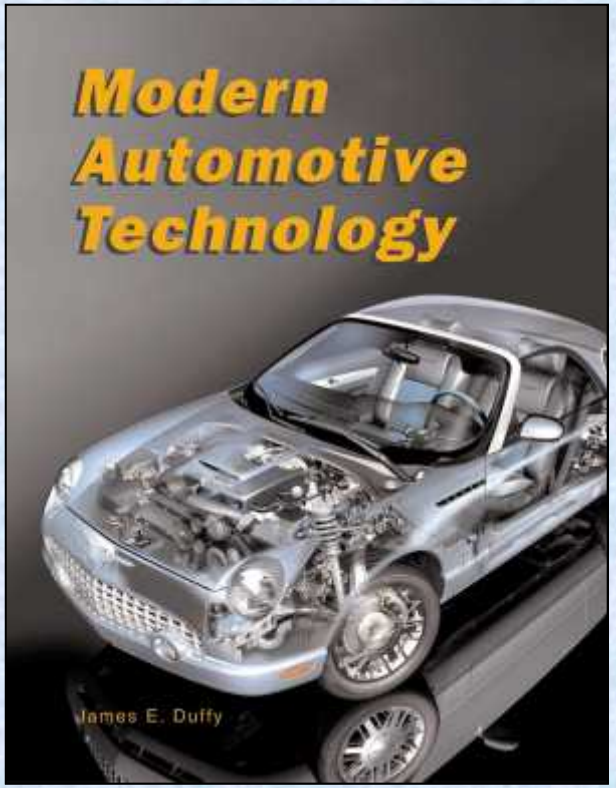
PowerPoint for

Modern Automotive Technology



by

Russell Krick

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Chapter 6

Automotive Measurement and Math

Contents

- Measuring systems
- Measuring tools
- Other measurements and measuring tools
- Using basic mathematics

Specifications (Specs)

- Maximum wear limits and dimensions of important parts
- If the measurements are not within these specifications, the part must be adjusted, repaired, or replaced
- Therefore, a technician must be able to make accurate measurements

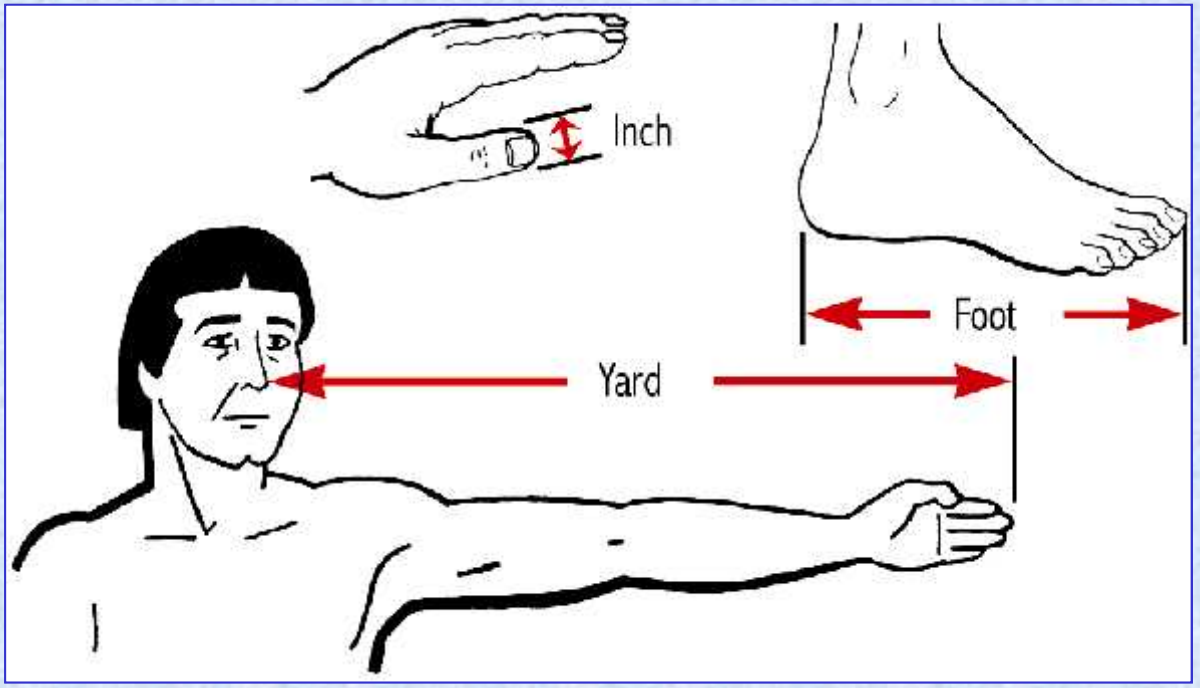
Measuring Systems

- Two measuring systems are commonly used when working in an auto shop:
- Customary measuring system
  - also called the U.S. customary units system or the English system
- Metric (SI) system

Customary and Metric Values

Quantity	Customary (abbreviation)	Metric (abbreviation)
Length	Inch (in) Foot (ft) Mile (mi)	Meter (m)
Weight (mass)	Ounce (oz) Pound (lb)	Kilogram (kg)
Area	Square inch (sq-in)	Square meter (m^2)
Dry volume	Cubic inch (cu-in)	Cubic meter (m^3) Cubic centimeter (cc)
Liquid volume	Ounce (oz) Pint (pt) Quart (qt) Gallon (gal)	Liter (L) Cubic centimeter (cc)
Road speed	Miles per hour (mph)	Kilometer per hour (km/h)
Torque	Foot-pounds (ft-lb)	Newton meter (N·m)
Power	Horsepower (hp)	Kilowatt (kW)
Pressure	Pounds per square inch (psi)	Kilopascal (kPa)
Temperature	Degrees fahrenheit (°F)	Degrees celsius (°C)

Customary Measuring System



Originated from sizes taken from parts of the human body

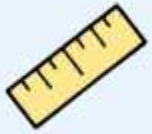
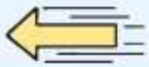
Metric Measuring System

- Uses a power of 10 for all basic units
- Simpler and more logical than the customary system
- Computation often requires nothing more than moving the decimal point
  - one meter equals 10 decimeters, 100 centimeters, or 1000 millimeters

Conversion Charts

- Conversion chart
  - needed when changing a value from one measuring system to another
- Decimal conversion chart
  - commonly used to find equivalent values for fractions, decimals, and millimeters
  - accurate to about 1/64 of an inch

Conversion Chart

Measurement		When you know:	You can find:	If you multiply by:
	Length	inch (in) foot (ft) yard (yd) mile (mi) millimeter (mm) centimeter (cm) meter (m) kilometer (km)	millimeter (mm) meter (m) meter (m) kilometer (km) inch (in) inch (in) yard (yd) mile (mi)	25.4 .3 .9 1.6 .04 .39 1.09 .6
	Pressure	pounds per square inch (psi) kilopascal (kPa)	kilopascal (kPa) pounds per square inch (psi)	6.89 .145
	Power	horsepower (hp) kilowatt (kW)	kilowatt (kW) horsepower (hp)	.746 1.34
	Torque	foot-pounds (ft-lb) Newton-meter (N□m)	Newton-meter (N□m) foot-pounds (ft-lb)	1.36 .74
	Volume	quart (qt) liter (L) cubic inch (cu-in) liter (L)	liter (L) quart (qt) liter (L) cubic inch (cu-in)	.95 1.06 .016 61.02
	Mass	ounce (oz) gram (g) pound (lb) kilogram (kg)	gram (g) ounce (oz) kilogram (kg) pound (lb)	28.35 .035 .45 2.20
	Speed	miles per hour (mph) kilometers per hour (km/h)	kilometers per hour (km/h) miles per hour (mph)	1.61 .62

Decimal Conversion Chart

Fraction				Inches	mm
			1/64	.01563	.397
		1/32		.03125	.794
			3/64	.04688	1.191
	1/16			.06250	1.588
			5/64	.07813	1.984
		3/32		.09375	2.381
			7/64	.10938	2.778
1/8				.12500	3.175
			9/64	.14063	3.572
		5/32		.15625	3.969
			11/64	.17188	4.366
	3/16			.18750	4.763
			13/64	.20313	5.159
		7/32		.21875	5.556
			15/64	.23438	5.953
1/4				.25000	6.350
			17/64	.26563	6.747
		9/32		.28125	7.144
			19/64	.29688	7.541
	5/16			.31250	7.938
			21/64	.32813	8.334
		11/32		.34375	8.731
			23/64	.35938	9.128
3/8				.37500	9.525
			25/64	.39063	9.922
		13/32		.40625	10.319
			27/64	.42188	10.716
	7/16			.43750	11.113
			29/64	.45313	11.509
		15/32		.46875	11.906
			31/64	.48438	12.303
1/2				.50000	12.700

Fraction				Inches	mm
			33/64	.51563	13.097
		17/32		.53125	13.494
			35/64	.54688	13.891
	9/16			.56250	14.288
			37/64	.57813	14.684
		19/32		.59375	15.081
			39/64	.60938	15.478
5/8				.62500	15.875
			41/64	.64063	16.272
		21/32		.65625	16.669
			43/64	.67188	17.066
	11/16			.68750	17.463
			45/64	.70313	17.859
		23/32		.71875	18.256
			47/64	.73438	18.653
3/4				.75000	19.050
			49/64	.76563	19.447
		25/32		.78125	19.844
			51/64	.79688	20.241
	13/16			.81250	20.638
			53/64	.82813	21.034
		27/32		.84375	21.431
			55/64	.85938	21.828
7/8				.87500	22.225
			57/64	.89063	22.622
		29/32		.90625	23.019
			59/64	.92188	23.416
	15/16			.93750	23.813
			61/64	.95313	24.209
		31/32		.96875	24.606
			63/64	.98438	25.003
1				1.00000	25.400

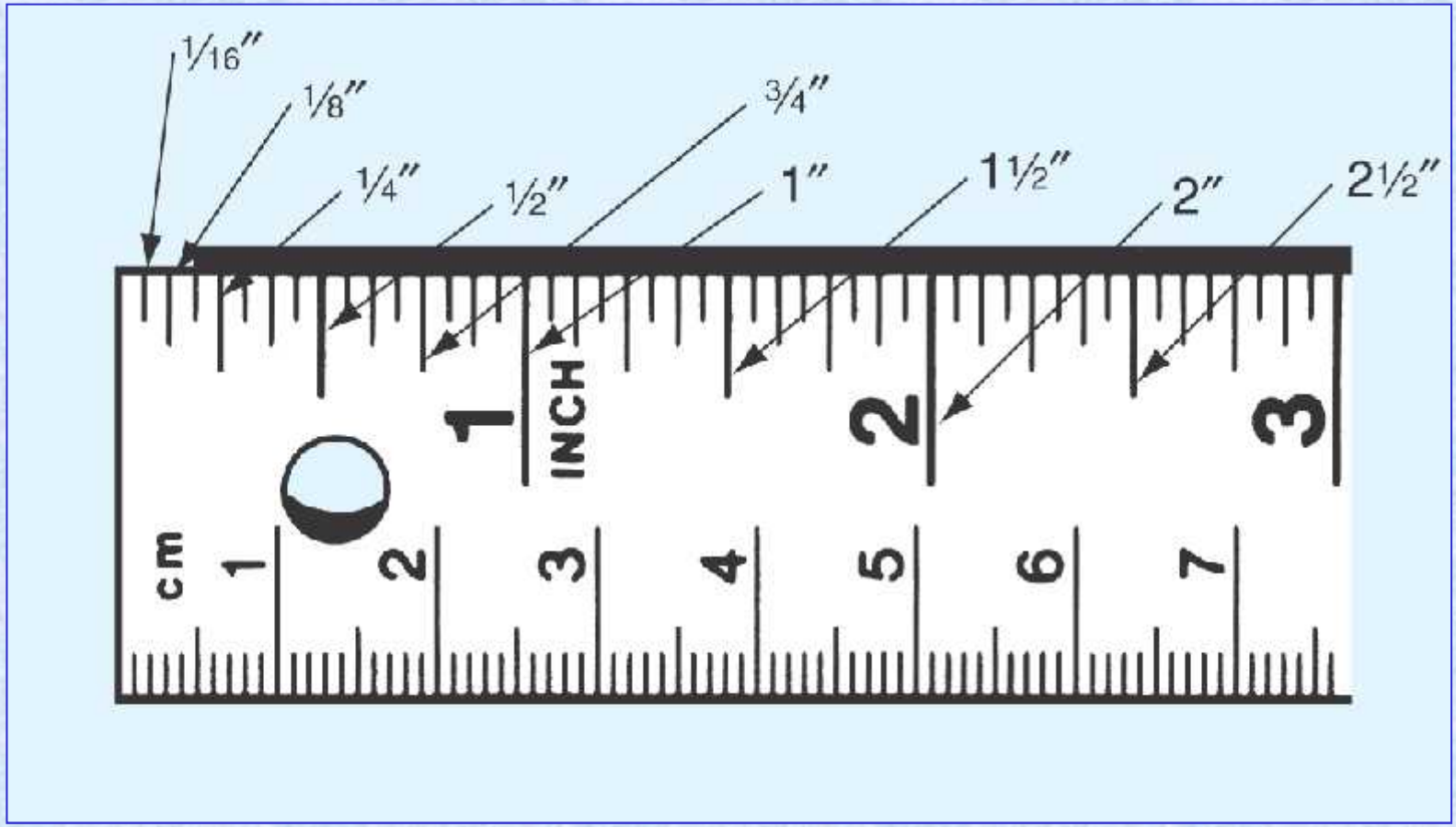
Measuring Tools

- There are various tools used by a technician to make accurate measurements
- Common measuring tools include the steel rule, caliper, micrometer, and dial indicator
- Most of these tools are available in both customary and metric units

Steel Rule

- Frequently used to make low-precision linear measurements
- Accurate to about 1/64" (0.5 mm)
- Customary rule has numbers that represent full inches
- Metric rule has numbers that represent 10 mm, or 1 cm

Steel Rule



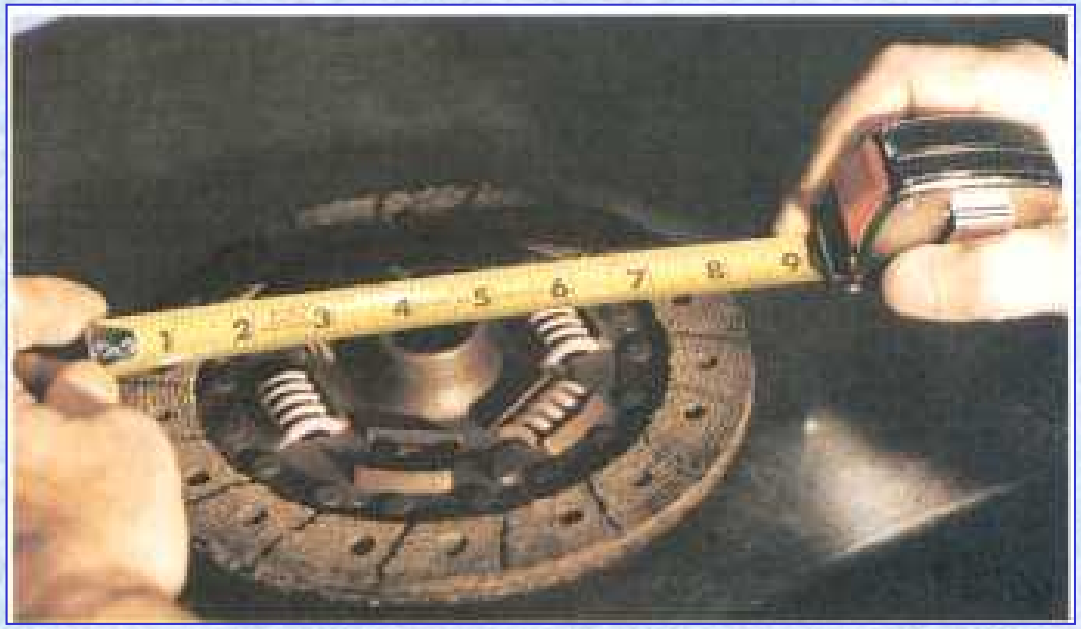
Tape Measure

- Extends to several feet or meters in length
- Sometimes needed for large distance measurements during body, suspension, and exhaust system repairs

Tape Measure

Digital-reading tape measure

Tape Measure



Used to make large straight-line measurements

Dividers

- Look like a drafting compass but have straight, sharply pointed tips
- Commonly used for layout work on sheet metal parts
- Sharp points can scribe circles and lines on sheet metal and plastic
- Used to transfer and make surface measurements

Outside Caliper

- Used to make external measurements when 1/64" (approximately 0.40 mm) accuracy is sufficient
- Fitted over the outside of parts and adjusted so that each tip just touches the part
- Caliper is then held against a rule and the distance between the tips is measured to determine part size

Inside Caliper

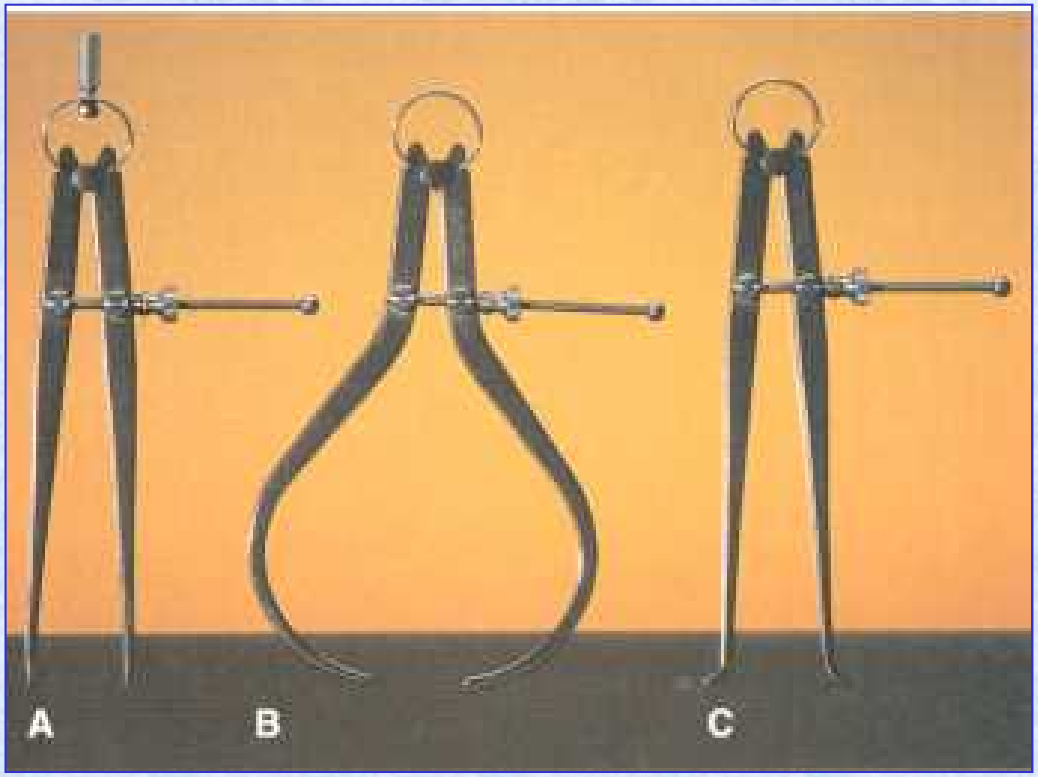
- Designed for internal measurements in holes and other openings
- Placed inside a hole and adjusted until the tips just touch the part
- Caliper is then held against a rule and the distance between the tips is measured

Dividers and Calipers

A. Dividers

B. Outside caliper

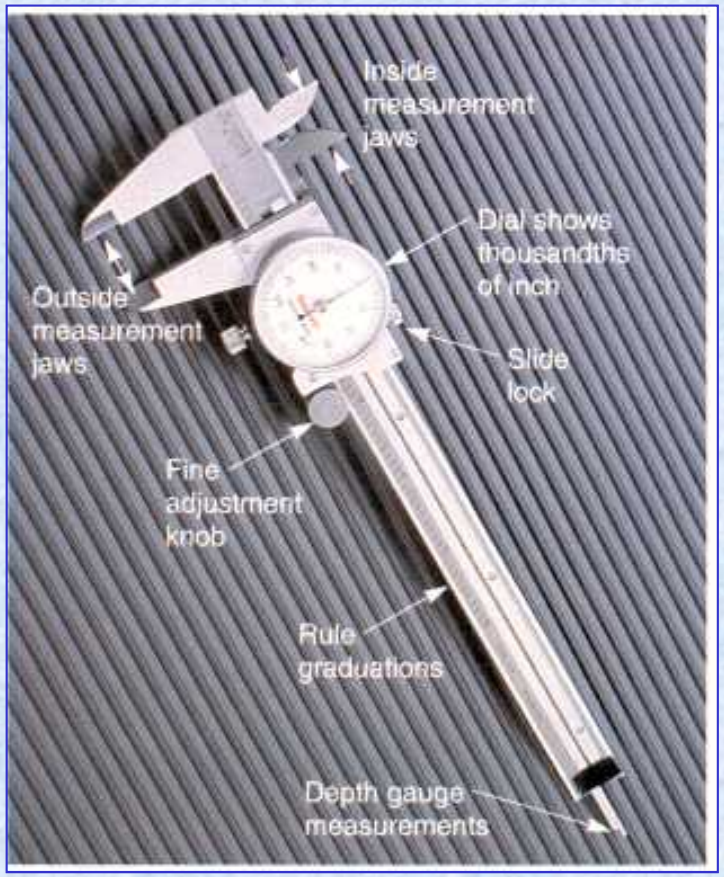
C. Inside caliper

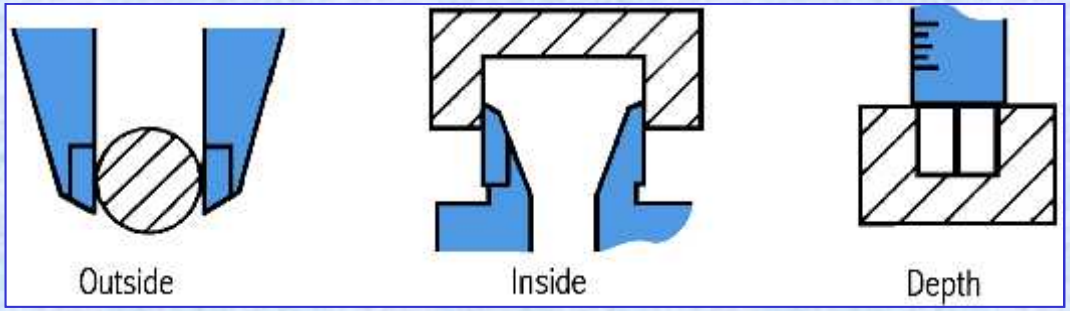


Vernier Caliper

- Sliding measuring device that can make inside, outside, and depth measurements with considerable accuracy
- Measurements as small as 0.001" (0.025 mm) can be taken
- May have a dial gauge attached
  - makes the “thousandths” part of a measurement easier to read

Vernier Caliper

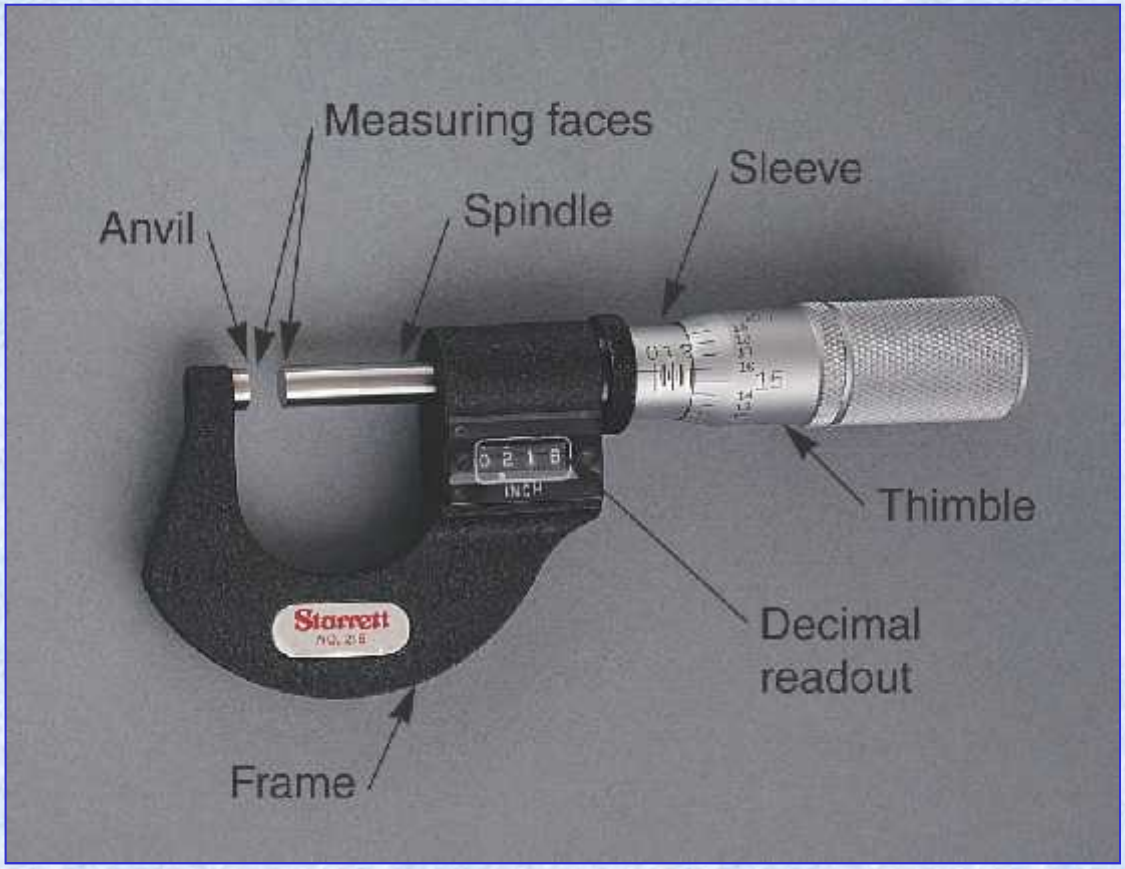




Micrometer

- Used to make very accurate measurements
- Measures to one ten-thousandth of an inch (0.0001") or one thousandth of a millimeter (0.001 mm)
- Outside, inside, and depth micrometers are available

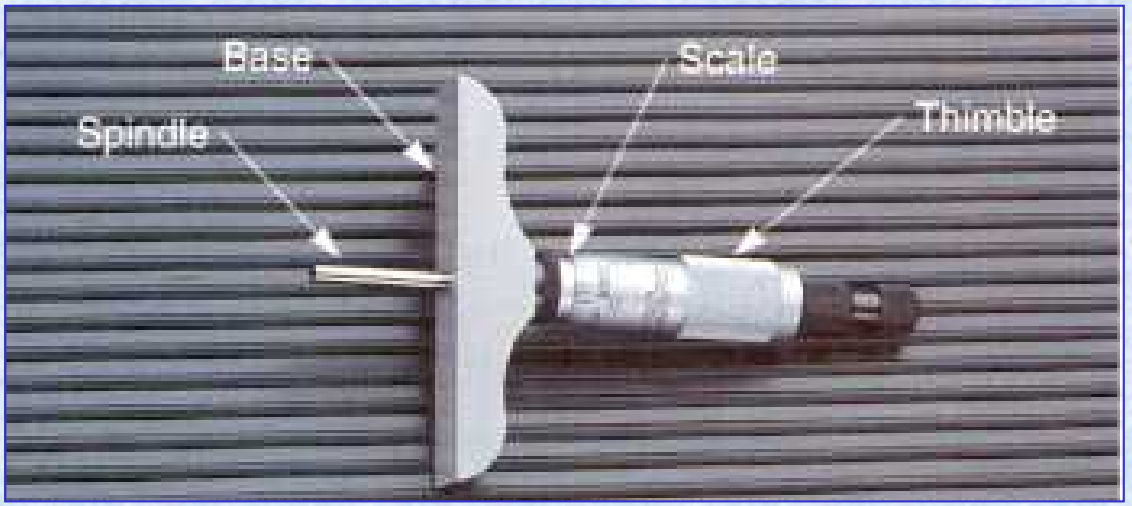
Outside Micrometer



Inside Micrometer

Used for internal measurements of large holes, cylinders, or other part openings

Depth Micrometer

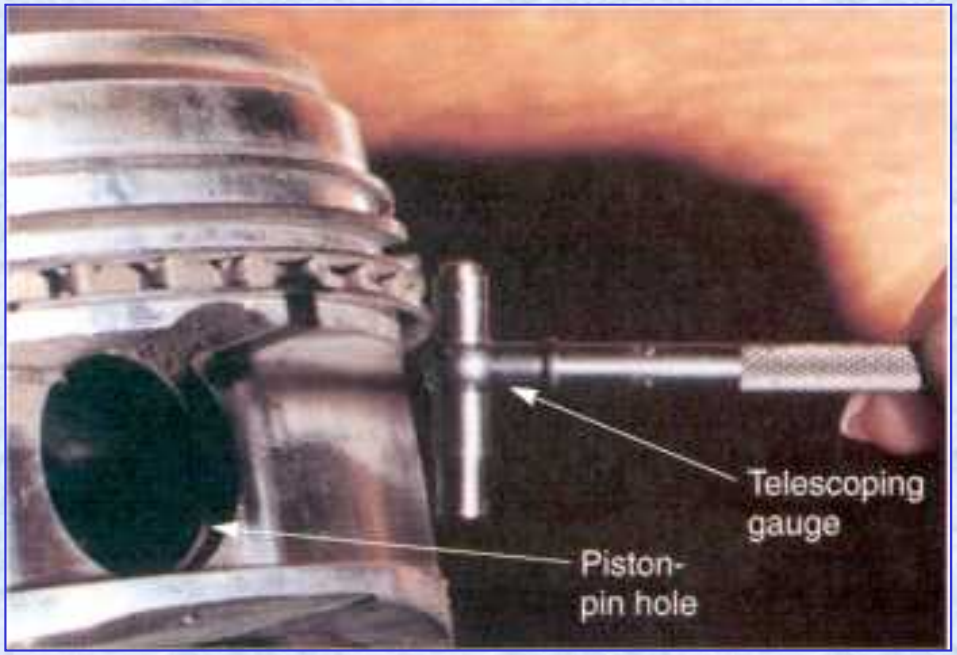


Used to precisely measure the depth of an opening

Using a Micrometer

- Turn the thimble until the measuring surfaces are just touching the part
- Read the graduations on the sleeve and thimble to determine the measurement

Telescoping Gauge



Used to measure internal part bores or openings

Using a Telescoping Gauge

- Compress the spring-loaded extensions and lock them with the thumb wheel
- Insert the gauge into the opening and release the thumb wheel
- After the extensions snap outward, lock them with the thumb wheel
- Measure across the extensions with an outside micrometer

Hole Gauge

- Used for measuring very small holes
- To use a hole gauge:
  - loosen the thumb wheel
  - insert the gauge into the hole
  - tighten the thumb wheel until the gauge just touches the part
  - remove the gauge and measure it with an outside micrometer

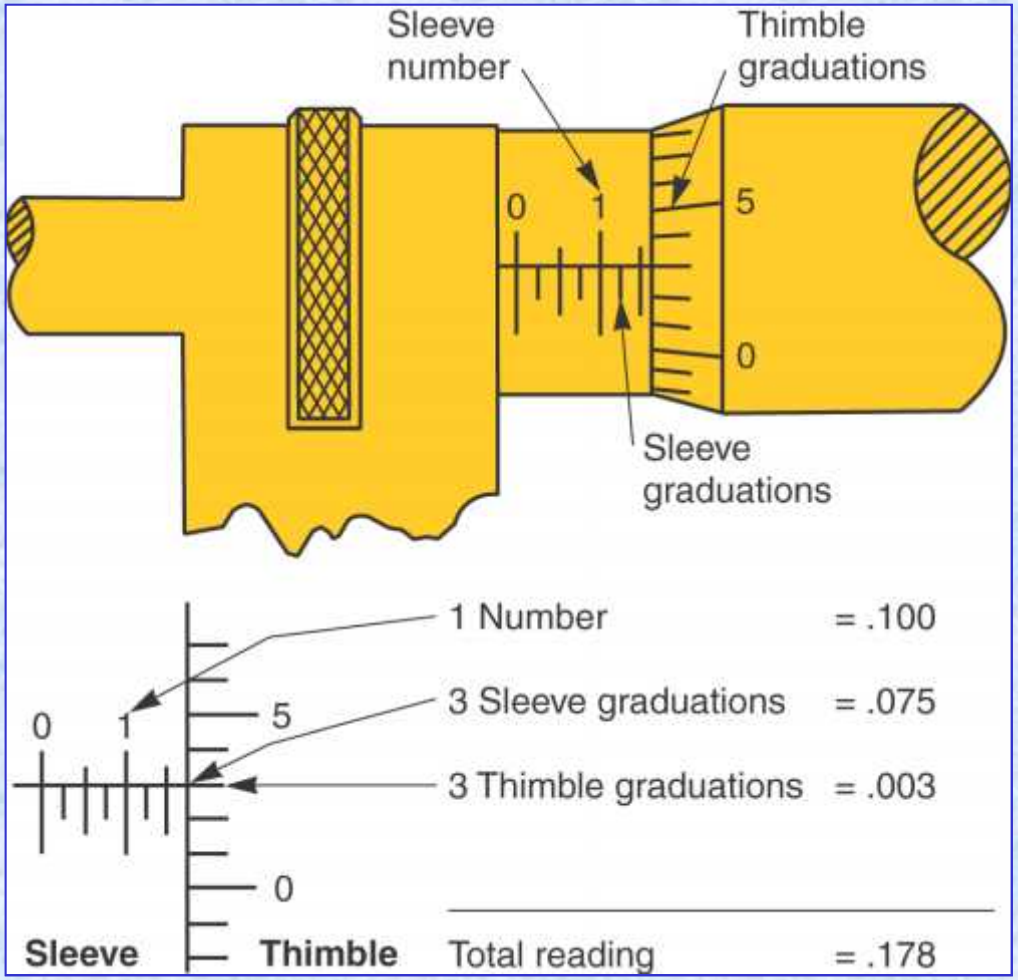
Reading a Customary Micrometer

1. Note the largest number visible on the sleeve–each number equals 0.100"
2. Count the number of graduations to the right of the sleeve number–each full sleeve graduation equals 0.025"

Reading a Customary Micrometer

3. Note the thimble graduation aligned with the horizontal sleeve line—each thimble graduation equals 0.001"; round off when the sleeve line is not directly aligned with a thimble graduation
4. Add the decimal values from steps 1, 2, and 3—also, add any full inches

Reading a Customary Micrometer



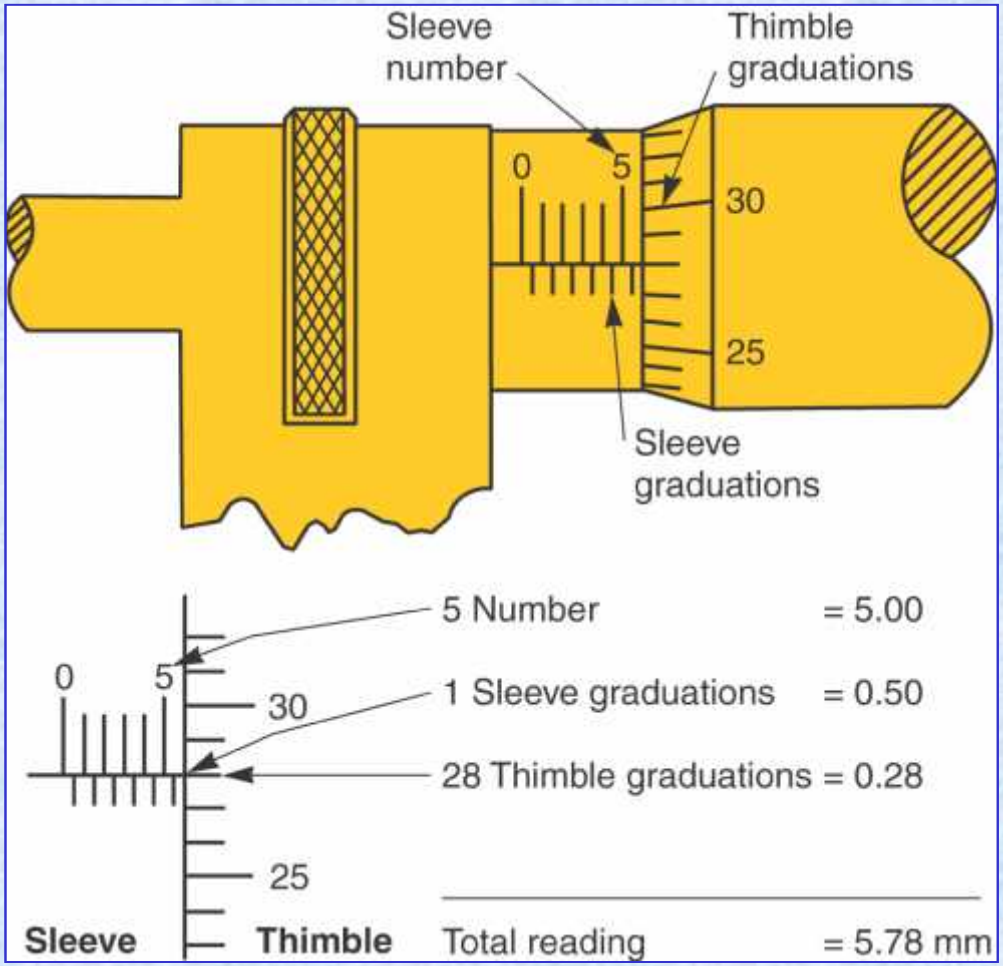
Reading a Metric Micrometer

1. Read the largest number visible on the micrometer sleeve–each number equals 1.00 mm
2. Count the number of graduation lines to the right of the sleeve number–each full sleeve graduation equals 0.50 mm

Reading a Metric Micrometer

3. Read the thimble graduation aligned with the horizontal sleeve line—each thimble graduation equals 0.01 mm
4. Add the values from the steps 1, 2, and 3

Reading a Metric Micrometer



Micrometer Rules

- Never drop or overtighten a micrometer
- Store micrometers where they cannot be damaged
- Grasp the micrometer frame in your palm and turn the thimble with your thumb and finger

Micrometer Rules

- Hold the micrometer squarely with the work or false readings can result
- Rock or swivel the micrometer as it is touched on round parts
- Place a thin film of oil on the micrometer during storage
- Always check the accuracy of a micrometer before use

Feeler Gauges

- Used to measure small clearances or gaps between parts
- There are two basic types:
  - flat feeler gauges
  - wire feeler gauges

Flat Feeler Gauge

Used to measure distances between parallel surfaces

Wire Feeler Gauge

Used to measure the distance between unparallel or curved surfaces

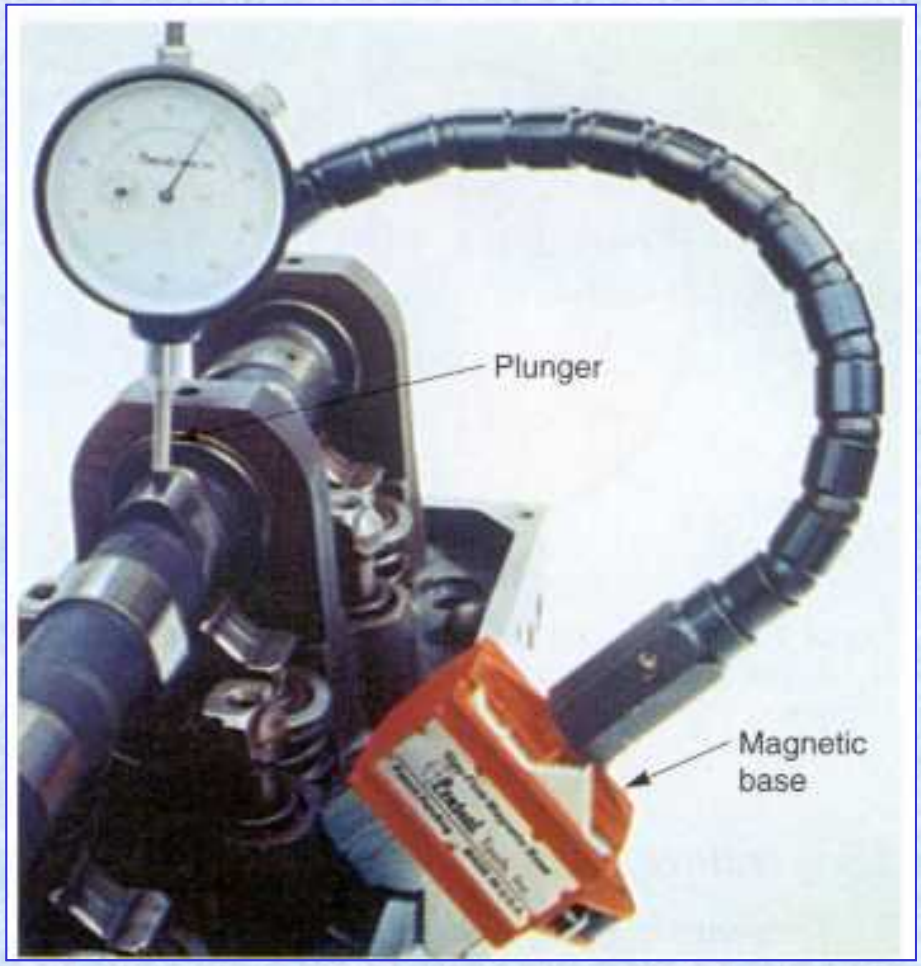
Using a Feeler Gauge

- Find the gauge blade or wire that just fits between the two parts being measured
- The gauge should drag slightly when pulled between the two surfaces
- The size given on the gauge is the clearance between the two components

Dial Indicator

- Used to measure part movement in thousandths of an inch (hundredths of a millimeter)
- Indicator needle indicates the amount of plunger movement
- Used to check gear teeth backlash, shaft end play, cam lobe lift, and similar kinds of part movements

Dial Indicator



Using a Dial Indicator

- Mount the indicator securely and position the dial plunger parallel with the movement to be measured
- Partially compress the indicator plunger before locking the indicator into place

Using a Dial Indicator

- Move the part back and forth or rotate the part while reading the indicator
- Subtract the lowest reading from the highest reading
  - the result equals the distance the part has moved, the clearance, or the runout

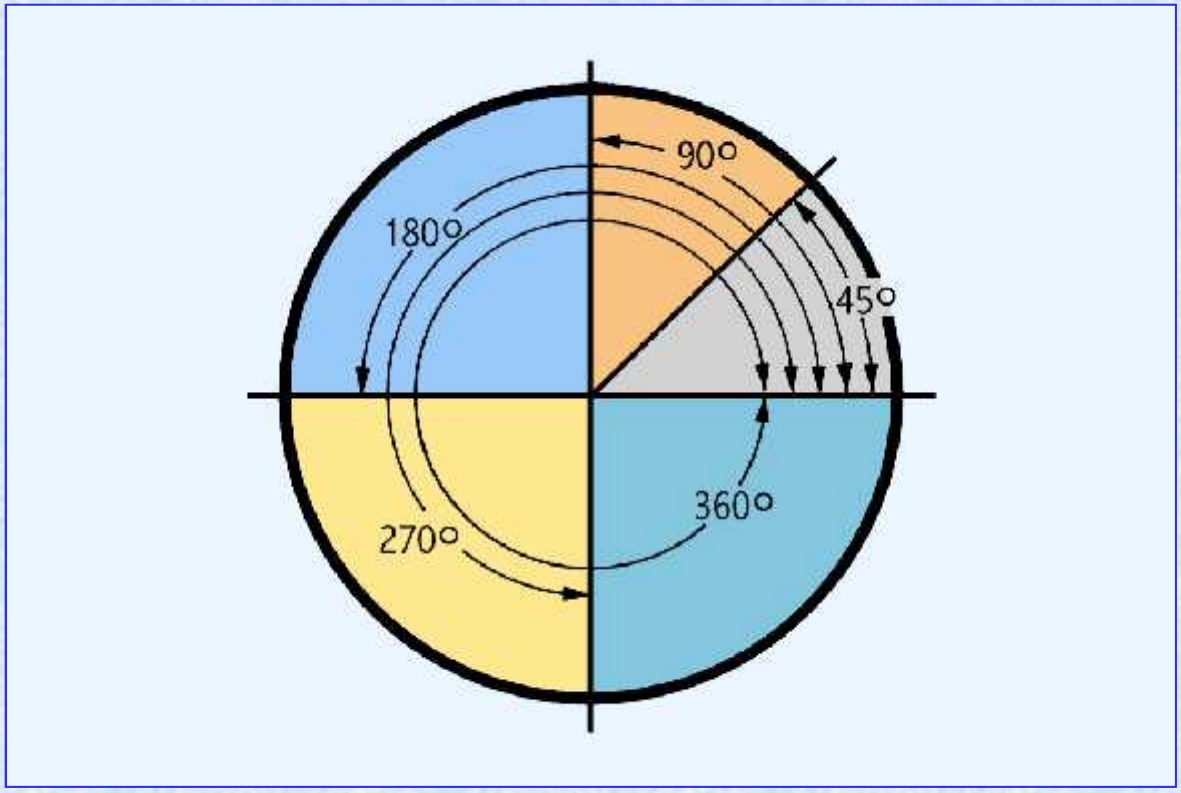
Other Measurements and Measuring Tools

A technician may make other types of measurements and use other types of measuring tools

Angle Measurement

- A circle can be divided into 360 equal parts, called degrees
  - abbreviated “deg.” or the symbol (º)
- Specifications are normally given in degrees when you are measuring rotation of a part or an angle formed by a part

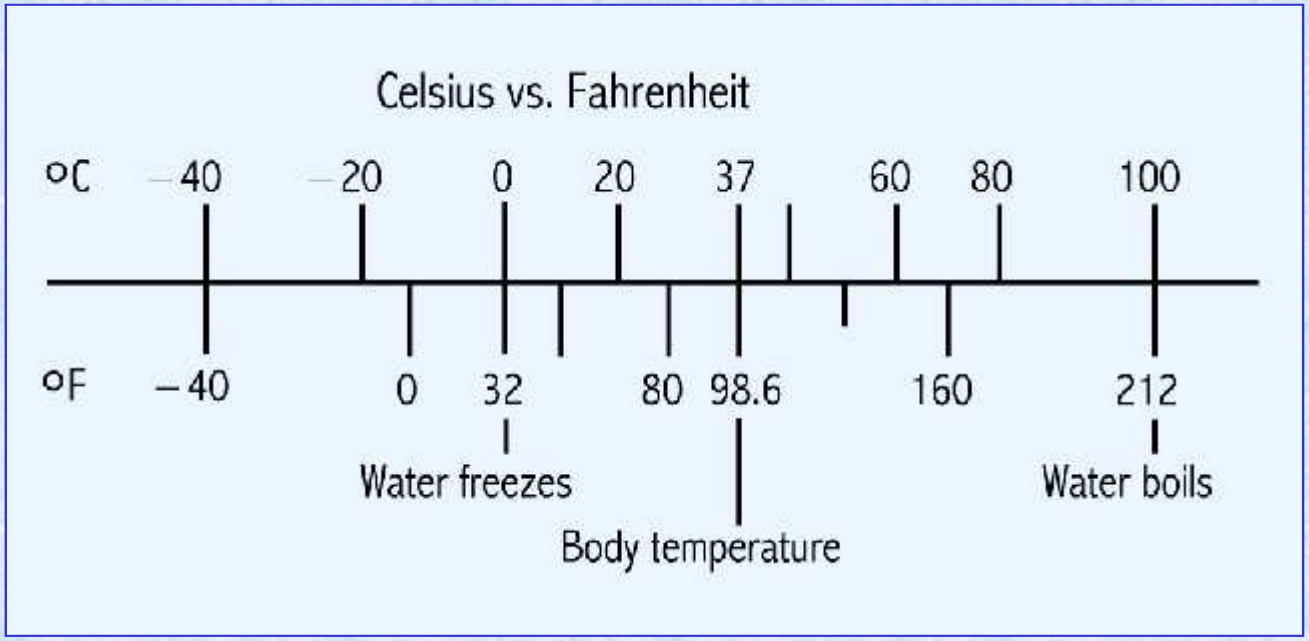
Angle Measurement



Temperature Measurement

- Temperature gauges, or thermometers, are used to measure temperature
- Temperature may be read in either customary Fahrenheit (F) or metric Celsius (C)

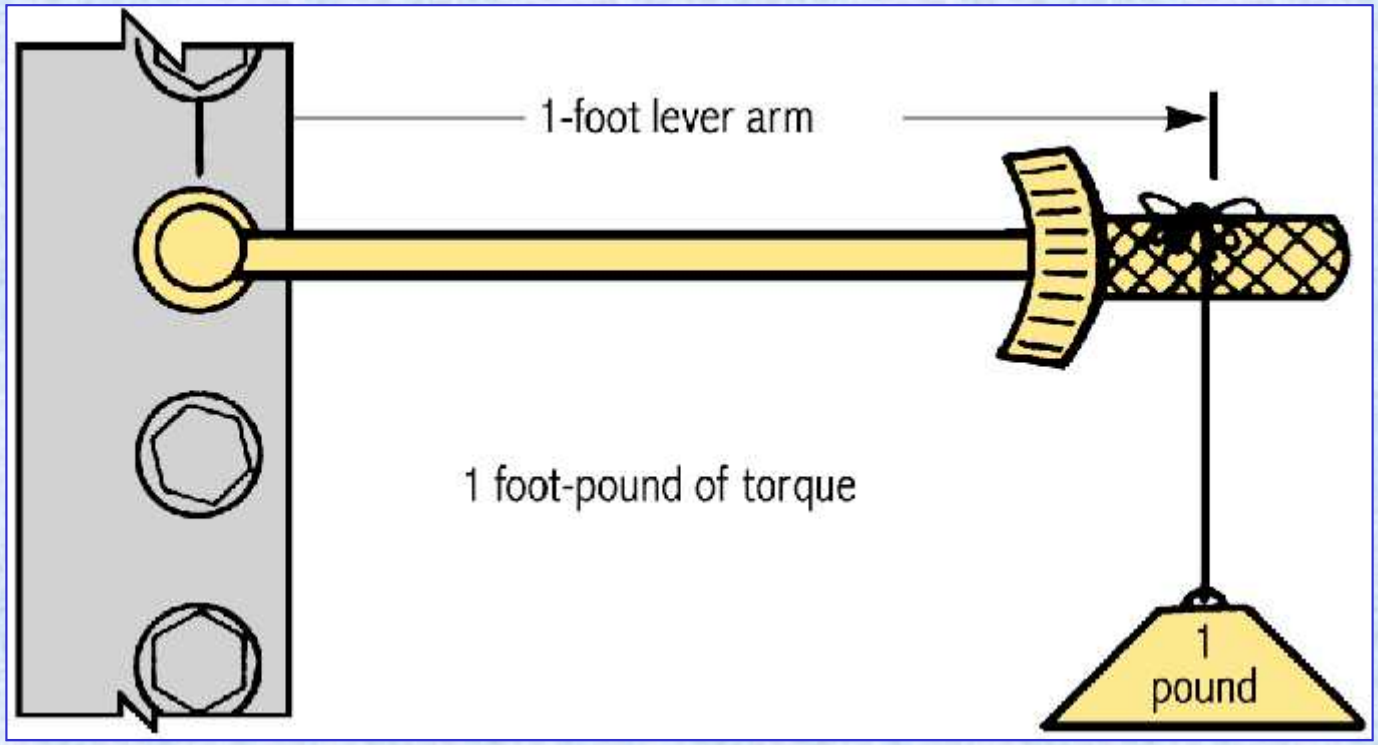
Temperature Measurement



Torque Wrench

- Used to apply a specific amount of turning force to a fastener, such as a bolt or nut
- Scales usually read in foot-pounds (ft-lb) and Newton-meters (N•m)

Torque Wrench Theory



One foot-pound equals one pound of pull on a one-foot-long lever arm

Flex Bar Torque Wrench

Uses a bending metal beam to make the pointer read torque on the scale

Dial Indicator Torque Wrench

Very accurate type of torque wrench

Ratcheting Torque Wrench

Torque value is set by turning the handle. The fastener is tightened until the wrench clicks.

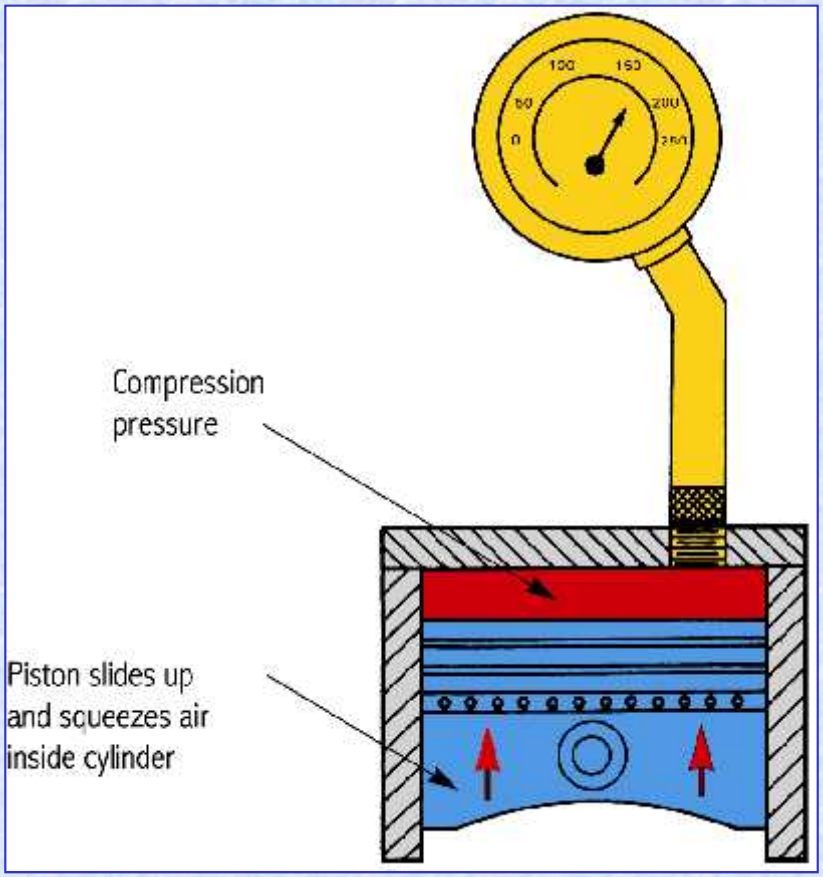
Pressure Gauge

- Used to measure air and fluid pressure
- Common units of measure found on the pressure gauge scale:
  - pounds per square inch (psi)
  - kilograms per square centimeter (kg/cm^2)
  - kilopascals (kPa)

Pressure Gauge

- Common pressure measurements taken in the automotive shop:
  - tire air pressure
  - fuel pump pressure
  - air conditioning system pressure
  - engine compression pressure

Pressure Gauge



Using a pressure gauge to measure engine compression pressure

Vacuum Gauge

- Used to measure negative pressure, or vacuum
- Common units of measure found on the vacuum gauge scale:
  - inches of mercury (in./hg.)
  - kilograms per square centimeter (kg/cm^2)
- Used to measure engine intake manifold vacuum and vacuum solenoid functions

Using Basic Mathematics

- Automotive technicians often use mathematics
- Technicians must be able to add, subtract, multiply, and divide
- Technicians must also be able to work with fractions and decimals

Addition

- Combining two or more numbers to find the total quantity or number of something
- Result is called the sum or total

Addition

- Numbers may be written in a string:

  5 + 3 + 4 = 12

- Numbers may be written in a column:

$$\begin{array}{r} 5 \\ 3 \\ +4 \\ \hline 12 \end{array}$$

Addition

- When there are large numbers or a long series of numbers, it is best to write them in a column so sums of 10 and over can be carried to the next column
- Always start adding from the right-hand column so that sums exceeding 9 can be carried from that column to the next column to the left

Addition

- Used in adding up the cost of parts and labor when preparing a bill
- If parts total $125, labor charges are $95, and tax is $8, what is the total bill?

$$\begin{array}{r} \$125 \\ 95 \\ +8 \\ \hline \$228 \end{array}$$

Subtraction

- Taking away a certain quantity from another
- Amount left after subtracting is the remainder or difference

Subtraction

- Numbers may be written in a string:

  495 - 125 = 370

- Numbers may be written in a column:

  495
  -125
  370

Subtraction

- A customer's bill totaled $253, but there had been a $25 deposit before the work was done. What is the amount due?

$253

-25

$228

Division

- Used to find out how many times one number is contained in another
- The number being divided is called the dividend
- The number a dividend is divided by is called the divisor
- The answer is called the quotient

Division

Numbers may be written in three ways:

860 ö **10 = 86**

or:

$$\frac{860}{10} = 86$$

or:

$$10\overline{)\,860}$$
$$86$$

Division

- Ten fuel pumps had been ordered and placed in stock
- The total bill for the pumps came to $860
- What is the cost of each fuel pump?
- The cost of each pump is $86

Multiplication

- Shortcut for adding the same number over and over
- Result is called the product

Multiplication

- Numbers may be written in a string:

  $15 \times 12 = 180$

- Numbers may be written in a column:

$$\begin{array}{r} 15 \\ \times\ 12 \\ \hline 180 \end{array}$$

Multiplication

- A customer purchased four new tires at a cost of $104 each
- What is the price for the four tires?

$$\begin{array}{r} \$104 \\ \times\ 4 \\ \hline \$416 \end{array}$$

Fractions

- Used to represent a portion of a whole number
- Fractions are written as two numbers, one over the other or one beside the other:

$\frac{4}{5}$ (numerator)
5 (denominator)

or:

4/5

Decimal Fractions

- Also have a denominator
- Denominator is always a multiple of 10, but it is never written
- A decimal point is used in its place– 9/10 is written as 0.9

Decimal Fractions

The number of digits to the right of the decimal point tells what multiple of 10 the denominator is:

0.9 is 9/10

0.09 is 9/100

0.009 is 9/1000

0.0009 is 9/10,000

Addition and Subtraction of Decimals

- Line up the decimal points in a column
- The decimal point in the answer must be in the same position as the decimal point in the column

```
  1.5
 9.356
 3.62
  .96
-----
15.436
```

Multiplying Decimals

- Multiply the two numbers, ignoring the decimal points
- Count the total number of digits to the right of the decimal points in both of the numbers that were multiplied
- Starting at the right-hand digit, count to the left the same number of digits in the answer
- Place the decimal point to the left of the last digit counted

Dividing Decimals

- Dividing decimals is similar to dividing whole numbers
- If neither the dividend nor the divisor contains a decimal point but the division does not come out even:
  - place a decimal point to the right of the last number of the dividend
  - add one or more zeros after the decimal and continue dividing

Dividing Decimals

$$
\begin{array}{r}
7.71 \\
7\overline{)\,54.00} \\
\underline{49} \\
50 \\
\underline{49} \\
10 \\
\underline{7} \\
3
\end{array}
$$

Dividing Decimals

- When the dividend has a decimal and the divisor does not:
  - divide as usual
  - place a decimal point in the answer directly above the decimal point in the dividend
  - it will occur at the time that the division process moves past the decimal point

Dividing Decimals

$$
\begin{array}{r}
2.01 \\
25\overline{)\,50.25} \\
\underline{50} \\
02 \\
\underline{\ 0} \\
25 \\
\underline{25} \\
0
\end{array}
$$

Dividing Decimals

- When the divisor has a decimal point:
  - if the dividend does not have a decimal point, add one at the far right
  - if the dividend has a decimal point, move it one place to the right for each decimal place in the divisor
  - move the decimal point in the divisor accordingly to the right
  - use zeros as place holders, if necessary

Dividing Decimals

$$2.5\overline{)\,50.25}$$

$$25\overline{)\,502.5}$$

$$\begin{array}{r} 20.1 \\ \underline{50} \\ 02 \\ \underline{0} \\ 25 \\ \underline{25} \\ 0 \end{array}$$

Place a decimal point in the answer directly above the relocated decimal point in the dividend