MEM12023A

Perform engineering measurements

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Unit Resource Manual

Manufacturing Skills Australia Courses

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Aims of the Competency Unit:

This unit covers performing measurement skills requiring straightforward use of mechanical measuring devices and associated calculations.

This unit covers straightforward measurement using devices which incorporate visual indications representing units of measurement.

It applies to the use of measuring devices in a range of manufacturing, engineering and related environments. It includes, where required, adjustment of measuring devices through simple means and typically includes zeroing or scale adjustment.

Measurements may be expressed in metric or imperial units. All measurements are undertaken to standard operating procedures. Electrical/electronic devices used are those not requiring the connection or disconnection of circuitry.

Unit Hours:

45 Hours

Prerequisites:

None.

Elements and Performance Criteria

1.	Select appropriate device or equipment	1.1	Measurement requirements are determined from specifications.
		1.2	Appropriate device or equipment is selected according to standard operating procedures, to achieve required outcome.
2.	Obtain measurements using a range of measuring devices	2.1	Correct and appropriate measuring technique is used.
		2.2	Measurements are accurately obtained .
		2.3	Dimensions are determined or verified using basic calculations, where required.
3.	Seek opportunities to improve environmental practices and resource efficiency.	3.1	Routine care and storage of devices is undertaken to manufacturers' specifications or standard operating procedures.
		3.2	Routine adjustments to devices are made and checked.
4.	Communicate measurements as required	4.1	Measurements are accurately recorded, where required.
		4.2	Freehand sketch which depicts required information is prepared, as required.

Required Skills and Knowledge

Required skills include:

- selecting the appropriate measuring device for given measuring tasks
- using appropriate measuring technique
- reading all measurements taken accurately to the finest graduation of the selected measuring device
- handling and storing measuring devices in accordance with manufacturers' specifications or standard operating procedures
- verifying all measuring devices before use
- making, where appropriate, routine adjustments to measuring devices
- reading, interpreting and following information on written job instructions, specifications, standard operating procedures, charts, lists, drawings and other applicable reference documents
- planning and sequencing operations
- checking and clarifying task related information
- checking for conformance to specifications
- undertaking numerical operations involving addition, subtraction, multiplication, division, fractions and decimals within the scope of this unit
- preparing drawings as required

Required knowledge includes:

- correct application of a range of measuring devices
- correct and appropriate measuring technique for a range of measuring devices
- addition, subtraction, multiplication, division, fractions, decimals to the scope required by this unit
- procedures for handling and storing a range of measuring devices
- procedures for adjusting and zeroing a range of measuring devices
- methods of communicating measurements by drawings, as required
- safe work practices and procedures

Range Statement:

Specifications	Drawings, sketches, job instructions, schematics, diagrams, technical manuals.
Range of measuring devices	Protractors, combination squares, set squares, dial indicators, thermometers, tapes, rules, micrometres, Vernier -scaled measuring equipment.
Basic calculations	Calculations needed to assist in determining measurements where a reading of the graduated device is not sufficient, for example subtracting one measurement from another to give a third measurement. Examples of calculations needed are addition, subtraction, multiplication, division, fractions and decimals. Calculations may be made using a calculator.
Routine adjustments	Validating the device using simple zeroing or scale adjustment.
Measurements	Measuring length, squareness, flatness, angle, roundness, clearances or any other measurements that can be read off analogue, digital or other measuring device.
Information	Dimensions, instructions, base line or datum points.

Lesson Program:

Topic	Skill Practice Exercise
Topic 1 – Measuring Devices:	MEM12023-RQ-0101
Topic 2 – Measurement Practices:	MEM12023-RQ-0201
Topic 3 – Rulers:	MEM12023-RQ-0301
Topic 4 – Micrometres:	MEM12023-RQ-0401
Topic 5 – Vernier Callipers:	MEM12023-RQ-0501
Topic 6 – Gauges:	MEM12023-RQ-0601
Topic 7 – Dumpy Level:	MEM12023-RQ-0701
Topic 8 – Combination Square:	MEM12023-RQ-0801
Topic 9 – Ancillary Measuring Equipment:	MEM12023-RQ-0901 MEM12023-SP-0902
Topic 10 – Hardness Testing:	
Practice Competency Test	MEM12023–PT-01

Contents:

Topic 1 – Measuring Devices:

Required Skills:

On completion of the session, the participants will be able to:

- Identify guiding principles to good measurement practice.
- Name the functions performed by measuring devices.
- List the advantages and disadvantages of analogue and digital measuring devices.
- Identify the errors associated with various measuring devices.

Required Knowledge:

- Different methods of measuring.
- Different types of measuring devices.

1.1 Introduction:

Tools for measuring weights and lengths were among the earliest tools invented by man. Primitive societies needed rudimentary measurement tools for many tasks: constructing dwellings of an appropriate size and shape, making weapons and shields, fashioning clothing, or bartering food or raw materials.

Among the earliest length measures was the foot, which varied depending on the location and era. For example, three different Greek standards are known: the Doric foot (327 mm), the Attic foot (333 mm in Aegina and 296 mm in Athens) and the Samian foot (349 mm). There were two common sizes for a "foot" - the foot of 246 to 252 mm based on a man's bare foot - the foot of 330 to 335 mm based on two hand measurements.

In the 11th, 12th and 13th century master builders carried their "foot" with them from job to job while many medieval towns had the yard or ell defined and affixed to the town hall or gate for reference. The first calibrated foot ruler, a measurement tool, was invented in 1675 by an unknown inventor. The French Revolution was first introduced to France in 1795 by Napoleon Bonaparte before being replaced by a similar method from 1815 until 1840 when the original and current system was reinstated.

The astronomer William Gascoigne devised an indicator that fitted to a telescope to measure the size of objects using a precision screw mechanism to accurately measure small lengths a rule was incapable of measuring.

Over the centuries and millennia, the methods for measuring objects have changed drastically. In the modern world, two systems of measurement are used; the "Imperial" system and the "Metric" system with the "Metric" system being used in the majority of countries throughout the world; the United States of America, the United Kingdom, Liberia and Burma are about the only countries not to have been "metricated". Due to these countries, it is important to be able to read Metric and Imperial measuring devices; many components in use may have been made before metrification and may need to have matching components fitted.

In the mid-1970's, all engineering measurements in Australia had fully converted from Imperial to the Metric S.I. Units. Most industries "hard converted", that is, the sizes of all dyes and equipment were altered to produce fully metric component, while a minority only "soft converted" or in other words, retained the imperial sizes and only changed the size on paper (catalogues, instruction sheets & manuals) to a metric equivalent, e.g. $^{3}/_{8}$" (9.525 mm) became 10 mm.

1.2 Good Measuring Practice:

There are six guiding principles to good measurement practice; they are:

- The Right Measurements: Measurements should only be made to satisfy agreed and well specified requirements.
- The Right Tools: Measurements should be made using equipment and methods that have been demonstrated to be fit for purpose.
- The Right People: Measurement staff should be competent, properly qualified and well informed.
- Regular Review: There should be both internal and independent assessment of the technical performance of all measurement facilities and procedures.
- Demonstratable Consistency: Measurements made in one location should be consistent with those made elsewhere.
- The Right Procedures: Well-defined procedures consistent with national or international standards should be in place for all measurements.

1.3 Measuring Devices:

Measuring devices are used for the measurement of certain physical quantity and are used frequently in our daily life for the measurement of various quantities such as length, weight, temperature, pressure, current, voltage etc. The instruments indicate the value of these quantities, based on which an understanding of the conditions, then make decisions and take appropriate actions.

There are two main types of the measuring instruments, analogue and digital. The analogue instruments indicate the magnitude of the quantity in the form of the pointer movement and usually indicate the values in whole numbers. Digital measuring instruments indicate the values of the quantity in numbers, which can be read easily read.

1.2.1 Analog V's Digital Measurements:

A great number of precision measuring tools are available as analog or digital versions. Analogue instruments indicate the magnitude of the quantity in the form of a pointer movement and usually indicate the values in the whole numbers, though one can get the readings up to one or two decimal places also. The readings taken in decimals places may not always be entirely correct, since some human error is always involved in reading. Analog readings can also consist of etched markings on a device that must be lined up and read-off.

The digital measuring instruments indicate the values of the quantity in digital format that is in numbers, which can be read easily. Operators do not need any prior training to read these instruments since they indicate the values directly in the numerical form. The displays can give the readings to one or more decimal places and since there is no human error involved in reading the instruments, they are more accurate than the analogue measuring instruments. Without sufficient experience and practice, errors will be made. A disadvantage to digital equipment is that the batteries will fail when there are no replacement batteries available.

Figure 1.1

Figure 1.2

Figure 1.1 shows an analog calliper while Figure 1.2 shows a digital calliper. The opening on each Vernier reads 37.99 mm; even in the reduced image the digital image can easily be read.

1.4 Functions of the Measuring Instruments:

Most of the measuring instruments indicate the value of parameter in the form of the indicator movement, which gives us the magnitude of that quantity; there are many other functions performed by the instruments as indicated below:

1.4.1 Indicating the Value of the Physical Quantity:

The instruments are calibrated against the standard values of the physical quantities. The movement of the pointer directly indicates the magnitude of the quantity, which can be whole numbers or also fractions. Digital instruments are becoming very popular, which indicate the values directly in numerical form and even in decimals thus making them easy to read and more accurate.

1.4.2 Measuring Instruments Used as the Controllers:

There are number of instruments that can be used as the controllers. For instance, when a certain value of the pressure is reached, the measuring instrument breaks the electrical circuit, which stops the running of compressor. Similarly, the thermostat starts or stops the compressor of the refrigeration system depending on the temperature achieved in the evaporator.

1.4.3 Recording the Data:

Some measuring instruments can also be used to record and also store the data. In this age of computerization storing the recorded data has become quite easy. There are number of instruments that are connected to the pen that moves on the paper. As the pointer of the instrument moves as per the changes in the magnitude of the quantity, the pen also moves on the paper making the graph against certain parameter like time. Attaching small memory to the PCB can also enable recording of the instruments in the chip.

1.4.4 Transmitting the Data:

The measuring instruments can also be used to transfer the data to some distant places. The instruments kept in unsafe locations like high temperature can be connected by wires and their output can be taken at some distant places which are safe for the human beings. The signal obtained from these instruments can also be used for operating some controls.

1.4.5 Do Calculations:

Some measuring instruments can also carry out a number of calculations like addition, subtraction, multiplication, division, etc. Some can also be used to find solutions to highly complex equations

1.5 Advantages and Disadvantages of the Digital Instruments:

In modern industrial workplaces, there is greater trend of using the digital instruments for measurement of all the important quantities like length, weight, pressure, vacuum, temperature, humidity, current, voltage, RPM. In the medical area, digital instruments are also available for measurement of the blood pressure, blood sugar level, heart beat rate, and others.

1.5.1 Advantages of Digital Instruments Over Analogue Instruments:

- They are very easy to read.
- Since there are very few moving parts in the electronic instruments, they are usually more accurate than the analogue instruments. Even the human error involved in reading these instruments is very less, which adds to the accuracy of digital instruments.
- The electronic items tend to be cheaper than the mechanical items.
- The data from the instruments can be recorded for future reference.
- The output of the digital devices can be obtained in the computer

1.5.2 Disadvantages of Digital Instruments:

- Sometimes they tend to indicate erratic values due to faulty electronic circuit or damaged display.

- In case of high humidity and corrosive atmosphere the internal parts may get damaged and indicate the faulty values.
- Sometimes these instruments show some readings even though there is no applied measurable parameter.
- Batteries invariably run flat when there are no replacement batteries available so the instrument is useless until a fresh supply is obtained.

On the whole, the advantages of the digital instruments outdo the disadvantages, which is why they have become highly popular. Digital instruments can be found in cars, air planes, motor cycles, boats, air ports, railway stations, public places etc. Digital clocks are one of the most widely used instruments for the personal use and also in public and private places. The trend is towards the digital instruments since they are convenient to use and are aesthetically pleasing.

1.6 Errors in Measuring Instruments:

When any physical quantities like temperature, pressure, voltage, current etc. are measured it is taken for granted that the instruments are accurate; very few people can imagine that there can be errors in the instrument they are using, but there are possibilities of errors in the measuring instruments especially the analogue instruments that indicate the magnitude or value by the movement of the pointer. There are three types of errors in the measuring instruments, assembly errors, environmental errors, and measurement errors.

1.6.1 Assembly Errors:

The assembly errors are the errors in the measuring instrument due to improper manufacturing of the instruments. Various components of the instrument are made separately and are then assembled; errors may exist in individual components or in the assembly of the components. If there are assembly errors in the instruments, the instrument will not provide the correct reading and users can do nothing to correct the error, but return it and have it replaced or repaired by a specialist technician.

Some of the possible assembly errors include:

1.6.1.1 Displaced Scale:

A displaced scale is the incorrect fitting of the measuring scale. For instance the zero of pointer may not coincide with actual zero on the scale. Sometimes the scale gets cracked, and displays faulty readings.

1.6.1.2 Non-uniform scale:

Sometimes the scale of the measuring instrument is not divided uniformly. In some part of the scale the markings may be too close and in other parts too far.

1.6.1.3 Bent Pointer:

A bent pointer occurs in many cases. The pointer may get bent in either horizontal direction or the vertical direction, in either case, is shows erroneous reading.

1.6.1.4 Manufacturing Errors in the Components:

The instruments are made up of a number of small components, which may be manufactured by different companies or industries; sometimes there are manufacturing errors in a number of the components like gears, levers, links, hinges etc.

Apart from the assembly and environmental errors there can be many other errors which may be very difficult to trace and predict; these are called as random errors. It is not possible to list all the random errors, but some of the prominent ones are:

- Frictional errors: There are number of moving mechanical parts in the analogue measuring instruments.
- Mechanical vibrations: When the instrument is used in vibrating place the parts of the instrument start vibrating giving faulty readings. Then there is backlash in movement, hysteresis of the elastic members, etc.

1.6.2 Environmental Errors:

Errors happen due to the environmental effects on the measuring device; temperature, light and heat are some of the effects. To avoid error, instruments must be kept in a remote place and by maintaining the atmospheric conditions as a whole. Many errors occur during measurement of a value. The following are the common measurement errors in measuring devices:

1.6.2.1 Static Error:

It arises due to the nature of the components of the measuring device; these errors are due to several environmental influences and other effects.

1.6.2.2 Characteristic Error:

It is the variation of the output of the measuring device to the standard device value. This is called as the characteristic error. Linearity, resolution and repeatability are some of the common characteristic errors.

1.6.2.3 Reading Error:

It occurs due to the faulty reading of the instrument by the human eye. Parallax error is the major error in measurement. Using a proper reflecting device would avoid such an error.

1.6.2.4 Loading Error:

Loading errors are very common in measurement. It occurs due to excessive loading on the measuring instrument. If the measuring device is deflected during the loading process it produces the loading error.

1.6.2.5 Dynamic Error:

Dynamic errors are time based errors. For instance, inertia, friction and other errors like velocity are very common time based errors. They can be classified into controllable and non-controllable errors.

1.6.2.6 Calibration error:

Calibration is the process where one instrument is compared with a standard instrument and the errors are found out. By using a standard instrument with error, a calibration error may develop in the apparatus.

1.6.3 Measurement Errors:

There are three types of random errors; mistakes, systematic errors and random errors.

1.6.3.1 Mistakes:

Typical mistakes include reading the wrong numbers from a tape measure, making a measurement with the tape snagged around some structure or reading the wrong values from a form when processing the measurements. Mistakes are sometimes called gross errors or blunders.

The procedures used for making measurements and then processing them to form a site plan should aim to remove mistakes and systematic errors. The effects of random error cannot be removed but it can be ensured that they are kept within acceptable limits.

There are two ways of getting rid of mistakes, avoid making them or find them during processing. It is usually better to avoid making mistakes at all, finding mistakes in processing means a repeat measurement must be made and having to repeat work is expensive.

1.6.3.2 Systematic Errors:

Systematic errors are ones that can be repeated and can be accounted for in processing. If a tape measure is calibrated against a known standard and finds that it always measures distances that are too long, the difference is a systematic error and can be removed when the measurements are processed.

1.6.3.3 Random Errors

A tape measurement made several times over a large distance while under the same conditions is unlikely to give exactly the same value for each measurement. Judgement of the tape reading will vary as will the tension on the tape depending on how hard it is pulled. If the mistakes and the systematic errors are removed then some variation in the repeated measurements will still be seen, this is called random error.

A random error is one whose value depends on chance and the analysis of random errors based on statistics. Tape and depth measurements are usually normally distributed, this means in practice that:

- Small errors occur frequently, large errors occur less frequently.
- Very large errors are likely to be mistakes
- Positive and negative errors of the same size are just as likely to happen.

In a set of measurements, called a sample, an average or mean value and standard deviation can be calculated. The standard deviation gives an indication of precision, the smaller the standard deviation the better quality the measurements.

1.7 Devices:

A measuring device is an instrument for measuring a physical quantity. In the physical sciences, quality assurance, and engineering, measurement is the activity of obtaining and comparing physical quantities of real-world objects and events. Established standard objects and events are used as units, and the process of measurement gives a number relating the item under study and the referenced unit of measurement. Measuring instruments, and formal test methods which define the instrument's use, are the means by which these relations of numbers are obtained. All measuring instruments are subject to varying degrees of instrument error and measurement uncertainty.

Scientists, engineers, technical officers, draftspersons and tradespersons use a vast range of instruments to perform their measurements; these instruments may range from simple objects such as rulers to electron microscopes and particle accelerators.

Measuring Devices used in Metal & Engineering fields can be classified into Common to All, Technical, Mechanical and Fabrication.

1.7.1 Measuring Devices Common to all Trade Disciplines:

1.7.1.1 – Rule/Ruler:

Is it a Rule or a Ruler? The Oxford dictionary defines a "rule" as "*a strip of wood or other rigid material used for measuring length or marking straight lines*" while it also defines a "ruler" as "*straight strip or cylinder of plastic, wood, metal, or other rigid material, typically marked at regular intervals and used to draw straight lines or measure distances*". Both names are correct and will be acceptable throughout this unit of competency; but for the sake of uniformity they will be referred to as rulers.

Since their first use, rulers have been made of many materials and in a wide range of sizes. Mechanical trades normally use 150 mm steel rulers, while welders could use 600 mm and 300 mm rulers or adjustable arc-rulers to mark-out around curves of any radius. Drafting operators could use plastic coated scale-rulers to measure off original drawings.

Rulers should be kept clean and dry to prevent staining the surface of the medium being measured. Transparent plastic rules can be easily scratched while the graduation marks on all rulers can be removed if drawing compasses are used to open to a specified radius.

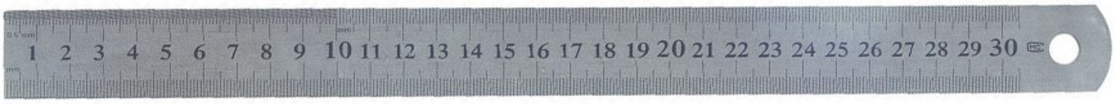


Figure 1.3

The ruler shown in Figure 1.3 is a 300 mm steel ruler; many rulers are produced displaying the major graduations in centimetres with the smaller graduations marked at 1 mm graduations.

Figure 1.4

Figure 1.5

Figure 1.4 shows a 150 mm steel ruler with the major graduations shown in millimetres. Steel rules are robust and very accurate. Figure 1.5 is an adjustable arc ruler and eliminates the need for a beam compass or expensive curve sets. It can be adjusted to any radius, from 150 mm to 5.0 m), to determine the radius of an existing curve for dimension drawings, to find centrelines and centre points, or determine what a curve must be to fair in existing points, or lines, on a drawing.

Figure 1.6

Figure 1.7

Figure 1.6 and Figure 1.7 are scale rules used by drafting officers, technicians, engineers and architects to produce scaled drawings. The rules are normally manufactured from white plastic with the markings in black. Various scales are represented on both sides of the rule as well as top and bottom edges; 2 scales are normally used on each edge. The rules are available as standard 2 sided rules, or, triangular shaped which gives an additional 4 scales.

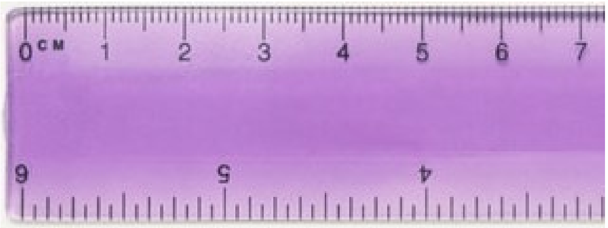


Figure 1.8

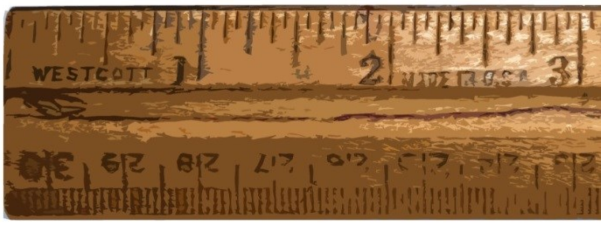


Figure 1.9

Figure 1.8 and Figure 1.9 are typical rulers used by school children; they are cheap and not as accurate as other rules and as such, are seldom used in a technical environment.

1.3.1.2 – Tapes:

A tape measure is a portable measurement device used to determine the size of an object or the distance between objects. Depending on the manufacturer and country of manufacture, the tape may be marked in metric units, or a combination of metric and imperial, or plain imperial units. Metric tapes are marked along the edges in un-numbered millimetres and numbered centimetres. Imperial markings use inches and fractional inches, typically in quarter- inch, eighth- inch and sixteenth-inch increments. Tape measures used in engineering are commonly 4 metre and 8 metres in length while in the building and surveying industries, cloth/fibreglass 33 metre wheel tapes are used.

Figure 1.10

Figure 1.11

Figure 1.10 shows a typical 8 metre tape used in engineering while Figure 1.11 shows a material/fibreglass wheel tape used by builders and surveyors.

Particular care should be taken with the use of metal tapes; each time the tape is used along the ground it should be dried as it is rewound. A light oiling helps prevent rusting. The tip may appear loose when played with but perform an important function when using the tape to measure internal and external distances. The tip is riveted onto the tape through slotted holes, the length of the slot being the same as the thickness of the metal tip. The slot allows the tip to move easily to give an accurate measurement.

A good quality tape is essential for use; metal tapes are somewhat flexible with slightly curved sides which makes them capable of remaining stiff and self-supporting when extended. Most tapes are 20 mm wide but 25 mm and 30 mm tapes can be purchased, the wider the tape the longer the tape becomes self-supporting.

1.3.1.3 – Protractor:

A protractor is a circular or semicircular measuring instrument, typically made of transparent plastic or glass, for measuring angles. Most protractors measure angles in degrees (°); radian-scale protractors measure angles in radians.

Protractors are used for a variety of mechanical and engineering-related applications, but perhaps the most common use is in geometry lessons in schools. Due to size of protractors (150 mm maximum radius) their accuracy is not sufficient in industrial applications and angles are often determined by vertical and horizontal distances.

Some protractors are simple half-discs. More advanced protractors, such as the bevel protractor, have one or two swinging arms, which can be used to help measure the angle.

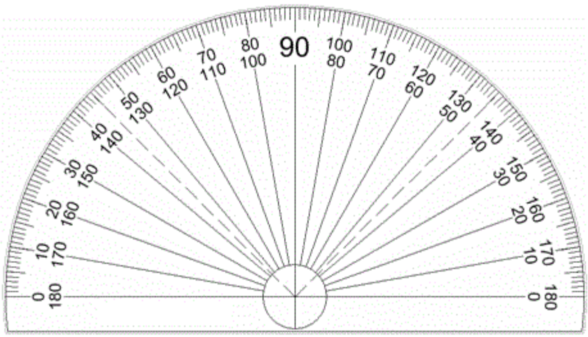


Figure 1.12

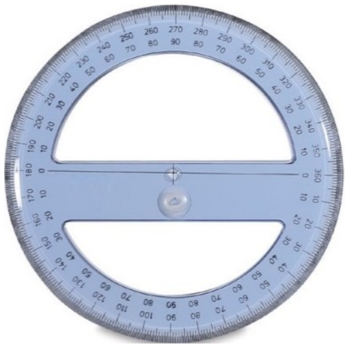


Figure 1.13

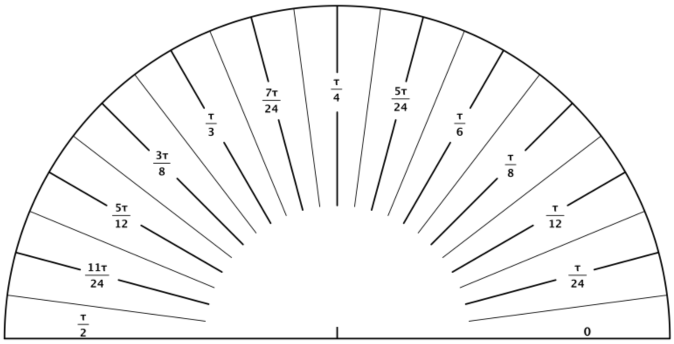


Figure 1.14

Figure 1.15

Figure 1.12 shows a 180° protractor while Figure 1.13 displays a 360° protractor. The radian protractor in Figure 1.14 is seen to differ from the standard protractors with the graduations being marked in algebraic style functions. Figure 1.15 is an example of a bevel protractor.

1.3.1.4 – Set Squares:

A set square is an object used in engineering and technical drawing, with the aim of providing a straightedge at a right angle or other particular planar angle to a baseline.

The simplest form of set square is a triangular piece of transparent plastic with the centre removed; before plastic, set squares were manufactured from polished timber or plywood. More commonly the set square bears the markings of a ruler and a half circle protractor with the outer edges being typically bevelled. Set squares are available in two usual forms, both right triangles: one with 90°-45°-45° angles, the other with 30°-60°-90° degree angles. Combining the two forms by placing the hypotenuses together will also yield 15° and 75° angles.

Less commonly found is the adjustable set square. Here, the body of the object is cut in half and re-joined with a hinge marked with angles. Adjustment to the marked angle will produce any desired angle up to a maximum of 180°.

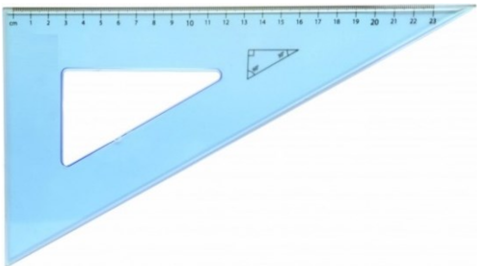


Figure 1.16

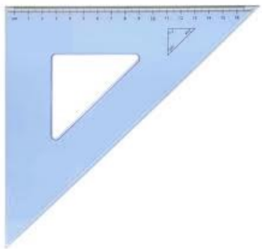


Figure 1.17

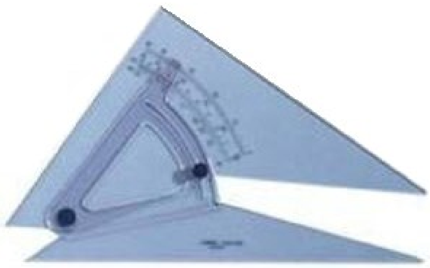


Figure 1.18

Figure 1.16 is a typical 60°-30° set square, Figure 1.17 is a 45° set square while Figure 1.18 is an adjustable bevel set square

1.3.1.5 – Thermometer:

The thermometer is a device that measures temperature or temperature gradient using a variety of different principles. A thermometer has two important elements: the temperature sensor (e.g. the bulb on a mercury-in-glass thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer).

Temperature sensors are used in a wide variety of scientific and engineering applications, especially measurement systems. Temperature systems are primarily either electrical or mechanical, occasionally inseparable from the system which they control (as in the case of a mercury-in-glass thermometer). Thermometers are used in roadways in cold weather climates to help determine if icing conditions exist. Indoors, thermistors are used in climate control systems such as air conditioners, freezers, heaters, refrigerators, and water heaters. Oceanologists record the different levels of sea temperature for research on current flow and effects of global warming.

Figure 1.19

Figure 1.20

Figure 1.21

1.7.2 Technical:

Technicians and engineers use a vast range of instruments to perform their measurements; these instruments may range from simple objects such as rulers and stopwatches to electron microscopes and particle accelerators. Typical applications of technical measuring equipment includes energy, time, electricity, water and gas flow, action, mechanics, length, area, volume, mass, linear momentum, force, pressure, angular velocity, torque, level, direction, magnetic field etc., the list is near endless. The following listed measuring devices are the more common types used in engineering:

1.7.2.1 – Dynamometer:

A dynamometer is a device for measuring force, moment of force (torque), or power. For example, the power produced by an engine, motor or other rotating prime mover can be calculated by simultaneously measuring torque and rotational speed (rpm). A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump. In that case, a motoring or driving dynamometer is used. A dynamometer that is designed to be driven is called an absorption or passive dynamometer. A dynamometer that can either drive or absorb is called a universal or active dynamometer.

1.7.2.2 – Planimeter:

The planimeter is a drafting instrument used to measure the area of a graphically represented planar region. The region being measured may have any irregular shape, making the instrument remarkably versatile. In modern age of CAD and digital images, the uses of the planimeter are limited and are heading toward obsolescence, but they are still being manufactured.

1.7.2.3 – Tachometer:

A tachometer, also known as a revolution-counter, is an instrument that that has a purpose of measuring the rotation speed of an engine, shaft or disc. Tachometers can be used in all types of engines and recording instruments.

Figure 1.22
Dynamometer

Figure 1.23
Planimeter

Figure 1.24
Tachometer

1.7.2.4 – Force Gauge:

A force gauge is a small measuring instrument used across all industries to measure the force during a push or pull test. Applications exist in research and development, laboratory, quality, production and field environment. Two kinds of force gauges are available; mechanical and digital force gauges.

1.7.2.5 – Barometer:

A barometer measures atmospheric pressure. The air in the atmosphere exerts a force called pressure that constantly changes due to moving weather systems; therefore, in conjunction with other meteorological instruments, this device can be used to help predict clear or rainy weather.

1.7.2.6 – Oscilloscope:

An oscilloscope is a diagnostic device that displays a time varying voltage. Oscilloscopes are used to view the signals coming directly from devices such as sound cards, allowing the real-time display of waves; they are used as electrocardiograms, to test circuits and to troubleshoot electronic devices such as televisions. Oscilloscopes with storage features allow signals to be captured, retrieved and analysed for later use.

Figure 1.25
Force Gauge

Figure 1.26
Barometer

Figure 1.27
Oscilloscope

1.7.2.7 – Electron Microscopy:

The surface roughness of a smooth surface is measured using an electron microscope which is a type of microscope that uses a beam of electrons to create an image of the specimen. It is capable of much higher magnifications and has a greater resolving power than a light microscope, allowing it to see much smaller objects in finer detail. The microscopes are large, expensive pieces of equipment, generally standing alone in a small, specially designed room and require trained personnel.

1.7.2.8 – Strain Gauge:

The electrical resistance of a length of wire varies in direct proportion to the change in any strain applied to it and is the principle upon which the strain gauge works. The most accurate way to measure this change in resistance is by using the Wheatstone bridge which is a balanced electrical circuit which displays any change on an indicator or feeds it into a process.

1.7.2.9 – Hydrometer:

A hydrometer is an instrument that measures the specific gravity of liquids. The specific gravity of a liquid is the density of that liquid divided by the density of water (in the same units). A hydrometer accomplishes this by measuring the amount of water it displaces. Hydrometers are commonly used by winemakers to determine the sugar content of wine, and they're also used in soil analysis.

1.7.2.10 – Material Hardness:

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. Brinell, Rockwell and Vickers hardness testers have been developed to measure the hardness of a wide range of materials. On completion of the test, the indentation is measured to determine the hardness factor.

Figure 1.28
Electron Microscope

Figure 1.29
Hydrometer

Figure 1.30
Material Hardness Testing

1.7.3 Mechanical:

1.7.3.1 – Micrometre:

A micrometre is a measuring tool for the accurate measurement of small distances, thicknesses, diameters, etc. The gap between the measuring faces is adjusted by a fine screw, the rotation of the screw giving a sensitive measure of the distance moved by the face with the distance being read from the sleeve and thimble.

1.7.3.2 – Vernier Calliper:

The Vernier Calliper are precision instruments used to measure internal and external distances with tremendous accuracy and are available in digital and manual types. Measurements are interpreted from the scale by the user. Manual Vernier Callipers are more difficult to read than a digital Vernier Calliper which has an LCD digital display on which the reading appears. The manual version has both an imperial and metric scale.

Digital versions require a small battery whereas the manual version does not need any power source; the disadvantage of the digital type is there of often times when a battery is dead, no replacement batteries are available.

1.7.3.3 – Dial Indicator:

In various disciplines of manufacturing such as machining, fabricating, and additive manufacturing, an indicator is any of various instruments used to accurately measure small distances and angles, and amplify them to make them more obvious. The name comes from the concept of indicating to the user that which their naked eye cannot discern; such as the presence, or exact quantity, of some small distance; for example, a small height difference between two flat surfaces, a slight lack of concentricity between two cylinders, or other small physical deviations.

Many indicators have a dial display, in which a needle points to graduations in a circular array around the dial. Such indicators, of which there are several types, therefore are often called dial indicators. Non-dial types of indicators include mechanical devices with cantilevered pointers and electronic devices with digital displays.

Indicators may be used to check the variation in tolerance during the inspection process of a machined part, measure the deflection of a beam or ring under laboratory conditions, as well as many other situations where a small measurement needs to be registered or indicated. Dial indicators typically measure ranges from 0.25 mm to 300mm, with graduations of 0.001mm to 0.01mm.

Figure 1.31
Micrometre

Figure 1.32
Vernier Calliper

Figure 1.33
Dial Indicator

1.7.3.4 – Torque Wrench:
A torque wrench is a tool used to precisely apply a specific torque to a fastener such as a nut or bolt and was designed to prevent over tightening bolts on engine head fastenings, water main and steam pipes. It is usually in the form of a socket wrench with special internal mechanisms.

A torque wrench is used where the tightness of screws and bolts is crucial. It allows the operator to measure the torque applied to the fastener so it can be matched to the specifications for a particular application; this permits accurate tension and loading of all parts. A torque wrench measures torque as a proxy for bolt tension. The technique suffers from inaccuracy due to inconsistent or uncalibrated friction between the fastener and its mating hole. Measuring bolt tension (bolt stretch) is more accurate but often torque is the only practical means of measurement.

1.7.3.5 – Feeler Gauge:
A feeler gauge is a tool used to measure gap widths. Feeler gauges are mostly used in engineering to measure the clearance between two parts. The gauges consist of a number of small lengths of steel of different thicknesses with measurements marked on each piece; they are flexible enough that, even if they are all on the same hinge, several can be stacked together to gauge intermediate values. Feeler gauges are manufactured in metric and imperial sizes. The lengths of steel are sometimes called leaves or blades, although they have no sharp edge.

1.7.3.6 – Bore Gauge:
A bore gauge is used to accurately measure the bore, or inside diameter of holes. A dial bore gauge is a special tool, calibrated in 0.025 millimetres or 0.0025 millimetre, which is used to accurately measure the inside diameter of a hole, cylinder or pipe. In conjunction with a micrometre, a bore gauge gives the exact reading of a bore size. A typical bore gauge is comprised of a shaft with a dial indicator at the top and a measuring sled at the base. The measuring sled consists of three guides and an actuating plunger. Dial bore gauges give quick and accurate readings on the size, less than perfect roundness or wear.

Figure 1.34
Torque Wrench

Figure 1.35
Feeler Gauge

Figure 1.36
Bore Gauge

1.7.3.7 – Surface Plate:

A surface plate is a solid, flat plate used as the main horizontal reference plane for precision inspection, marking out (layout), and tooling setup. The surface plate is often used as the baseline for all measurements to the workpiece, therefore one primary surface is finished extremely flat with accuracy up to 250 nm (nanometre) for a grade AA or AAA plate. Surface plates are a very common tool in the manufacturing industry and are often permanently attached to robotic type inspection devices such as a coordinate-measuring machine.

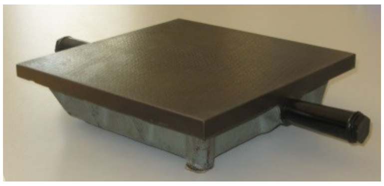


Figure 1.37
Surface Plate

1.7.4 Fabrication:

The tools involved in fabrication trades are normally restricted to rules and squares, however, a small range of other measuring instruments may be required.

1.7.4.1 – Dumpy Level:

A dumpy level is an optical instrument levelling instrument are used to transfer, measure, or set horizontal levels. Although they are used mainly in surveying and building, they can be of valuable use when setting out special projects. Dumpy levels have a bubble level to ensure they have and accurate level. The instrument is set to level in each quarter-circle, to make sure it is correct through an entire 360° range. The level is set up on a tripod stand and a telescope is attached to one side of the instrument's axis of rotation then an operator uses the eyepiece of the telescope, while his helper applies a tape measure or fine-tuned staff erect at the level under measurement.

1.7.4.2 – Scribing Block:

A scriber is a hand tool used in metalworking to mark lines on workpieces, prior to machining. The process of using a scriber is called scribing and is just part of the process of marking out. It is used instead of pencils or ink lines, because the marks are hard to see, easily erased, and inaccurate due to their wide mark; scribe lines are thin and semi-permanent. On non-coated workpieces marking blue is commonly used to increase the contrast of the mark lines.

1.7.4.3 – Profile Gauge:

A profile gauge or contour gauge is a tool for recording the cross-sectional shape of a surface. Contour gauges consist of a set of steel or plastic pins that are set tightly against one another in a frame which keeps them in the same plane and parallel while allowing them to move independently, perpendicularly to the frame. When pressed against an object, the pins conform to the object. The gauge can then be used to draw the profile or to copy it on to another surface.

Figure 1.38
Dumpy Level

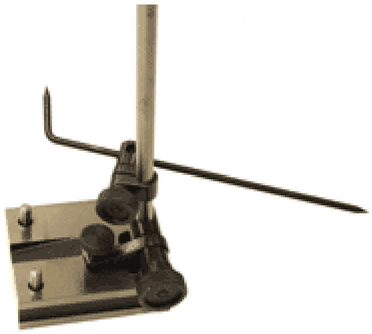


Figure 1.39
Scribing Block

Figure 1.40
Profile Gauge

1.7.4.4 – Beam Compass:

A beam compass is a compass with a beam and sliding sockets or cursors for drawing and dividing circles larger than those made by a regular pair of compasses. The instrument can be as a whole, or made on the spot with individual sockets (called trammel points) and any suitable beam.

A beam compass can also be used to make a series of repetitious measurements in a precise manner. Each point is rotated 180° and this process is repeated until the desired measurement is reached. The indentation created by the sharp point of the trammel is easily seen and makes a precise point to reference to the next location

1.7.4.5 – Dividers:

Although technically dividers are not used traditionally for measuring, they can be used in transferring known distances. A divider is used in the process of marking out shapes and locations. The points are sharpened so that they act as scribers, one leg can then be placed in the dimple created by a centre or prick punch and the other leg pivoted so that it scribes a line on the workpiece's surface, thus forming an arc or circle.

A divider calliper is also used to measure a distance between two points on a map. The two calliper's ends are brought to the two points whose distance is being measured; the calliper's opening is then either measured on a separate ruler and then converted to the actual distance, or it is measured directly on a scale drawn on the map.

Figure 1.41
Beam Compass

Figure 1.42
Dividers

Skill Practice Exercise:

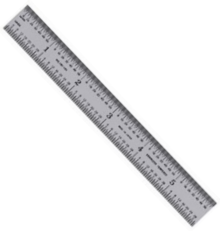
Skill Practice Exercise MEM12023-RQ-0101.

1. Which preferred instrument would be used to measure the distance between the walls of a building?

A. B. C. D.

2. Which measuring instrument would be used to determine the depth of a Ø6 hole?

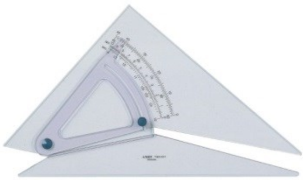
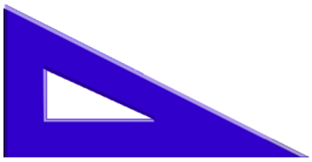
   

A. B. C. D.

3. An advantage of using a digital measuring device is:
   - A. The storage compartment requires less space.
   - B. The instrument is always ready for use.
   - C. The maintenance of the instrument can be omitted.
   - D. The display is easier to read.

4. Which measuring instrument would be used to measure a distance of over 45 metres?
   - A. Steel Rule.
   - B. Metal Tape.
   - C. Tape Wheel.
   - D. Protractor.

5. What instrument can be used to set an angle of 54.5° on an engineering drawing?

A. B. C. D.

6. A dynamometer is used to measure:
   - A. Direction.
   - B. Area.
   - C. Torque.
   - D. Pressure

7. Which measuring instrument can determine the gap between 2 features to within 0.01 mm?


A.


B.


C.

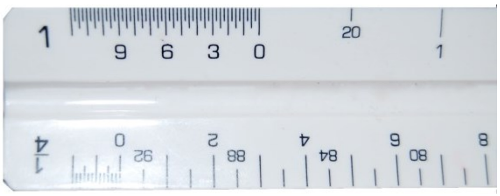
D.

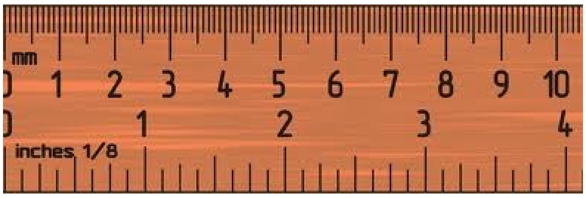
8. Which of the following names is given to a method for testing the hardness of a material?
   A. Rockwell.
   B. Honeywell.
   C. Ryobi.
   D. McCandles

9. Name a type of block which is used in metalworking to mark lines on workpieces?

____

10. Which measuring instrument would be used to mark of a measurement of 1952 mm at a scale of 1:5?


A.



B.


C.


D.

11. Name three errors in measuring instruments.

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____

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12. What measuring instrument would be used to determine the area directly from a plan or blueprint?

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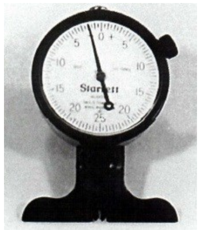
13. Where are torque wrenches used?

14. Which instrument would be used to record the cross-sectional shape of a surface?

15. Which of the following instruments can measure an gap of 0.025 mm?

A.

B.



C.

D.

16. What is a systematic error?

17. List two advantages for using a digital instrument.

18. List three good measuring practices.

19. Name the two systems for units of measurement?

20. What type of an error is a mistake?