frequency and impulse measurement tool.

In detail we describe the experiment of a pendulum. For the experimental setup refer to Fig. 6:



Fig. 6: Experimental setup: Frequency measurement of a pendulum. (In Fig. 1 the alternative with the 4-decade counter is shown).

Principle

The oscillation of a thread pendulum is investigated using a light barrier. The frequency is assessed in different ways by means of the digital counter.

Setup and Procedure

– Determination of the period of oscillation by means of a digital counter used as a **manual stop-watch**.

A fork light barrier is not required for this experimental setup. The “FUNKTION” push-button is pressed repeatedly until the “TIME” operating mode is activated. The pendulum is set to oscillate and the START button is pressed. The STOP button is pressed after about 10 complete oscillations. After this, the measured time is divided through the number of oscillations to obtain the period of oscillation T .

– Determination of the thread pendulum oscillation **frequency** 6 decade counter, for higher frequencies the 4 decade can also be used.

Connect the fork light barrier to Eingang/Input. Set to “FREQ.” operating mode with the “FUNKTION” button. Press the button repeatedly until the unit “Hz” appears on the display (only 6 decade counter). Push the thread pendulum to let it oscillate and press the START button. The display is now continuously updated. The oscillating frequency, which is based on the half period, is displayed $f = 1/(T/2)$.

- Measurement of the **period duration** (only 6 decade counter). Connect the light barrier to Eingang/Input and set “PERIODE” function mode. Start the pendulum and press the START button. The display, which is continuously updated, indicates the period on which the half period T/2 is based.
- Measurement of the complete **period T** (only 6 decade counter). Connect the light barrier to the START/STOP input of Timer 1. Select  for triggering condition and “AUTO” for operating mode. After starting the pendulum and pressing the START buttons, the actual period T is continuously displayed. The number of displayed digits can be varied by means of the + and – buttons.
- Measurement of the **half period T/2** (6 and 4 decade counter). Connect the light barrier to the START/STOP input (of timer 1). Select  for triggering condition. After starting the pendulum and pressing the START button, the half period T/2 is displayed.
- Measurement of the **period duration** through addition of about ten oscillations (only 6 decade counter). Connect the light barrier to the START/STOP input of timer 1. Select  for triggering condition and “ADD” for operating mode. After starting the pendulum and pressing the START button, ten oscillations are counted, after which the STOP button is pressed. Then the measured time is divided by the number of oscillations, in order to obtain the duration of the oscillating period T.

Result

In the case of a thread pendulum, the measured oscillating time T is independent from the oscillating amplitude, it only depends from the length of the pendulum thread.

Evaluation

For small oscillating amplitudes, an exact evaluation of the thread pendulum theory yields the following relation:

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

where

L = length of the pendulum thread

g = 9.81 m/s², earth’s gravitational acceleration

T = duration of period

In the following example of measurement, the length of the thread is L = 0.49 m. This yields a duration of period T = 1.404 s, T/2 = 0.7021 s and the oscillating frequency 1/(T/2) = 1.42 Hz. These data are in good agreement with the measured data.

Notice

- If the fork light barrier is used for this experiment, the light beam should be interrupted by the fishing line and not by the ball. Press the “Set” button if the red control lamp on the housing of the light barrier is lit at the beginning of the experiment.
- A measuring microphone can be connected to Eingang/Input instead of the fork light barrier. This allows to measure the duration of period and the frequency of acoustic phenomena (e.g. tuning fork oscillations).