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für metalltechnische Berufe

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TECHNISCHES ENGLISCH zur FACHKUNDE METALL

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Vorwort

Das Buch **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** dient zum systematischen Erlernen des technischen Englisch für die metalltechnischen Berufe.

Es erfüllt damit die Forderung der Rahmenlehrpläne zur Erlangung der sprachlichen Kompetenz in technischem Englisch im Berufsfeld der metalltechnischen Berufe: Werkzeug- und Industriemechaniker, Feinwerk-, Fertigungs- und Zerspanungsmechaniker sowie der entsprechenden Meister und Techniker des Berufsfeldes.

Auch für Schüler technischer Gymnasien, für Praktikanten und Studierende der Fachrichtung Maschinenbau sowie für Praktiker in der metallverarbeitenden Industrie und im Metallhandwerk ist es geeignet.

Voraussetzung des Lernens und Arbeitens mit dem Buch **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** sind Grundkenntnisse des Englischen, die einem mittlerem Schulabschluss (Sekundarstufe 1) entsprechen und im Europäischen Fremdsprachen-Referenzrahmen in A2/B1 eingeordnet werden können.

Das Buch basiert auf den Inhalten wesentlicher Kapitel der FACHKUNDE METALL.

Es kann begleitend zum Unterricht mit der FACHKUNDE METALL oder anderen Lehrwerken des Berufsbereichs eingesetzt werden. Zu empfehlen ist z. B. nach der Einführung der Fachinhalte im deutschen Fachkundeunterricht der Einsatz des Buches **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** zur Vertiefung und Festigung der Fachinhalte in englischer Sprache.

Eine weitere Vertiefung der Englisch-Kompetenz ist durch ein paralleles Arbeiten mit einem englisch-sprachigen Tabellenbuch, wie z. B. MECHANICAL AND METAL TRADES HANDBOOK des Verlags Europa-Lehrmittel, möglich.

Die Lerneinheiten im Buch **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** werden in derselben Reihenfolge wie im Buch FACHKUNDE METALL dargeboten.

Es handelt sich beim Buch TECHNISCHES ENGLISCH zur FACHKUNDE METALL jedoch nicht um eine Übersetzung der entsprechenden Kapitel und Inhalte aus dem Buch FACHKUNDE METALL.

Im Buch **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** ist der Inhalt der jeweiligen Kapitel in Englisch in einem Konzentrat zusammengefasst. Darin werden die Fachausdrücke des Sachgebiets, wichtige Redewendungen und die erforderlichen englischen Sachwörter eingeführt und vertieft.

Durch die erworbene Sprachkompetenz beim Arbeiten mit dem Buch ist auch das Lesen und Verstehen anderer Texte zu diesem Sachgebiet möglich.

Das Buch **TECHNISCHES ENGLISCH zur FACHKUNDE METALL** ist in Lerneinheiten gegliedert, die einem technischen Sachgebiet entsprechen. Die im Text der Lerneinheit neu verwendeten englischen Fachausdrücke werden am rechten Rand der Seite in einem Kurzwörterbuch (Words) mit deutscher Übersetzung genannt. Dadurch ist ein zügiges Erarbeiten des Textes und der Inhalte ohne Umblättern oder zeitraubendes Suchen in einem Wörterbuch oder einem Übersetzungsprogramm des Internets möglich. Der Lernende kann sich voll auf das Verstehen des Textes konzentrieren.

Jede Lerneinheit des Buches enthält vielfältige Übungen (Exercises) mit unterschiedlichem Schwierigkeitsgrad zu den technischen Inhalten der Lerneinheit. Mit ihrer Hilfe kann die Englischkompetenz zum Sachthema vertieft und/oder geprüft werden. Die Aufgabentypen decken auch Teilkompetenzen (Comprehension, Writing, Mediation) ab, die zur Vorbereitung der KMK-Zertifikatsprüfung Englisch dienen können.

Am Ende des Buches befindet sich ein **Dictionary Englisch – Deutsch** sowie ein **Wörterbuch Deutsch – Englisch** mit sämtlichen im Buch verwendeten Fachwörtern. Dies ermöglicht auch die Bearbeitung fremder Texte zu den im Buch behandelten Sachgebieten.

Die Englischschreibung entspricht dem **britischen Englisch.**

In der vorliegenden 2. Auflage wurde ein Anhang eingefügt (Seite 102). Er enthält die englischen Zahlwörter, Ordnungs-, Dezimal- und Bruchzahlen sowie die mathematischen Operatoren.

Die Autoren und der Verlag sind allen Nutzern des Buches für kritisch-konstruktive Hinweise und Verbesserungsvorschläge dankbar. Bitte senden Sie Ihre Hinweise per E-Mail an: Lektorat@europa-lehrmittel.de.

Sommer 2018 Die Autoren, der Verlag

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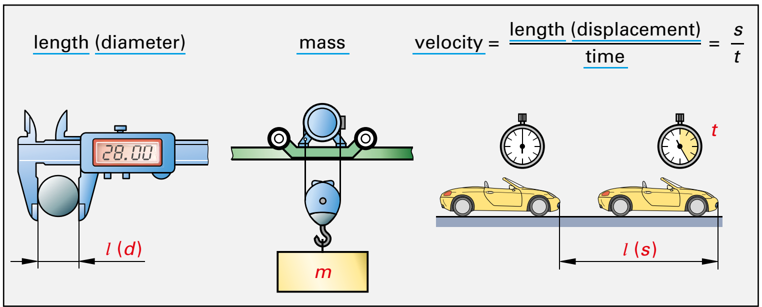
1 Measuring technique

1.1 Physical quantities and units

The properties, states and processes of an object, which can be measured, are called physical quantities **(figure)**.



Base quantities

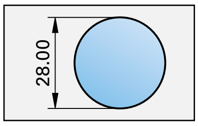
The base quantities are described in accordance to DIN 1304 by a defined symbol (quantity symbol), for example *l* for length, *s* for displacement, *m* for mass, *t* for time, *I* for electric current, *T* for temperature and so on.

The value of a physical quantity is written in abbreviated form by a letter and equals the product of a numerical value and a unit.

Example:

A workpiece has a diameter *d* of 28.00 mm **(figure):** ⇒ ***d* = 28.00 mm**

The expression consists of:



d physical quantity (*d* stands for diameter)

28.00 numerical value

mm unit for length (mm stands for millimeter)

Units

Every physical quantity has a certain unit. The International System of Units SI is based on seven basic quantities **(table)**. These basic quantities cannot be transferred into another quantity.

They form the basis for other derived quantities.

Table: Base quantities and base units in accordance to SI

Base quantity	Quantity symbol	Base unit	
		Name	Symbol
Length	*l*, *d*, *s*	metre	m
Mass	*m*	kilogram	kg
Time	*t*	second	s
Electric current	*I*	Ampere	A
Temperature	*T*	Kelvin	K
Amount of substance	*n*	mole	mol
Luminous intensity	I_v	Candela	cd

Words

English	German
measuring technique	Messtechnik
physical quantity(-ies)	physikalische Größe(n)
unit	Einheit
property (-ies)	Eigenschaft(en)
state	Zustand
process	Vorgang
length	Länge
diameter	Durchmesser
mass	Masse
velocity	Geschwindigkeit
time	Zeit
displacement	Weg, Strecke
base quantity	Basiseinheit
to describe	bezeichnen
in accordance	gemäß
defined	festgelegt
electric current	Elektrischer Strom
value	Wert
abbreviated form	Kurzform
letter	Buchstabe
to equal	gleichen
product	Produkt
numerical value	Zahlenwert
example	Beispiel
workpiece	Werkstück
diameter	Durchmesser
expression	Ausdruck
System of Units SI	SI-Einheitensystem
to base on	basieren auf
table	Tabelle
to transfer	umrechnen
derived quantity	abgeleitete Größe
quantity symbol	Formelzeichen
amount of substance	Stoffmenge
luminous intensity	Lichtstärke
second	Sekunde
speed	Geschwindigkeit
to define	definieren
to answer	beantworten
following	folgende
questions	Fragen

Exercises

1. Working with words. Which words from the text are described here?
   a) Every material has certain ________________ for example it can be very hard.
   b) In order to find out the correct diameter of a workpiece, you need to ______________ it with an instrument.
   c) The speed of a car is also called _________________________.
2. Define physical quantities in German by using the information from the text above.
3. Answer the following questions in English.
   a) Which two elements does a physical quantity have? Find an example to explain it.
   b) Which 7 base quantities does the International System of Units IS define?
   c) What is the difference between base quantities and derived quantities?

Prefixes

It is easier to use decimal multiples or factors in front of units to avoid very high or low values **(table).**

Example: The length of a shaft is 0.030 m.

The prefix milli (m) is added: $l = 30.00$ mm

Table: Prefixes for decimal multiples and factors of units

Prefix		Meaning	Factor
M	mega	millionfold	10^6 = 1 000 000
k	kilo	thousandfold	10^3 = 1 000
h	hecto	hundredfold	10^2 = 100
da	deca	tenfold	10^1 = 10
d	deci	tenth	10^{-1} = 0.1
c	centi	hundredth	10^{-2} = 0.01
m	milli	thousandth	10^{-3} = 0.001
µ	micro	millionth	10^{-6} = 0.000 001

Derived quantities and units

Derived quantities are needed to describe physical properties of materials or processes in machines and production. The derived units are determined by a formula and consist of two or more base units **(table).**

Table: Examples for derived quantities and units

Derived quantity	Derived unit	Unit symbol	Relationship (formula)	Definition of the derived unit
Volumen V	Cubic meter	m^3	$V = l \cdot b \cdot h$ $[V] = 1\ m \cdot 1\ m \cdot 1\ m = 1\ m^3$	One cubic metre
Force F	Newton	N	$F = m \cdot a$ $[F] = 1\ N = 1\ \frac{kg \cdot m}{s^2}$	One kilogram times metre **per (over)** square second
Work W	Joule	J	$W = F \cdot s$ $[W] = 1\ N \cdot m$	One Newton times one meter

Example: The volume is calculated by the formula $V = l \cdot b \cdot h$

The volume equals the length times the width, times the height (e.g. $V = 2\ m \cdot 3\ m \cdot 4\ m = 24\ m^3$)

The unit of the volume V results from inserting the base units into the formula:

$[V] = [l] \cdot [b] \cdot [h] = m \cdot m \cdot m = m^3$ (cubic metre)

Imperial Units

Imperial units (Non SI-Units) are used in Great Britain and in the USA. This is a traditional measuring system, in which short distance units are based on standardised dimensions of the human body, e.g. one inch represents the width of a thumb. The foot (= 12 inches) is the length of a human foot. These countries have also different units for weight, mass and temperature.

The imperial units can be converted into the SI-Units.

Example: 1 inch (*in*/″) = 25.4 mm — 1 pound (*pd*) = 453.6 g
1 foot (*ft*) = 0.3048 m — 1 barrel (*bl*) = 158.8 dm^3
1 mile (*mi*) = 1.609 km — 1° Fahrenheit (*F*) = –17.77 °C

Words

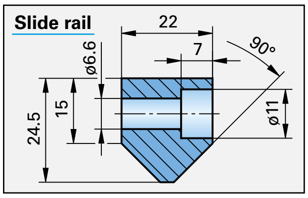
English	German
prefix	Vorsatz
decimal multiples	dezimale Vielfache
in front of	vor
to avoid	vermeiden
high	groß, hoch
low	niedrig
millionfold	Millionenfaches
tenth	Zehntel
shaft	Welle
to add	hinzufügen
to need	benötigen
process	Prozess
to determine	bestimmen
formula	Formel
to consist of	bestehen aus
relationship	Beziehung
times	multipliziert mit (mal)
per (over)	dividiert durch
force	Kraft
square second	Quadrat Sekunde
times	mal
work	Arbeit
to calculate	berechnen
equals	entspricht, ist gleich
width	Breite
height	Höhe
to result	(sich) ergeben
to insert	einsetzen
imperial unit	britisch-amerikanische Maßeinheit
bar	Stange
Great Britain	Großbritannien
standardised dimension	festgelegtes Maß
human body	menschlicher Körper
e. g. (for example)	z. B. (zum Beispiel)
thumb	Daumen
foot	Fuß
weight	Gewicht
to convert	umrechnen
tension	Spannung
pressure	Druck
rod	Stab
density	Dichte
turning tool	Drehmeißel
feed velocity	Vorschub-geschwindigkeit

Exercises

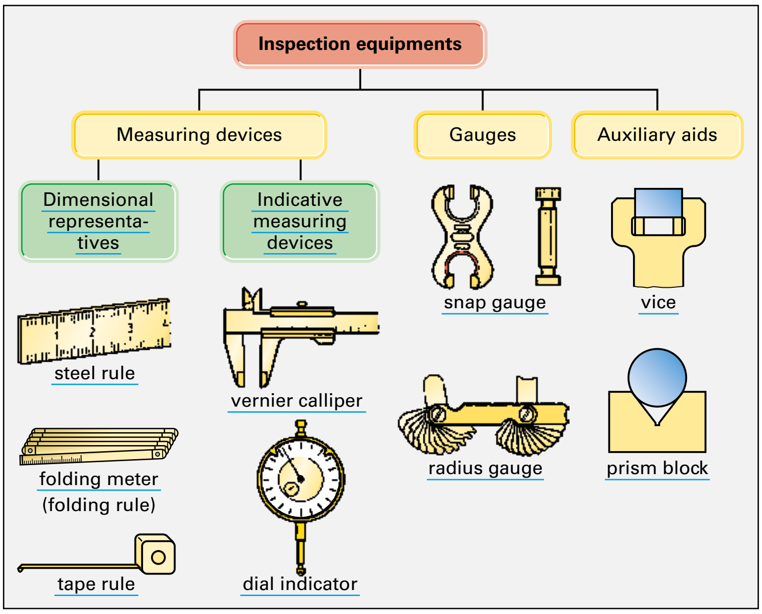
1. Write down the formula and explain the correct derived units. (Use your **Metal Trades Handbook**)
   a) pressure p b) velocity v c) density ϱ
   d) tension σ e) electrical energy W f) frequency f
2. Convert the measurements from imperial units into metric units. (Use your **Handbook**)
   a) 120 miles in km b) 3,300 ft in metres c) $1\frac{1}{2}$ pints in litres
   d) 4.5 ounces in kilogram e) $\frac{1}{8}$ inch in mm f) 22.5 pounds in kg
3. Calculate the physical quantities by using SI-Units.
   a) A compact disc (CD) has a diameter of 120 mm. Calculate the area in mm^2.
   b) The volume of a steel rod is 0.5 dm^3 and has a density of 7.85 kg/dm^3. Calculate the mass in kg.
   c) A turning tool moves 9.3 cm in a time of 3 seconds. Calculate the feed velocity in mm/s.

1.2 Fundamentals of measuring technique

If components are produced in a workshop, e.g. a slide rail **(figure)**, the dimensions of the workpiece must be given precisely. Important dimensions of the slide rail are the length of 22 mm, the height of 24.5 mm, the angle of 90° and the internal diameters of 6.6 mm and 11 mm.



In order to measure these features, different inspection aids are needed **(figure).** They can be divided into three main categories: measuring devices, gauges and auxiliary aids.



With some measuring devices you compare a certain dimension, such as the height of 24.5 mm with a scale of a measuring device. These instruments are called dimensional representations, e.g. steel rules or folding meter.

If you read the dimension from a scale of the measuring device you use an indicative measuring device, such as a vernier calliper, a protractor, or a micrometer.

With gauges you can test e.g. the diameter of a ∅ 6.6 mm hole (bore) with a plug limit gauge, or you can check the radius of R9 by a radius gauge.

Words (English)	Words (German)
fundamentals	Grundlagen
measuring technique	Messtechnik
component	Bauteil
workshop	Werkstatt
slide rail	Führungsschiene
precise	präzise, genau
important	wichtig
angle	Winkel
internal diameter	Innendurchmesser
feature	Größe
different	unterschiedlich
inspection aid	Messmittel
to divide	unterscheiden
category (-ies)	Bereich, Kategorie
measuring device	Messgerät
gauge	Lehre
auxiliary aid	Hilfsmittel
dimensional representative	Maßverkörperung
indicative measuring devices	anzeigende Messgeräte
steel rule	Stahlmaßstab
folding meter (folding rule)	Gliedermaßstab
tape rule	Bandmaßstab
vernier calliper	Messschieber
dial indicator	Messuhr
snap gauge	Rachenlehre
radius gauge	Radienlehre
vice	Schraubstock
prism block	Prisma, V-Block
to compare	vergleichen
scale	Skala
protractor	Universalwinkelmesser
micrometer	Bügelmessschraube
to test	prüfen
hole (bore)	Loch/Bohrung
plug limit gauge	Grenzlehrdorn
groove	Nut
result	Ergebnis

Exercises

1. Translate the following inspection aids and name the main group of these devices.
   a) plug limit gauge b) prism block c) folding rule
   d) micrometer e) snap gauge f) vernier calliper
2. Name the correct inspection aid to find out these measurements.
   a) the diameter of a shaft of 22 mm b) the length of a rail of 1.80 m c) the angle of 120°
   d) the hole of ∅ 20 mm e) the depth of 10 mm of a groove f) the radius R5
3. Answer the questions in English.
   a) What are dimensional representatives?
   b) Which result do you get when you use a gauge? Give an example.
   c) Which result do you get when you use an indicative measuring device? Give an example.
   d) When do you need an auxiliary help? Give an example.

Measuring errors

The indicated values of a measuring instrument are afflicted with different measuring errors. The errors can be caused by:

– Deviation of the standard temperature of 20 °C

Operator variations:

– thin workpieces could be deformed by a high measuring force
– parallax error is due to the incorrect eye position when reading the scale

Measuring errors can be divided into two categories:
Systematic errors: They are caused by constant variations, such as the temperature in the workshop, the measuring force or an inaccurate scale or wear of the measuring instrument. Systematic errors can be avoided by eliminating the cause of the error, such as a proper calibration of the measuring instrument.

Random errors are caused by unknown variations, such as an unintended change in temperature or measuring force or parallax error. They can be reduced by repeating the measurement for a few times and using a calculated mean value.

Measuring capability

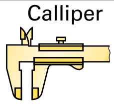
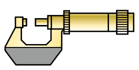
If you need to measure a workpiece, it is difficult to know which measuring instrument should be used. The correct choice of measuring device saves time, money and can provide you with an accurate result.

The choice of a suitable measuring instrument for a certain measuring task depends on the required accuracy and the dimension of the workpiece.

By using your Metal Trade Handbook **(extract in the table)** you can find out the uncertainty and the range of the instrument.

Example:
The uncertainty of mechanical measuring instruments is one scale interval. Digital measuring instruments have an uncertainty of three numerical intervals.

Table: Range of measuring and uncertainty of measuring instruments

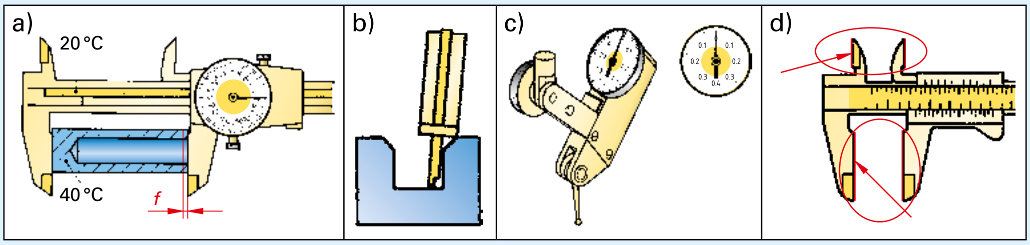
Measuring instrument	Measuring range	Measuring uncertainty
Calliper  Scale interval 0.05 mm	0...150 mm	$U \geq 50$ µm = 0.05 mm
Micrometer  Scale interval 0.01 mm	50...75 mm	$U = 10$ µm = 0.01 mm

Words

English	German
measuring error	Messfehler
indicated value	angezeigter Wert
to be afflicted with	mit etwas behaftet sein
deviation	Abweichung
operator variation	Ableserabweichung
thin	dünn
to be deformed	verformt sein
measuring force	Messkraft
parallax error	Parallaxefehler
to be due to	bedingt werden durch
reading	Ablesung
systematic error	systematischer Messfehler
to be caused by	verursacht werden von
inaccurate	ungenau
wear	Abnutzung/Verschleiß
to avoid	vermeiden
to eliminate	beseitigen
calibration	Kalibrierung, Einstellung
random error	zufälliger Messfehler
unknown	unbekannt
unintended	unbeabsichtigt
repeating	wiederholen
mean value	Mittelwert
measuring capability	Messfähigkeit
choice	Auswahl
measuring device	Messgerät
to save	sparen
to provide	liefern
accurate result	genaues Ergebnis
the choice	die Auswahl
suitable	geeignet
measuring task	Messaufgabe
uncertainty	Unsicherheit
required	gefordert
range	Messbereich
scale interval	Skalenteilungswert
numerical interval	Ziffernschrittwert
to match	zuordnen
common	üblich

Exercises

1. Match the pictures a) – d) to the type of measuring error (1) – (4). Explain if it is a systematic or a random error.



Type of measuring error: (1) parallax error (2) wear of measuring surfaces
(3) bad positioning of device (4) high temperature

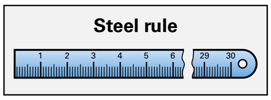
2. Make a list of six common measuring devices (e.g. steel rule, vernier calliper, gauge block, dial gauge protractor, etc) and find out their type of inspection aid/range/accuracy.
(Use a webpage of a company for measuring devices e.g. www.mitutoyo.com; www.mahr.de; www.hoffmann.de).

Measuring device	Type of inspection aid	Range	Accuracy
steel rule	dimensional representative	150 – 1000 mm	0.5/1 mm
...	...	...	...

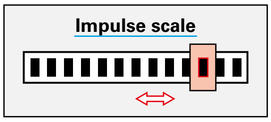
1.3 Length Measuring Instruments

For measuring the length of a workpiece, there is a variety of test instruments with different degrees of accuracy. You can measure the length with a rule or a tape rule and check the size with a gauge or a gauge block.

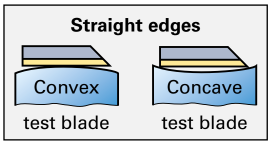
Rules (figure) represent the length measurement by the distance of little lines on a scale. There are different types of rules available: flexible steel rules, tape rules or folding meters.



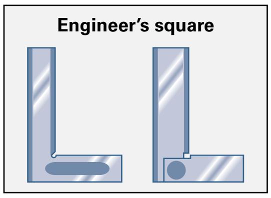
Scales (figure) for the position measurement systems are made of glass or steel and are operated by the photoelectronic scanning principle. When parallel light passes through a scale, light and dark surfaces are projected at a certain distance and signals are generated.



Straight edges (figure) are used to check the straightness and flatness. They have lapped test blades with a high flatness. These accurate test blades enable the naked eye to realize different tiny light gaps. The light gap between the test blade and the workpiece could be as small as 2 µm.



Engineer's squares (figure) are form gauges and represent mostly an angle of 90°. They are used to check the perpendicularity and flatness of surfaces. Besides, cylindrical or flat surfaces can be adjusted.



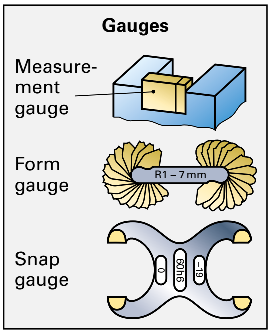
The measuring tubes can have dimensions up to 100 × 70 mm with a class of accuracy of 00. The limit of perpendicularity deviation is only 3 µm.

Gauges represent certain dimensions or geometric forms **(figure).**

Measurement gauges come in sets, e.g. gauge blocks or test pins.

Form gauges can check angles, radii and threads using the light gap method.

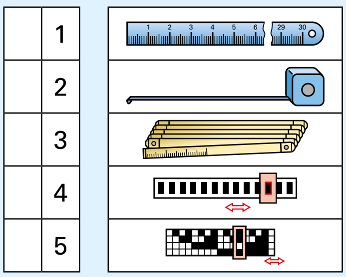
Plug gauges and **snap gauges** represent the admissible maximum and minimum limit dimension. Some gauges represent also the form, e.g. to test the cylindrical form of a bore as well as the dimension of the hole.



Words (English)	Words (German)
degree of accuracy	Genauigkeitsgrad
rule	Lineal
tape rule	Maßband
size	Größe
gauge	Lehre
gauge block	Endmaß
to represent	darstellen
distance	Entfernung
folding meter	Meterstab
scale	Maßstab
position measurement system	Wegmesssystem
to operate	bedienen, arbeiten
scanning principle	Abtast-Prinzip
impulse scale	Impulsmaßstab
light	hell
dark	dunkel
surface	Fläche/Feld
to project	projizieren
to generate	erzeugen
straight edge	Haarlineal
straightness	Geradheit
flatness	Ebenheit
lapped	geläppt
test blade	Messfläche
naked eye	mit bloßem Auge
tiny	winzig
light gap	Lichtspalt
engineer's square	Haarwinkel
perpendicularity	Rechtwinkligkeit
to adjust	einstellen
measuring tube	Messschenkel
class of accuracy	Genauigkeitsklasse
test pin	Prüfstift
thread	Gewinde
plug gauge	Lehrdorn
snap gauge	Rachenlehre
admissible	zulässig
absolute scale	Absolutmaßstab
to mention	nennen

Exercises

1. Match the correct expression of the following measuring devices to the pictures at the right.
   a) absolute scale b) flexible steel rule c) tape rule
   d) folding rule e) impulse scale



2. Answer the questions below in English.
   a) What is the difference between measuring instruments and gauges?
   b) Why do straight edges and engineer's squares have lapped test blades?
   c) What can you check with straight edges?
   d) What is the light gap method?
   e) Mention 3 different types of gauges and choose a certain measurement of a workpiece which can be checked by them.

Working with plug gauges, snap gauges and gauge blocks

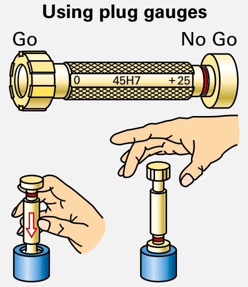
The specified limits of bores of toleranced workpieces can be checked by plug gauges. Snap gauges or ring gauges are used to test the specified limits of shafts.

Plug gauges (figure)

When using a cylindrical plug gauge, the diameter of one side, the Go should enter while the No Go should fail to enter the hole. As a result, it is stated to be within the specified limits.

Cylindrical plug gauges are made from alloyed steel or tungsten carbide. They are ground and lapped. They can be produced to any size up to 250 mm diameter.

Using plug gauges

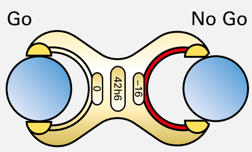


The Go side should slide into the bore by its own weight. A minimal insertion of the No Go gauge may be tolerated at the entry fit. The Go side is longer and often has carbide inserts to reduce the wear of the surface. The No Go side is shorter, marked with a red ring and shows the maximum limit size.

Snap gauges (figure)

The Go side represents the maximum limit size. It must slide over the measured surface by its own weight. The No Go member is smaller and should fail to slide over the surface. It has slightly angled measuring surfaces, which are red and show the minimum limit size.

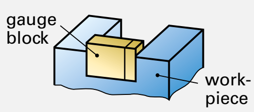
Using a snap gauge



Gauge blocks

Gauge blocks are the most important and precise dimensional representations. They are usually made in sets of rectangular, square or angular steel blocks or ceramic blocks **(figure)**. Each block has two opposite faces lapped flat and parallel to a definite size within an extremely tight tolerance. In order to assemble a gauge block stack of a certain size, you first write down the correct combination of gauge blocks for these dimensions. Tip: start with the smallest available gauge block.

Using a gauge block



Example: Assemble a gauge block stack for the dimension: 57.005 mm.

Careful: There is no gauge block of 0.005 mm. It would break!

Gauge block combination	
1. Gauge block	1.005 mm
2. Gauge block	6.000 mm
3. Gauge block	50.000 mm
Total dimension	57.005 mm

Words (English)	Words (German)
plug gauge	Grenzlehrdorn
snap gauge	Grenzrachenlehre
gauge block	Endmaß
specified limit	Grenzmaße
ring gauge	Lehrring
shaft	Welle
diameter	Durchmesser
Go side	Gutseite
to enter	eindringen
No Go side	Ausschussseite
to fail	scheitern
result	Ergebnis
to state	feststellen
alloyed steel	legierter Stahl
tungsten carbide	Wolframkarbid, Hartmetall
to grind, ground	schleifen, geschliffen
to lap	läppen
to slide	gleiten
own weight	Eigengewicht
minimal insertion	Anschnäbelung
to tolerate	tolerieren
entry fit	Ansatz-Passung
carbide insert	Hartmetalleinsatz
wear	Abnutzung, Verschleiß
surface	Oberfläche
to designate	beschriften
maximum limit size	Höchst-Grenzmaß
slightly angled	leicht angeschrägt
rectangular	viereckig
square	quadratisch
angular	winkelig
opposite	gegenüberliegend
definite size	bestimmte Größe
tight	eng
to assemble	zusammenstellen
gauge block stack	Endmaßstapel
available	verfügbar
to tick	ankreuzen
mating	passend
to create	herstellen

Exercises

1. Find the correct answer of the questions and tick it in the table below ✓

a) A tolerance is a …	clearance between a shaft/mating bore	measurement error	variation in manufacturing
b) Which of the following statement of plug gauges is true (only 1)?	The Go side is smaller than the No Go side of the plug gauge.	Only slight pressure is needed to slide the Go member into the bore.	The No Go member is designated with the minimum limit size.
c) Which of the following statement of snap gauges is true (only 1)?	The Go member should fail to slide into the bore.	The Go member is marked in red.	The Go member doesn't represent the minimum limit size.

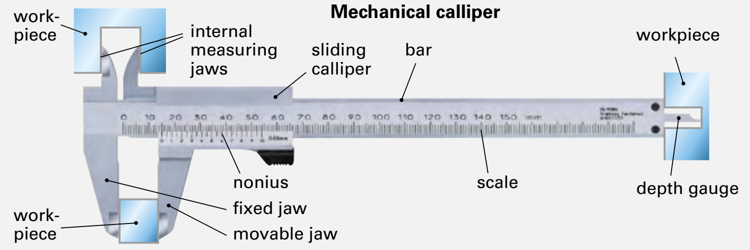
2. Create a stack of gauge blocks and write down the combination of blocks.
   a) 42.123 mm   b) 74.357 mm   c) 81.685 mm

1.4 Vernier calliper

The vernier calliper, also called sliding calliper or shortly calliper, is the most common precision measuring instrument used in mechanical engineering. It can be used to measure internal and external measures as well as the depth of e.g. holes or grooves of parts. There are mechanical and digital callipers. The mechanical calliper is more difficult to read. A digital calliper has a display to show the measurement.

The mechanical calliper, used in Germany and in other countries of the EU, has a metric scale with $^1/_{10}$, $^1/_{20}$ or $^1/_{50}$ mm nonius. In the United Kingdom and USA, it has an imperial scale with an inch nonius.

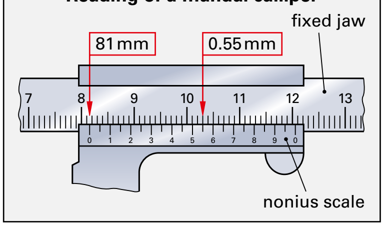
A mechanical calliper consists of a bar which shows the amount of millimetres **(figure).** It has two jaws; a movable jaw and a fixed measuring jaw. The workpiece is placed between the fixed and movable jaw.



Mechanical calliper

The depth of a workpiece can be checked by the depth gauge. The width of a groove can be measured by the internal measuring jaws.

The reading of a mechanical calliper is a little difficult. When you want to find out the exact value, shown on a mechanical calliper, first read the millimeter mark on the scale of the fixed jaw: 81 mm **(figure).** Then look along the ten marks on the scale of the movable jaw and the millimeter marks on the adjacent fixed scale, until you find the two marks that line up: 0.55 mm. To get the correct reading, add the two values: 81 mm + 0.55 mm = 81.55 mm.

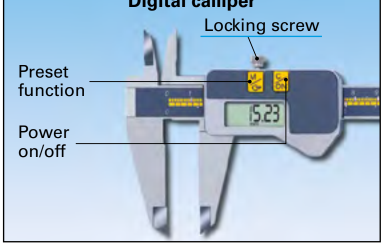


Reading of a manual calliper

Most common today is using a **digital calliper**. It shows the reading directly on the display **(figure).** It is much easier and faster to read. There are no errors in reading precise measuring values. The accuracy is between 0.01 mm to 0.02 mm.

Additionally, a digital calliper has certain functions:

- Choosing the reading in mm or inch.
- Reset the zero-point at any position.
- Presetting tolerances.
- Setting for absolute and comparison measurements.
- Possibility for a serial data output to be interfaced with a PC.



Digital calliper

Words	
vernier calliper	Messschieber
shortly	kurz
most common	gebräuchlichste(r)
mechanical engineering	Maschinenbau
internal measure	Innenmaß
external measure	Außenmaß
depth	Tiefe
groove	Nut
mechanical calliper	mechanischer Messschieber
display	Anzeige
nonius	Nonius
bar	Schiene
amount	Betrag, Anzahl
jaw	Schenkel
movable	beweglich
fixed	fest, fixiert
to place	platzieren
depth gauge	Tiefenmaß
reading	Ablesen, Ablesewert
mark	Markierung
adjacent	anschließend
to line up	übereinstimmen
digital calliper	digitaler Messschieber
accuracy	Genauigkeit
to choose	auswählen
to reset	zurücksetzen
presetting	Voreinstellung
locking screw	Feststellschraube
comparison measurement	Unterschiedsmessung
to interface	verbinden
least	wenigsten(s)
thickness	Dicke
possible	möglich(e)
nowadays	heutzutage

Exercises

1. Five of the following six statements are wrong. Find these statements and correct them.
   a) A vernier calliper is the least frequently used measuring device in the workshop.
   b) A calliper can measure diameters of bores and shafts, the width and thickness of a part.
   c) There are three different types of callipers: manual, digital and CNC callipers.
   d) With the aid of a $^1/_{20}$ nonius a measuring of 0.02 mm is possible.
   e) Measurements of 0.001 inch, 0.01, 0.02 and 0.05 mm are also possible.
   f) Digital callipers are easier to read, cheaper and more often used nowadays.
2. Translate the example of reading a mechanical calliper into German.

1.5 Micrometer (screw gauge)

The micrometer can be used to measure even smaller dimensions than the vernier callipers. There are mechanical and digital micrometers.

The **mechanical micrometer (figure below the page)** has a main scale for reading the millimeters and an auxiliary scale for measuring hundredths of a millimeter. The auxiliary scale is on a rotary thimble. The main scale is on the sleeve of the micrometer. The basic structure of a micrometer is a screw with an accurately constant pitch. It is the amount by which the thimble moves forward or backward for one complete revolution.

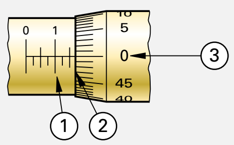
In order to measure a workpiece, the part is placed between the two measuring faces, the anvil and the spindle. These parts are connected by the frame, which is covered by an insulation plate. The thimble is rotated using the ratchet until the workpiece is secured. It is locked by three clicks of the ratchet before reading the measurement. The clicking noise comes from a little spring which is inside the ratchet. The lock may be used to ensure that the thimble does not rotate while you read the value.

Example of reading an imperial micrometer (figure):

First read the whole inch marking (1) and the 25 thousandth-markings (2) on the scale ⇒ **1 inch + 0.75 inch**
Then read the value (3) on the thimble.
⇒ **0.000 inch**

Finally add the three values:
1 inch + 0.75 inch + 0.000 inch
⇒ **1.750 inch**

Reading an imperial micrometer



The **digital micrometer** has a similar construction and mode of operation as the mechanical micrometer **(figure)**. The measuring is quicker. Errors don't appear as often because of the reading of the value on the display. It has an accuracy of 0.01 mm.

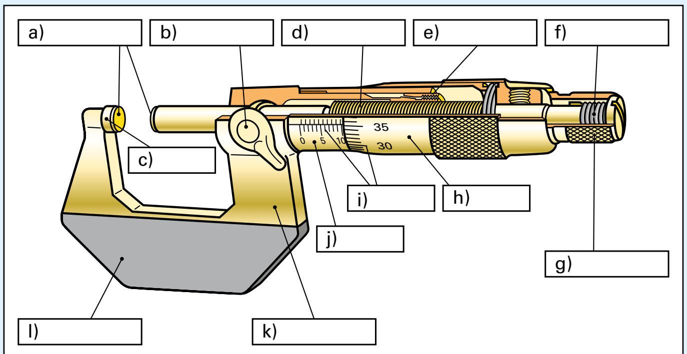
Digital micrometer

The digital micrometer has the same **additional functions** as the digital calliper:
- Readings can be displayed in mm and inches.
- Absolute and comparison measurements can be set.
- Tolerances can be preset, zero-point can be reset.

	Words	
micrometer/ screw gauge		Bügelmessschraube
auxiliary scale		Hilfsskala
rotary		drehbar
thimble		Skalentrommel
main scale		Hauptskale
sleeve		Skalenhülse
basic structure		grundsätzlicher Aufbau
screw		Schraube
pitch		(Gewinde-) Steigung
to move		bewegen
forward		vorwärts
backward		rückwärts
complete		ganz, vollständig
revolution		Umdrehung
measuring face		Messfläche
anvil		Amboss
spindle		Spindel
to connect		verbinden
frame		Bügel
insulation plate		Isolierplatte
ratchet		hier: Kupplung
to secure		fixieren
to lock		klemmen
noise		Geräusch
spring		Feder
lock		Spindelfeststellung
to ensure		sicherstellen
marking		Markierung
thousandth		Tausendstel
to add		addieren
similar		ähnlichen
construction		Aufbau
mode of operation		Betriebsweise
to appear		vorkommen
accurancy		Genauigkeit
to label		beschriften
sketch		Skizze, Zeichnung

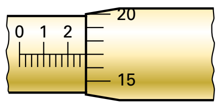
Exercises

1. Label the sketch of the mechanical micrometer a) to l) by reading the text above.

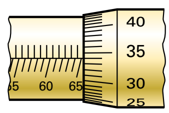


2. Read the correct measurements of the micrometers shown below.

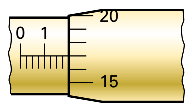
a) in inch



b) in mm



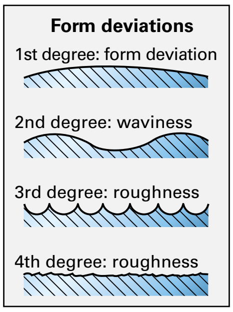
c) in inch



1.6 Surface testing

In industrial manufacturing the machined surface has a major influence on the quality and performance of the end product.

The surface texture of a workpiece is the deviation of a surface from its ideal shape e.g. perfect flat, cylindrical or spherical form. The measure of the surface texture indicates the form, the waviness and the roughness **(figure)**.



The **form deviation** (1st degree of deviation describes the straightness or roundness of the part. Deviations from the required form can result from clamping marks or wear in the guides of the machine tool.

Waviness (2nd degree deviation) usually relates to the characteristics of an individual machine or to external environmental factors. It may result from the machine itself, e.g. its vibrations.

The **roughness** (3rd/4th degree deviation), e.g. grooves or bumps result from the production process. It is influenced by the geometry or the material structure of the cutting tool and the feed or the depth of the tool.

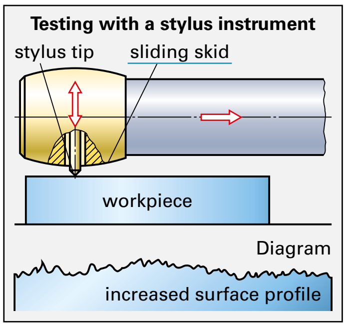
The irregularities of a surface can be checked by different measuring instruments. The output of these devices are certain profiles. The base of a roughness (R) and waviness (W) profile is the primary (P) profile.

Types of surface testing

Surface roughness comparators are used for touch and sight comparison. In order to get an accurate measuring result you need to use the same material of the test specimen and workpiece and the correct manufacturing technology, e.g. turning, milling, grinding etc.

You need to scrape the comparator specimen with your fingernail or use a small copper coin. Then you can compare the surface of the workpiece with the comparator specimen. If you compare it visually, you need an optimum light source angle or use a magnifying glass.

Stylus instruments are surface roughness testers, which record the peaks and valleys by a diamond stylus **(figure)**. The stylus is drawn at a constant speed across the workpiece. The amount to which the stylus is raised or lowered is printed in a diagram. It shows the increased surface profile.



Words (English)	Words (German)
machined surface	bearbeitete Oberfläche
major	bedeutend
influence	Einfluss
performance	Leistung
texture	Struktur
deviation	Abweichung
shape	Form
spherical	kugelförmig
to indicate	kennzeichnen
waviness	Welligkeit
roughness	Rauheit
degree	Grad
clamping mark	Einspannkratzer
wear	Abnutzung
guide	Führung
to relate to	zusammenhängen
characteristic	Kennzeichen
environmental	umgebungsbedingt
groove	Rille
bump	Erhebung
feed	Vorschub
depth	Tiefe (hier: Zustellung)
irregularity	Unregelmäßigkeit
output	Ausgabe
roughness comparator	Oberflächenvergleichsmuster
touch sight comparison	Tast-/Sichtvergleich
turning	Drehen
milling	Fräsen
grinding	Schleifen
to scrape	kratzen
fingernail	Fingernagel
copper coin	Kupfermünze
light source angle	Lichteinfallwinkel
magnifying glass	Lupe
stylus instrument	Tastschnittgerät
to record	aufzeichnen
peak	Spitze
valley	Tal
stylus	Tastnadel
to be drawn	gezogen werden
to raise	anheben
to lower	senken
sliding skid	Gleitkufe

Exercises

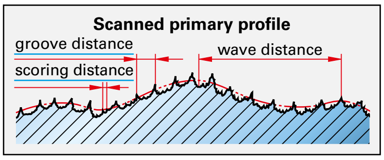
1. Complete the missing information about form deviations in the table.

Degrees of form deviation	Examples	Possible cause
1st degree: form deviation	...	...
...	waves	...
3rd degree: roughness	...	...
...	...	Sequence of chip formation surface deformation during fabrication

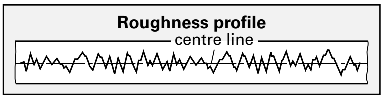
2. Answer the questions in English.
   a) Which surface testing instrument is very quick and easy to use? Why?
   b) Explain why you can compare the surface roughness visually and by touching.
   c) Describe how a stylus instrument works.

Surface texture parameters

The scanned primary profile **(figure)** shows the total heights of a surface.



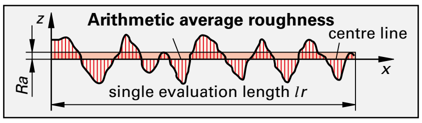
Filtering the primary profile (P-profile) leads to the roughness profile (R-profile) and the waviness profile (W-profile).



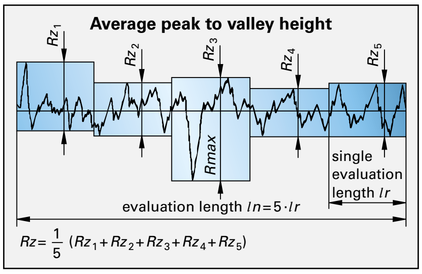
The R-profile **(figure)** shows the peaks, the valleys around a centre line.

The surface texture parameters are mostly calculated by the R-profile. There are several surface parameters:
$\boldsymbol{R_z}$ is widely used in Europe, $\boldsymbol{R_a}$ is the most specified U.S. parameter. Another parameter is $\boldsymbol{R_{max}}$ (maximum peak to valley height).

$\boldsymbol{R_a}$ (arithmetic average roughness) considers all peaks and valleys of the roughness profile **(figure)**. One deep scratch in material is neutralised and has no significant influence on the final result.



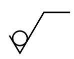
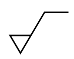
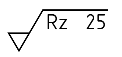
$\boldsymbol{R_z}$ (average peak to valley height) considers only the five highest peaks and the five deepest valleys **(figure)**. Extremes have a much greater influence on the final result. The complete evaluation length is divided into 5 cut-offs. In each cut-off the highest distance between peak and valley is a value (R_{z1}–R_{z5}).



$\boldsymbol{R_{max}}$ (maximum peak to valley height) is the maximum height of the five values in the sampling length.

The surface parameters are shown in technical drawings by symbols **(table)**. To achieve a very high surface texture you need to choose the correct type of manufacturing. In your *Metal Trades Handbook* are tables to choose the correct manufacturing technology.

Table: Surface finish symbols

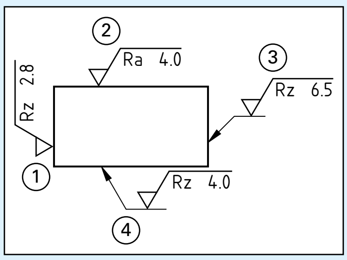
Symbol	Meaning
	All manufacturing processes are allowed
	Material removal not allowed or surface remains in delivered condition
	Material removal specified, e.g. turning, milling
	Material removal machining R_z = 25 µm

Achievable $\boldsymbol{R_z}$-values:
Grinding: R_z = 1.6–4 µm
Milling: R_z = 10–63 µm
Drilling: R_z = 40–160 µm

Words	
surface texture parameter	Oberflächenkenngröße
to scan	abtasten
primary profile	Primärprofil
total height	Gesamthöhe
groove distance	Rillenabstand
wave distance	Wellenabstand
scoring distance	Riefenabstand
roughness profile	Rauheitsprofil
waviness profile	Welligkeitsprofil
peak	Spitze
valley	Tal
centre line	Mittellinie
specified	vorgeschriebene
arithmetic average roughness R_a	Mittelrauwert R_a
to consider	berücksichtigen
scratch	Kratzer
to neutralise	ausgleichen
significant	bedeutend
final result	Endergebnis
average peak to valley height R_z	Mittlere Rautiefe R_z
extreme	Grenzwert
evaluation length	Messstrecke
cut-off	Einzelmessstrecke
maximum peak to valley height R_{max}	Maximale Rautiefe R_{max}
technical drawing	technische Zeichnung
to achieve	erreichen
to choose	wählen
type of manufacturing	Fertigungsverfahren
grinding	Schleifen
milling	Fräsen
drilling	Bohren
material removal	Materialabtrag
to allow	erlauben
to remain	verbleiben
delivered	angeliefert
reliable	zuverlässig

Exercises

1. Answer the questions in English.
   a) Which surface texture parameters are often used in USA and which in Germany?
   b) Explain the difference between the surface parameter R_{max} and R_z.
   c) Why is the surface texture parameter R_{max} not a very reliable value?
   d) Explain the surface texture parameter R_a.
2. Name the type of surface parameters and its value of the positions (1) to (4) shown in the right figure.
3. Draw a roughness profile and add the three parameters: R_{max}, $R_{z1\text{-}z5}$ and R_a.



1.7 Fits

A fit is the dimensional relationship of two mating construction components. The components have the same nominal size at the fitting location. They differ in the quantity and range of the tolerance.

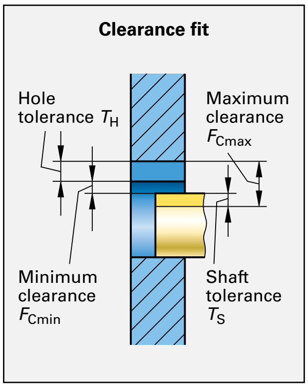
There are three different kinds of fits, depending on the dimensional difference between the matching components. The choice of the different fit is determined either by the use or by the production of the parts.

Clearance fit (figure)

Clearance fit always enables some space between the hole and shaft. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

The maximum clearance (F_{Cmax}) equals the hole maximum dimension (G_{UH}) minus the shaft minimum dimension (G_{IS}).

⇒ $F_{Cmax} = G_{UH} - G_{IS}$

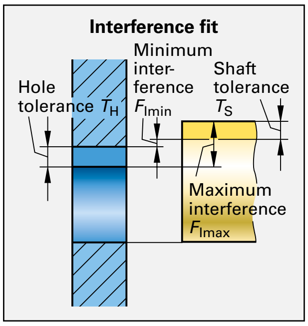


The minimum clearance (F_{Cmin}) is calculated by the hole minimum dimension (G_{IH}) minus the shaft maximum dimension (G_{US}).

⇒ $F_{Cmin} = G_{IH} - G_{US}$

Interference fit (figure)

It is a type of fit which always has some excess material between the hole and shaft. The upper limit size of the hole is smaller or at least equal to the lower limit size of the shaft.



The maximum interference (F_{Imax}) is calculated by the hole minimum dimension (G_{IH}) minus the shaft maximum dimension (G_{US}).

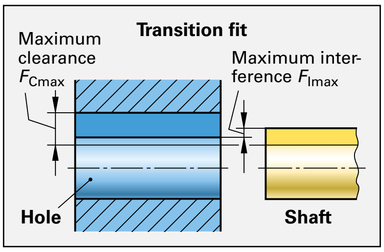
⇒ $F_{Imax} = G_{IH} - G_{US}$

The minimum clearance (F_{Cmin}) equals the hole maximum dimension (G_{UH}) minus the shaft minimum dimension (G_{IS}).

⇒ $F_{Imin} = G_{UH} - G_{IS}$

Transition fit (figure)

It is a fit where both types of fit may occur. The tolerance zones of the hole and shaft partly or completely interfere. There can be a clearance fit or an interference fit.



Words (English)	Words (German)
fit	Passung
dimensional relationship	Größenbeziehung
mating	passend
construction component	Bauteil
nominal size	Nenngröße
to differ	sich unterscheiden
range	Spannweite
tolerance	Toleranz
to depend on	abhängig sein von
difference	Unterschied
matching	zusammengehörend
choice	(Aus-)wahl
to determine	bestimmen
use	Einsatz
production	Herstellbarkeit
clearance fit	Spielpassung
to enable	ermöglichen
space	Spiel/Raum
hole	Bohrung
shaft	Welle
lower limit size	Mindestmaß
at least	mindestens
upper limit size	Höchstmaß
hole max. dimension	Höchstmaß Bohrung
shaft max. dimension	Höchstmaß Welle
hole minimum dimension	Mindestmaß Bohrung
shaft minimum dimension	Mindestmaß Welle
interference fit	Übermaßpassung
excess	Überschuss
transition fit	Übergangspassung
to occur	vorkommen
to interfere	überlagern
criteria	Kriterium
to select	auswählen
expression	Begriff
abbreviation	Abkürzung

Exercises

1. Answer the following questions in English.
   a) What is a fit?
   b) Which two criterias are given to select the type of fit?
   c) What are the dimensions of the hole and shaft, when a clearance fit is given?
   d) Which three types of fits are possible? Explain!

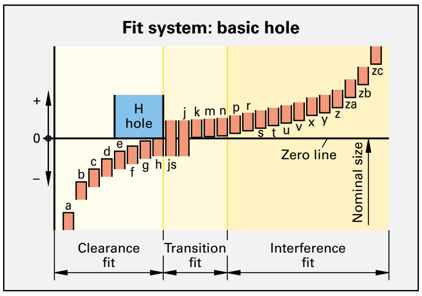
2. Find the correct expressions and match them to the abbreviation.
   a) F_{Imin}/F_{Imax}
   b) G_{IH}/G_{UH}
   c) T_H/T_S
   d) G_{IS}/G_{US}
   e) F_{Cmin}/F_{Cmax}

1.8 Fit Systems

Fit systems are needed to limit the amount of tolerances of two mating parts. In a fit system one of the parts is produced with a basic tolerance and the other part has the tolerance according to the specific fit system.

Fit system: Basic hole system

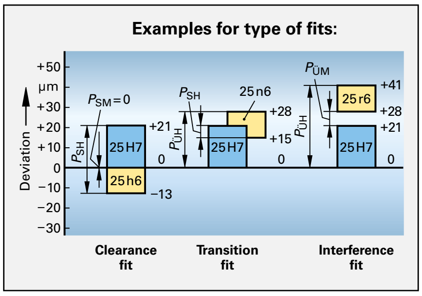
When the basic hole system is used, the diameter of the hole is produced with the fundamental deviation H **(figure)**. The basic hole system is attached to different basic sizes of the shaft, e.g. d, e or k, m. The basic hole system is widely used in mechanical engineering and in the automotive industry.



Range for type of fits

There are three general type of fits according to the different basic sizes of the shaft **(figure beside)**.

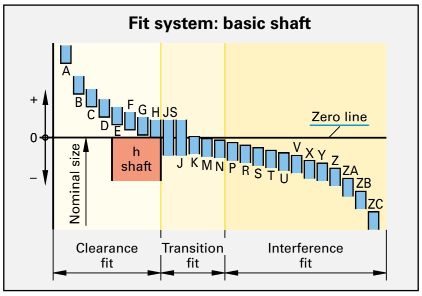
Clearance fits: H/a…h
Transition fits: H/j…n or p
Interference fits: H/n or p…z



Fit system: Basic shaft system

When the basic shaft system is applied, all shaft dimensions have the fundamental deviation h **(figure)**, e.g. clearance fit: h/A…H

The basic shaft system is used for shafts that are produced in standard sizes; the mating hole must be calculated.



Words	
fit system	Passungssystem
to limit	begrenzen
mating	passend
basic tolerance	Grundtoleranz
diameter	Durchmesser
basic hole system	Einheitsbohrung
fundamental deviation	Grundabmaß
to attach	zuordnen
basic size	Grundabmaß
widely	weitgehend
mechanical engineering	Maschinenbau
automotive industry	Automobilindustrie
according	entsprechend
range for type of fits	Bereiche der Passungsarten
basic shaft system	Einheitswelle
to apply	anwenden
zero line	Nulllinie
standard size	Normgröße
to create	erzeugen
nominal size	Nennmaß
letters	Buchstaben
to determine	bestimmen
required	erforderlich

Range for the type of fits

The different type of fits are achieved by different fundamental deviations of the hole.

Clearance fits: h/A…H   Transition fits: h/J…N or P   Interference fits: h/N or P…Z

Example of the calculation of a fit:

Which important values need to be calculated to create a fit of 8.2 H7/d9?

Use the tables of a ***Metal Trades Handbook*** *to look up the different limits of the shaft and hole.*

8.2 H7/d9 ⇒ clearance fit   Nominal size $N = 8.2$ mm

Hole limits: maximum dimension (G_{UH}) = 8.215mm; minimum dimension (G_{IH}) = 8.200 mm

Shaft limits: maximum dimension (G_{US}) = 8.160 mm; minimum dimension (G_{IS}) = 8.124 mm

Clearance limits: Maximum clearance (F_{Cmax}) = $G_{UH} - G_{IS}$ = 8.215 mm − 8.124 mm = 0.091 mm

Minimum clearance (F_{Cmin}) = $G_{IH} - G_{US}$ = 8.200 mm − 8.160 mm = 0.040 mm

Exercises

1. Answer the questions in German.
   a) Which difference do the two basic systems have?
   b) Where is the basic hole system used?
   c) Which letters are used in the basic hole system for interference fits?

2. Determine the type of fit of the following fits:
   a) 8H9/d9   b) 24H7/s6   c) 9K7/h6   d) 153 H11/c11

3. a) Read the required values for the fit of Nr. 2 a) to d) from a **Metal Trades Handbook**.
   b) Calculate the maximum and minimum clearance or interference, by using your **Metal Trade Handbook.**

2 Quality management

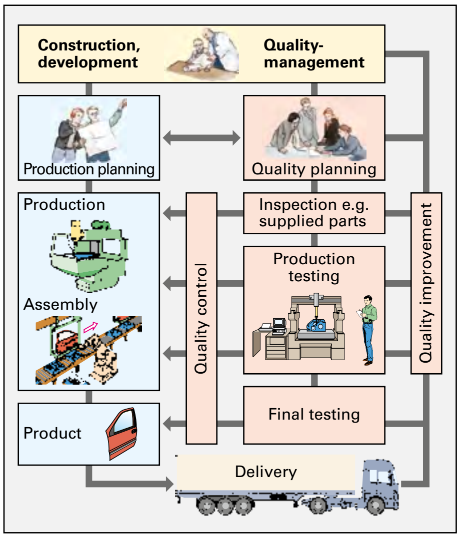
2.1 Basics of quality management

If a company wants to be successful on the market, the product quality must match the satisfaction of the customer. Customer's requirements are e.g. an appealing design, performance, functionality, reliability, maintainability and a good customer service.

Therefore, many companies have become certified and implemented a quality management system according to ISO 9000 standards.

Operating areas of quality management

Modern quality management encompasses all activities in a company, e.g. quality planning, quality control, quality assurance and quality improvement **(figure).**



It is carried out successfully if all employees follow the guidelines of the ISO standards. In this way the quality of work processes can be controlled. Errors can be detected as early as possible so that production costs can be decreased.

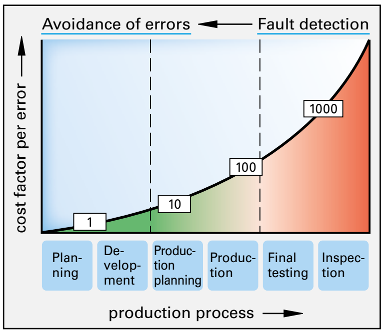
Quality characteristics and errors

There are two different categories of quality characteristics:

- **Quantitative (variable) characteristics**
  can be measured or counted, e.g. the length of a workpiece or the diameter of a shaft.
- **Qualitative (attributive) characteristics**
  describe a quality, e.g. the quality of the painting of a vehicle.

Errors are present when one or more quality requirements are not fulfilled, e.g. a dimension is not correct or there is a malfunction in production.

The 1-10-100 rule **(figure)** states that when a product moves through a production sequence, the cost of correcting an error multiplies by 10 from stage to stage.



Words	
quality management	Qualitätsmanagement
successful	erfolgreich
to match	erfüllen
satisfaction	Zufriedenheit
customer	Kunde
requirement	Anforderung
appealing	ansprechend
performance	Leistungsfähigkeit
reliability	Zuverlässigkeit
maintainability	Instandhaltungsfähigkeit
customer service	Kundendienst
to certify	zertifizieren
to implement	umsetzen
operating area	Arbeitsbereich
to encompass	umfassen
quality assurance	Qualitätssicherung
quality improvement	Qualitätsverbesserung
to carry out	durchführen
employee	Arbeitnehmer
guideline	Richtlinie
error	Fehler
to detect	erkennen
to decrease	vermindern
quality characteristics	Qualitätsmerkmale
quantitative	mengenmäßig
present	vorhanden
to fulfill	erfüllen
malfunction	Störung
to state	aussagen
sequence	Abfolge
to correct	korrigieren
to multiply by	multiplizieren mit
stage	Phase
avoidance of error	Fehlervermeidung
fault detection	Fehlerentdeckung

Exercises

1. Working with words. Which words from the text are described here?
   a) If the product looks really good, the design is very ______________.
   b) If the device runs without a problem for a long time, it is very ______________.
   c) If the product can be used in many different ways, the ______________ is very high.
2. Translate the definition of quantitative and qualitative characteristics.
3. Answer the following questions in English.
   a) Which 3 quality characteristics (= requirement of the customer) should your next smart phone have?
   b) Which system supports the quality process in companies?
   c) What does the 1-10-100 rule describe?
   d) Which different stages appear in a product circle?

2.2 Quality tools

In order to fulfill the quality requirements in a company, quality tools are used. They are often graphical aids, such as diagrams and charts, because they are easy to understand for the staff members and give a quick overview about the process or the measuring results. Besides, the employees are involved in the improvement process.

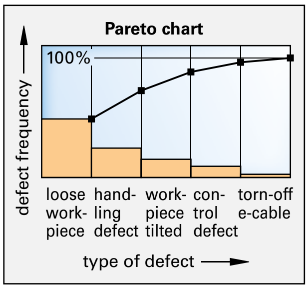
Graphical aids

The **defect chart** is a simple method to list and detect different errors in a production process **(figure)**. The tally marks of the errors are sorted and counted up. This information forms the base for the Pareto analysis.

Defect chart

Type of defect	Oct.	Nov.	Dec.	Σ
workpiece tilted	𝍸𝍷𝍷𝍷	𝍷𝍷𝍷	𝍸𝍷𝍷	18
handling defect	𝍸𝍸𝍷	𝍸𝍸𝍷𝍷	𝍸𝍸𝍸	38
control defect	𝍷𝍷𝍷	𝍷𝍷𝍷𝍷	𝍷𝍷	9
loose workpiece	𝍸𝍸𝍸𝍷	𝍸𝍸𝍸𝍷𝍷	𝍸𝍸𝍷𝍷	45
torn-off e-cable		𝍷		1
Total defects	38	37	36	111

The **Pareto chart** shows the frequency of different defects **(figure)**. They are sorted by their importance. The bars indicate the type and the frequency of the defects. The line displays the cumulative total of the errors. The purpose of the chart is to highlight the most freuently occurring error. It gives an idea of which problems should be solved immediately to improve the process most efficiently.



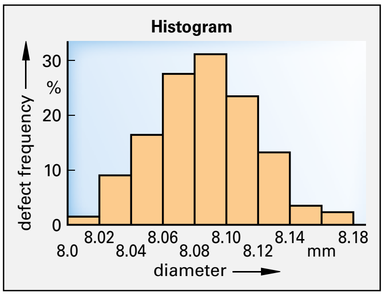
The **cause-and-effect diagram**, also called fishbone chart or Ishikawa diagram is used to find the causes of problems. It combines the techniques of brainstorming with a type of mind map. It considers all possible causes of a problem rather than just the ones that are most obvious. The main branches of the fishbone-skeleton are for example the 6 Ms: **m**anpower, **m**achine, **m**ethod, **m**aterial, **m**ilieu, **m**easurement.

In order to draw a histogram, a **tally sheet** to summarise data is used **(figure)**. In a tally sheet all the classes with their values are listed. The tally marks are added, sorted according to the values and counted up.

Tally sheet (extract)

class nr.	measured value *D* in mm	frequency	Σ
1	8.00 – 8.02	𝍷	1
2	8.02 – 8.04	𝍸𝍷𝍷𝍷𝍷	9
3	8.04 – 8.06	𝍸𝍸𝍸𝍷	16

The **histogram** is a bar chart and shows the distribution of measured results **(figure)**. It indicates the frequency of data within a range of values, called a class. The frequency of the data that falls in each class is displayed by the height of the bar.



Words

quality tools	Qualitätswerkzeuge
requirement	Anforderung
graphical aids	zeichnerische Hilfsmittel
chart	Schaubild
staff member	Mitarbeiter
employee	Arbeitnehmer
to be involved	miteinbezogen sein
improvement	Verbesserung
defect chart	Fehlersammelliste
to list	aufführen
to detect	erkennen
tally marks	Zählstriche
Pareto analysis	Paretoanalyse
frequency	Häufigkeit
importance	Wichtigkeit
bar	Balken
cumulative total	kumulierte Gesamtzahl
purpose	Zweck
to highlight	hervortreten
to occur	auftreten
immediately	sofort
cause-and-effect diagram	Ursache-Wirkungs-Diagramm
fishbone	Fischgräte
brainstorming	Ideensammlung
mind map	Gedankenstütze
cause	Ursache
obvious	offensichtlich
main branch	Hauptast
skeleton	Skelett
manpower	Arbeitskraft
histogram	Histogramm
tally sheet	Strichliste
to summarise	zusammenfassen
to count up	aufaddieren
bar chart	Säulendiagramm
distribution	Verteilung
frequency	Häufigkeit
range	Spannweite
to display	anzeigen

Exercises

1. Answer the questions:
   a) Which two type of graphs are used in a Pareto chart?
   b) Why is the Ishikawa diagram also fishbone diagram?
   c) What is meant by the 6 Ms?
   d) Which function has a tally sheet?
   e) What is shown in a histogram?
   f) What shows the height of a bar in a histogram?
2. Draw a histogram on an extra sheet of paper by using the data below.

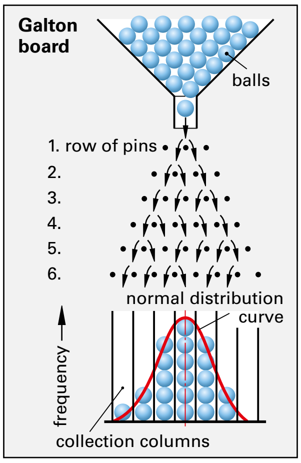
Length of the shaft in mm

Measured values	14.990	14.995	15.000	15.005	15.010	15.015	15.020	15.025	15.030	15.035
Frequency n_j	2	5	10	13	15	16	13	9	6	3

2.3 Normal distribution

If you look at nature or your working environment you realise that the values of some quantities do not have all an exact number, e.g. the height of humans or the measured size of produced components. Their values are distributed around a mean value.

The mathematician *Carl Friedrich Gauss* recognised, that data, which only depends on random influences is distributed in a certain way. It is called normal distribution or Gaussian distribution.

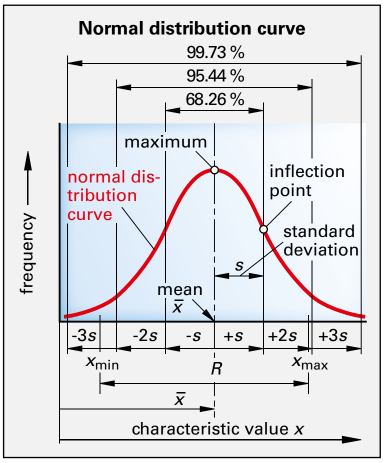


Another scientist, *Francis Galton*, demonstrated this phenomenon by a machine called the Galton board **(figure).**

The machine consists of a vertical board with rows of pins, which are arranged in staggered order. The front of the device is covered with a glass pane to allow watching the different paths of the balls. Then balls are dropped from the top, and bounce randomly either to the left side or the right side as they touch the pins. At the end, they are collected into one-ball-wide columns at the bottom.

The different heights of the ball columns show a curve in the shape of a bell. It is named the bell curve, the Gaussian distribution curve or the normal distribution curve.

The **normal distribution curve** is reached when measured data values are only influenced by random parameters.



The curve is symmetrical with a maximum at the mean value, decreasing to both sides **(figure).** They have an inflection point at each side.

The bell-shaped curve is defined by two characteristic parameters:

a) The mean $\bar{x}$ at the peak of the curve.

b) The standard deviation *s* represents the distance from the mean to the inflection point and shows how values deviate from the mean.

The height of the normal distribution curve characterizes the frequency of the values. The area below the curve from –*s* to +*s* includes 68.28 % of the values, from –2*s* to +2*s* there are 95.44 %.

Words	
normal distribution	Normalverteilung
working environment	Arbeitsumfeld
quantity	Mengen
number	Wert
height	Größe
human	Mensch
to distribute	verteilen
random influences	zufällige Einflüsse
normal distribution	Normalverteilung
Gaussian distribution	Gauß'sche Verteilung
scientist	Wissenschaftler
phenomenon	Phänomen
Galton board	Galton Brett
row of pins	Nagelreihe
staggered order	versetzt angeordnet
front	Vorderseite
device	Gerät
to cover	bedecken
glass pane	Glasscheibe
to allow	erlauben
path	Weg, Pfad
to drop	herunterfallen
top	oberes Ende
to bounce	abprallen
randomly	zufallsbedingt
to touch	berühren
to collect	sammeln
bottom	unteres Ende
shape of a bell	Glockenform
to decrease	abnehmen
inflection point	Wendepunkt
application	Anwendung
to propose	aufstellen
mean	Mittelwert
peak	Höchstwert
standard deviation	Standardabweichung
bell-shaped curve	Glockenkurve
to deviate	abweichen
frequency	Häufigkeit
construction	Aufbau
procedure	Durchführung
result	Ergebnis

Exercises

1. Give three examples of nature or technology in which data can be normally distributed.
2. Explain the experimental principle of a Galton board in German. Use the following structure:
   a) Construction of the board b) Experimental procedure c) Experimental result
3. Translate the sentences according the normal distribution into English:
   a) Die Normalverteilung entsteht, wenn viele zufallsbedingte Einflüsse wirksam sind.
   b) Sie zeigt eine typische Glockenkurve der Häufigkeit über dem Merkmal $\bar{x}$.
   c) Der Mittelwert $\bar{x}$ liegt beim Kurvenmaximum und zeigt die Lage der Verteilung.
   d) Die Standardabweichung kennzeichnet die Streuung, d. h. die Verteilung um den Mittelwert.