Metrics for Mechanics

Self-Study Program
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Goals

After completing this self-study course, you should:

- **Be comfortable with measurements and calculations using metric units**
- **Understand the functions, advantages and limits of various measuring tools**
- **Know why to choose a particular tool for a particular job**

As a technician, you use many different kinds of tools to make effective repairs, and to help make your job faster and easier. Some are common hand tools, used with skills that you developed early, through your own experience. Others are special tools and test equipment with very specific functions that may require special training. For this course, we want to focus on measuring tools.

Like other special tools, these require some specialized knowledge and training. Precise measurement techniques are not foolproof. There are correct ways to use these tools to achieve meaningful results. Whether diagnosing a problem, evaluating wear, verifying proper specifications or making precise adjustments, accurate measurements can be the foundation of an entire repair. Remember, too, that any measurement is only as accurate as the tool you are using to make it. We need to understand the limits of our tools, and not expect more precision than they can deliver. Careful handling of the tools themselves is also necessary to ensure that they maintain their accuracy.

The title of this self-study course, *Metrics for Mechanics,* has a double meaning. “Metric” is a word that dictionaries define as a noun, meaning “a standard of measurement” or “a means of specifying values.” So, when we say “metrics” we refer to the science of measurement. “Metric” is also defined as an adjective referring to the “metric” system of measurement—based on the unit of length called a “meter.”

In this course, we are concerned with both meanings. We will explore the use of measuring tools and the task of making measurements, including capabilities and limits of various tools, how to choose the best one for a particular task, and how to make accurate measurements.

We will also be almost exclusively talking about measurements based on units of the metric system. Volkswagen designers and engineers work in metric units. The factories check their work and evaluate quality using metric units. It follows, then, that the specifications we find in the repair literature and use in our repairs are also given in metric units. To start, we will highlight the basics, so this will also serve as a metric system refresher course.

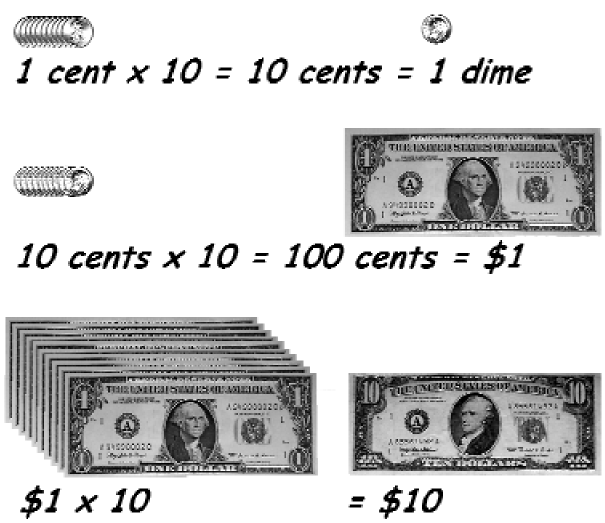
The self-study program is divided into an introductory section, as well as separate sections on:

- Vernier calipers
- Micrometers
- Dial indicators
- Dial bore gauges, feeler gauges and torque wrenches

You have the option of covering each section individually, as time permits, before completing the Teletest.

12 inches = 1 foot
3 feet = 1 yard
1,760 yards = 1 mile

8 ounces = 1 cup
2 cups = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon



Metric System Basics

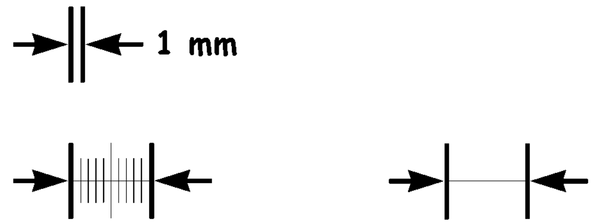
As a Volkswagen technician, you need to be able to understand and work with metric units and measurements. Our cars are designed and built according to metric specifications, and it’s what we see in the official service and repair information supplied by the factories.

You are already familiar with units of measurement that are similar to the metric system, and some that are much more complicated. In the common English system, we know that there are 12 inches to a foot, three feet to a yard, 1,760 yards to a mile, and so on. There are also eight ounces to a cup, two cups to a pint, two pints to a quart, and four quarts to a gallon! The only reason we “know” and can recall these relationships, is that we use them often and probably have them memorized. Otherwise, there is little logic or common sense to fall back on.

Relationships in the metric system are all based on factors of 10, 100 and 1000. The basic unit of length is the *meter*, and other units of length are all derived from multiplying or dividing by 10. Without any memorization, the inherent logic of the system always applies when converting between larger and smaller units.

You already know and use a similar system—the system of currency using dollars and cents. Our basic unit of currency is the dollar, and a basic smaller unit—the cent—is 1/100th of a dollar. We also tend to think of larger amounts as hundreds and thousands of the basic dollar unit. (We’ll ignore, for now, the fact that we also use quarters and $20 bills!)

In the metric system, the basic unit—the meter—may be expressed as smaller units such as *centi*meters (1/100th) or *milli*meters (1/1000th). Larger units are also described in multiples of 10. A mile may be 5,280 feet, but a *kilo*meter is exactly 1000 meters!



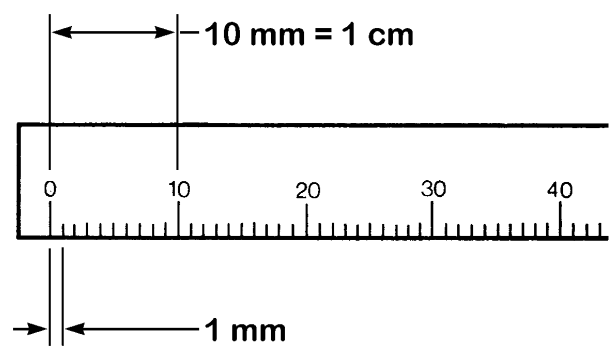
1 mm x 10 = 10 mm = 1 cm

1 cm x 100 = 100 cm = 1 meter

1 m x 1000 = 1000 m = 1 kilometer

If we need to convert from one unit to another in the metric system, we only need to know how many times to multiply or divide by 10. 1000 millimeters equals one meter. 10 millimeters equals one centimeter and 100 centimeters equals one meter. It's all determined by factors of ten, a hundred or a thousand.

We can get a practical feeling for these relationships from a simple metric ruler. The smallest divisions are millimeters, about the same as the thickness of a dime. Ten of these smallest divisions are equal to one larger division—a centimeter. And, for example, 40 smaller millimeters are exactly the length of four larger centimeters. If our ruler were a meter stick, one meter long, we could also *see* for ourselves that 1000 millimeters or 100 centimeters equal one meter.



Conversions

<u>Starting with</u>:	<u>To convert to</u>:	<u>Multiply by</u>:	-or-	<u>Divide by</u>:
Millimeters (mm)	**Centimeters (cm)**	0.1		10
	Meters (m)	0.001		1000
Centimeters (cm)	**Millimeters (mm)**	10		0.1
	Meters (m)	0.01		100
Meters (m)	**Millimeters (mm)**	1000		0.001
	Centimeters (cm)	100		0.01

Measurement Basics

There are a few basic concepts about the accuracy of measurements and measuring tools that are worth examining. Understanding these basics will help you determine exactly how much confidence you can have in a particular measurement.

It will also help you choose tools that are precise enough to give accurate results for the measurement you are making. Even an inexperienced technician would not try to measure a shim thickness or piston diameter with a ruler. The tool is simply not precise enough for the task, and any measurement would be hopelessly inaccurate.

You might use a caliper or micrometer to measure shim thickness, because it is described by precise specifications, but you would not use such tools to check brake pad thickness, because that level of precision just isn't necessary, and it would be a waste of time.

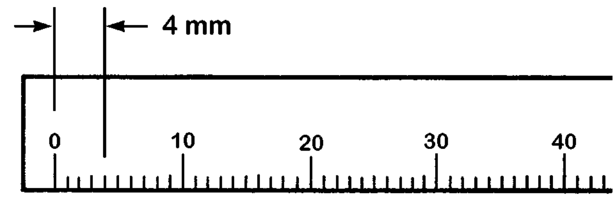
Any time you choose a measuring tool, you must ask yourself some questions:

1. What is the smallest unit or part of a unit that needs to be measured?
2. Does the measuring tool allow one to reliably read units that small?
3. If so, is the tool accurate at that degree of precision?

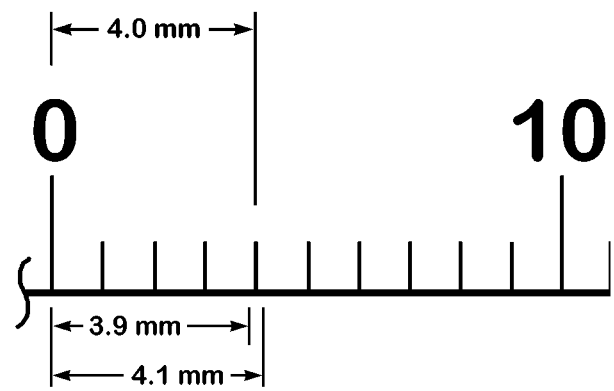
To answer these questions, we consider the precision of the specification for the value to be measured. The specification itself contains all the information necessary to determine how accurate the measurement, and the tool, needs to be. The key is the number of *significant digits*.

Precision and significant digits

A specification expressed as “4 mm” has no significant digits to the right of the decimal point. With no specific tolerance, the *implied* degree of precision calls for measurement to the nearest millimeter. We want *about* 4 mm—closer to 4 mm than 3 mm, and closer to 4 mm than 5 mm. This measurement requires some judgment, but requires a tool no more precise than a ruler marked in millimeters.

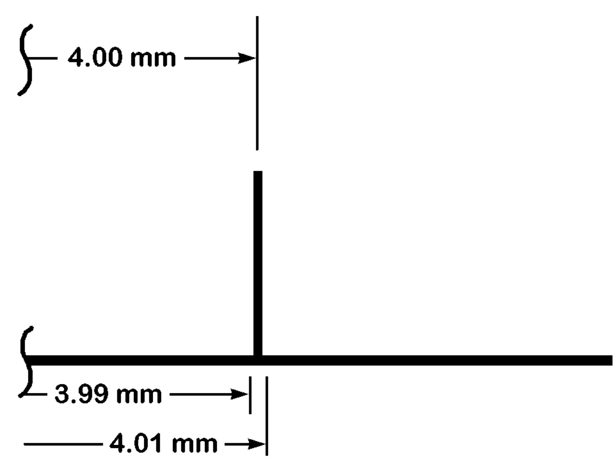


A specification of “4.0 mm” is different. At first, it appears to be the same as 4 mm, but there is an extra digit to the right of the decimal point—the value is more precise. The implied degree of precision calls for measurement to the nearest 0.1 mm or 1/10th millimeter. While 3.9 mm or 4.1 mm are very close, they are different from 4.0 mm, and do *not* meet that specification.



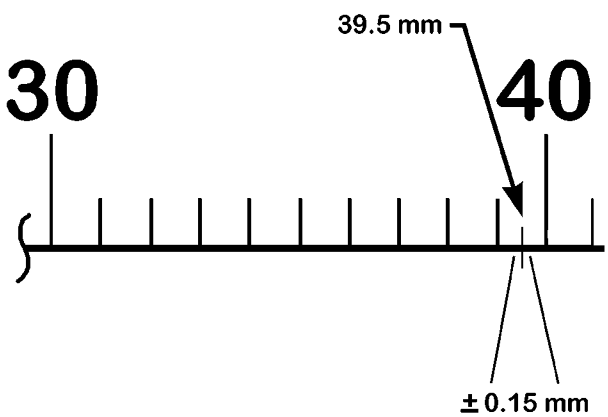
A ruler is *almost* good enough to measure 4.0 mm, because 4 mm and 4.0 mm are fundamentally the same. But, consider trying to measure 4.3 mm with a ruler. Could you read 4.3 mm accurately? With a ruler marked in whole millimeters only, we have to visually estimate how far 4.3 is from 4.0, and from 5.0. Such estimates are unreliable because there is no precise way to read 1/10th millimeter the same way every time. It requires a more precise tool, such as a vernier caliper.

A specification of “4.00 mm” is even more precise. There are *two* significant digits to the right of the decimal point. This means 4.00—not 3.99, and not 4.01—so it is implied that we want to be able to measure accurately to the nearest 0.01 mm or 1/100th millimeter. A very good caliper may be sufficient but, generally, this degree of precision demands a micrometer or dial indicator.



Expressed tolerances

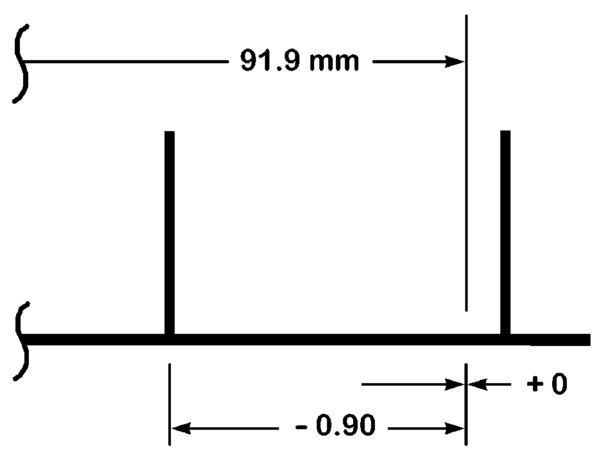
Until now, we have described measurement precision and accuracy based on *implied* tolerances—the degree of precision that is suggested by the way a specification is expressed, and the number of significant digits. In some cases, the factory will specify the same kind of nominal or desired value, and *also* clearly express a tolerance or range of values that is acceptable.



Example:

Valve head diameter — 39.5 ± 0.15 mm

According to the base specification of 39.5 mm, and the number of significant digits, we might assume the degree of precision to be to the nearest 0.1 mm. In fact, the factory intends to express a slightly broader, less precise tolerance. This specification means that the nominal diameter is 39.5 mm (39.50), but anything within the range from 39.35 to 39.65 mm is acceptable.



Example:

Valve length — 91.9 +0/–0.90 mm

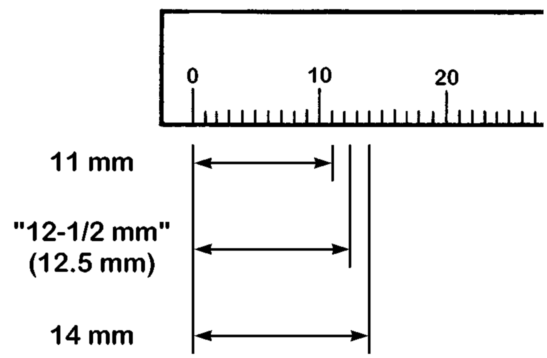
Notice that, in this case, there are different tolerances permitted for values greater than or less than the specified nominal value. “+0” indicates that there is *no* tolerance for values greater than the nominal value—and the maximum allowable length is the same 91.9 mm (91.90) as the nominal value. On the other hand, it is allowed to be shorter. Any value within the range from 91.90 mm down to 91.00 mm is acceptable.

Practical complications

A specification does not always clearly indicate the degree of precision intended by the factory. The real meaning can be more complicated. Consider an example:

	Brake pad thickness:
Application #1:	11 mm
Application #2:	12.5 mm
Application #3:	14 mm

The specifications for #1 and #3 suggest that we need to measure pad thickness to the nearest millimeter. Does #2 need to be measured with 10 times the precision, to the nearest 1/10th millimeter (0.1 mm)? Probably not. By comparing the similar specifications, we can assume “12.5” really means “12 + ½” mm, a value that can only be expressed as 12.5 mm.



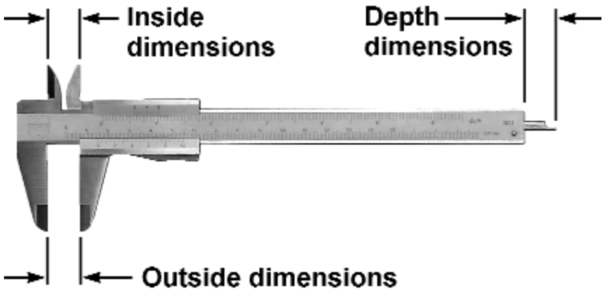
Let’s look at another example:

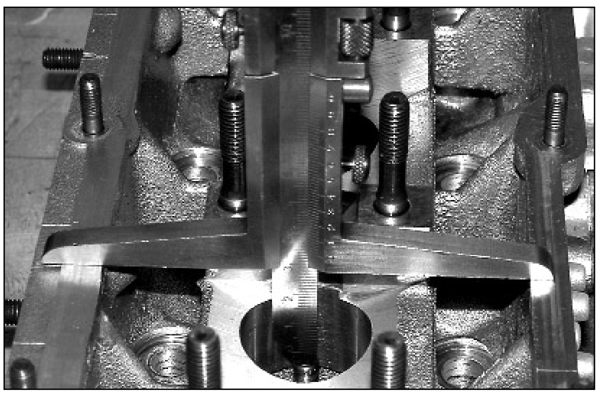
	Piston dia.:	Bore:
Application #1:	80.985 mm	81.01 mm
Application #2:	79.48 mm	79.51 mm
Application #3:	82.485 mm	82.51 mm

Do these applications require different degrees of precision? It seems unlikely. Measuring cylinder bore diameter to the nearest 1/100th millimeter (0.01), and pistons to the nearest 1/1000th mm (0.001) makes little sense. Comparing similar specifications, we can determine that we require measurements to the nearest 1/100th mm. Piston diameter #1, for example, should be “halfway” between 80.98 mm and 80.99 mm, which can only be expressed as 80.985 mm.

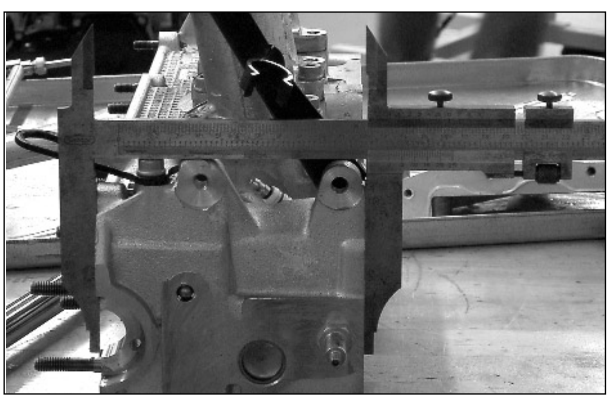
Specificartions like these require you to make a judgement. Use your knowledge and experience to determine whether the last significant digit indicates greater precision, or the extra “5” is just “½.”

Vernier Caliper





This vernier caliper is specially designed for depth measurements. It is used here to measure the position of a valve stem relative to the top of the cylinder head, to ensure proper clearance for hydraulic valve lifter operation.



This large vernier caliper is being used to precisely measure the overall height of a cylinder head.

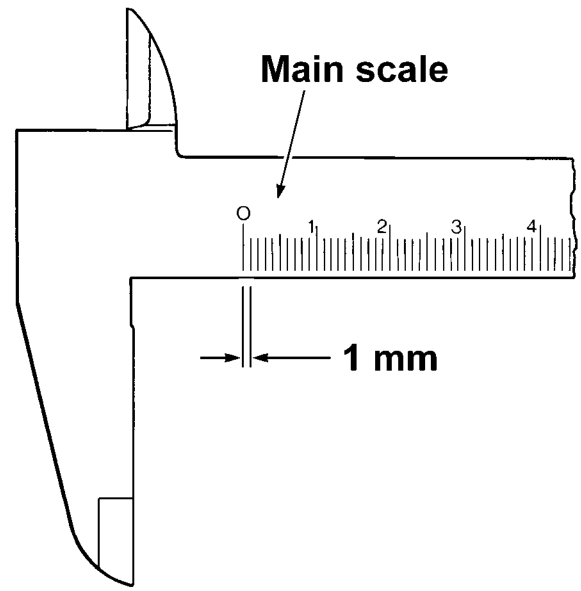
Vernier Caliper

Perhaps the most common and versatile of the precision measuring tools in the workshop is the vernier caliper. Two different sets of jaws are designed to make outside measurements such as component thickness, and inside measurements such as hole diameter or clearance between parts. Most vernier calipers also have a mechanism for depth measurements, such as a difference in height between two parallel surfaces.

The jaws are specially designed so that, when used carefully, they are properly aligned and perpendicular to the measured surfaces. This helps produce measurements that are as accurate as possible.

The name refers to its unique measuring scale, the vernier scale, named for 17th century mathematician Pierre Vernier. It provides a reliable and repeatable means of estimating fractions of millimeters, and gives a higher level of precision and accuracy.

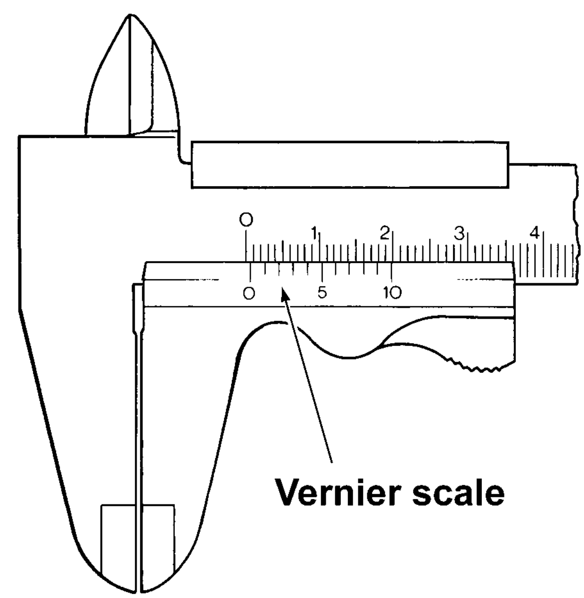
The vernier caliper's main scale is very much like a conventional ruler. It measures whole millimeter. In this way, the vernier caliper is no more precise than any other ruler.



The difference lies with the second scale, the vernier scale. Do you remember the problem we had trying to estimate 10^{ths} of millimeters on a ruler? The vernier scale is designed to overcome that problem and give us a reliable and repeatable way to measure fractions of millimeters with an additional degree of precision.

Depending on the type of vernier scale, a vernier caliper may be accurate to the nearest 1/10th (0.1) or 5/100^{ths} (0.05) millimeter. This degree of precision is useful for many routine measurements that need to be made in the workshop.

Some vernier calipers are equipped with vernier scales that can reliably indicate measurements to the nearest 2/100^{ths} (0.02) mm. Any measurements that require greater precision than a vernier caliper call for the use of a micrometer.



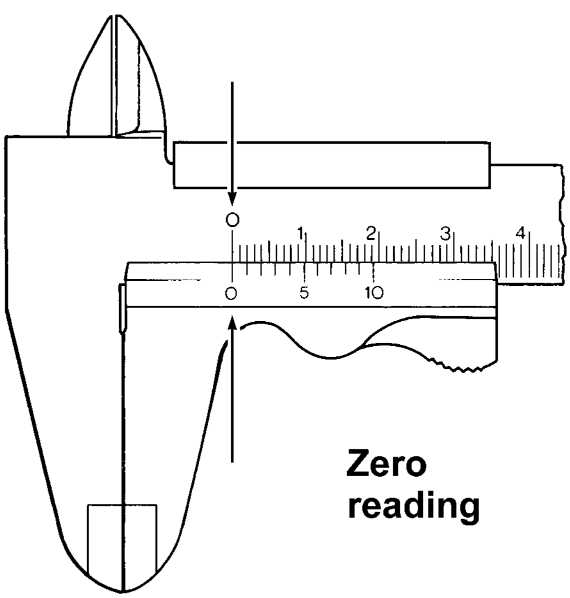
Digital caliper—all the function and versatility of a vernier caliper, with the added simplicity and convenience of digital read-out.

A dial caliper operates the same way as a vernier caliper, except that it combines the versatility of a caliper with the mechanical display of a dial indicator. Likewise, a digital caliper offers the benefits of an electronic digital display. A dial or digital caliper is more expensive than a vernier caliper, but easier to read. For information about reading a dial caliper, see the section on dial indicators later in this booklet.

Reading a vernier caliper

A combination of steps is used to arrive at the final, most precise reading. With practice, the sequence will become second nature. For now, however, we will exaggerate the details of each, and treat them as separate steps to make the whole process more clear.

Step 1 — Whole millimeters



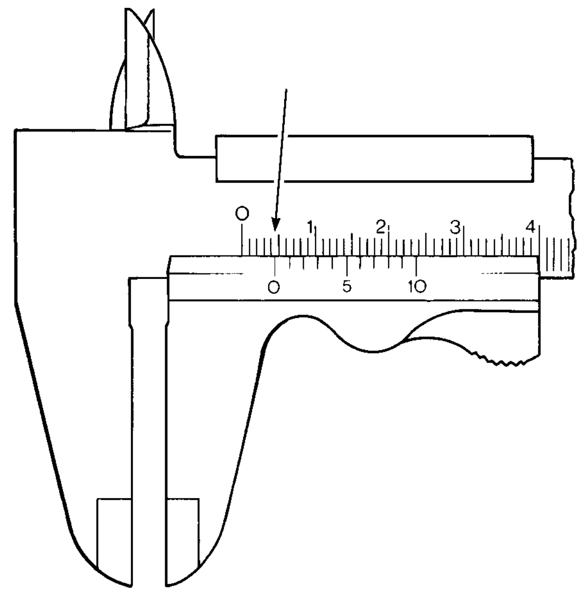
First, use the main scale to determine the value to the left of the decimal point—the initial part of the measurement in whole millimeters (mm). When the jaws are fully closed, when the caliper reads zero, the “0” on the vernier scale is exactly aligned with the “0” on the main scale.

As we open the caliper jaws to make a measurement, the “0” mark on the vernier scale acts as a pointer. Use it to read the first part of the measurement—the number of whole millimeters. Count the number of lines that appear between the “0” on the main scale and the “0” on the vernier scale.

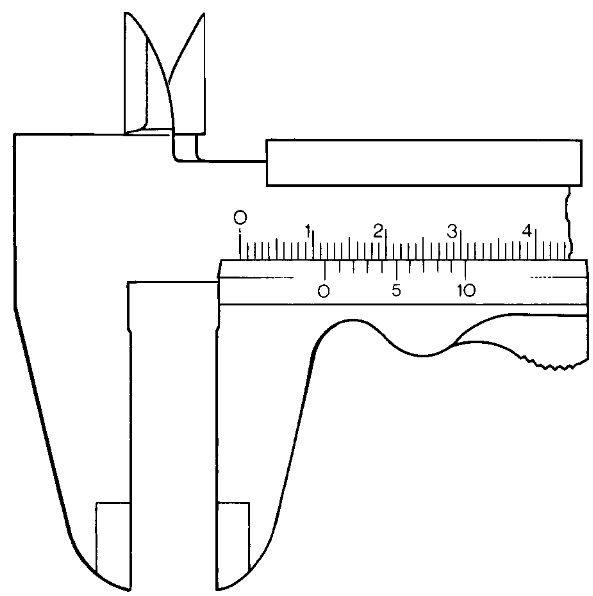
Example:

In this example, we count four lines from “0” on the upper scale (arrow), and determine that the measurement is at least 4 mm, but not as large as 5 mm.

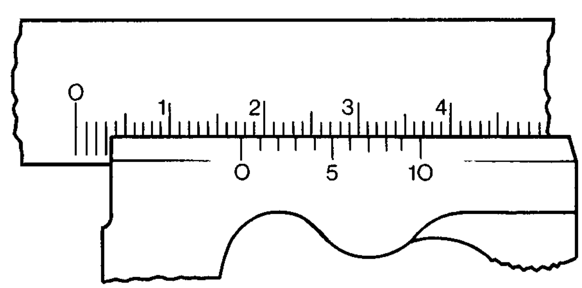
Try the next two as exercises. What is the first part of the measurement, the whole millimeter (mm) value, indicated in each case?



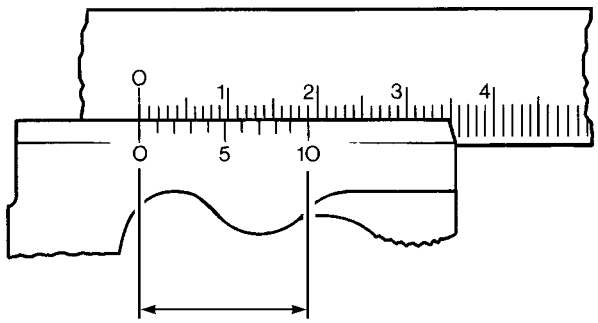
In the first exercise, we should count 11 lines from “0” on the main scale, so the whole millimeter value is 11 mm and the indicated measurement is at least 11 mm, but less than 12 mm.



In the next exercise, we count lines and find that the “0” pointer from the vernier scale is between the 17th and 18th lines on the main scale. If you said 3 mm, you made the mistake of taking your reading from the end of the sliding vernier element, where it overlaps the main scale. Using the “0” mark for the first part of the measurement, the whole millimeter (mm) value, we read 17 mm.

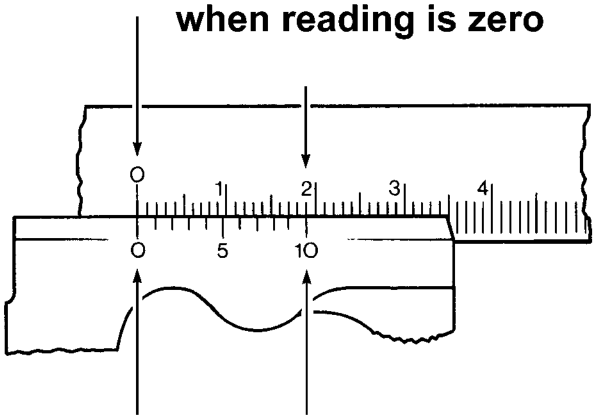


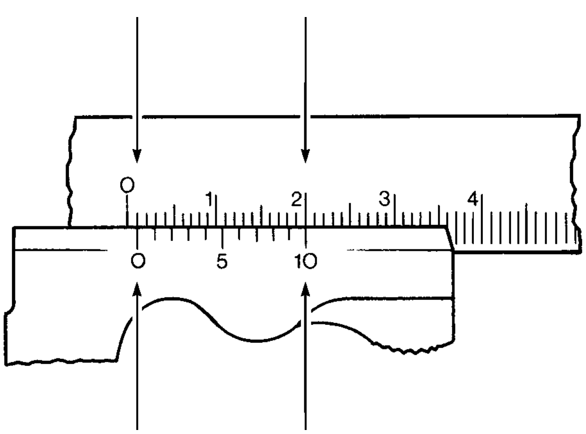
Always use the “0” mark on the vernier scale as the pointer to count whole millimeters.



Entire vernier scale *represents* 1 mm

"0" marks align and two other marks align when reading is zero





Step 2 — Fractions of millimeters

For the next part of the reading, the similarity to a ruler ends. Vernier's scale allows us to accurately read tenths of millimeters, which we could never do with a ruler.

You will notice that the vernier scale is short. Its total length *represents* just *one* whole millimeter. In the version shown, there are ten increments marked along its length, labeled "0" to "10," so each increment *represents* $1/10^{th}$ millimeter.

We emphasize the word "represents" because, as we can see, these marks are greater than $1/10^{th}$ mm apart. In fact, these "$1/10^{th}$ mm" increments are *larger* than the whole millimeter markings on the main scale. By the genius of Vernier's design, we are able to use these large, easy-to-see markings to accurately read values that are actually much smaller.

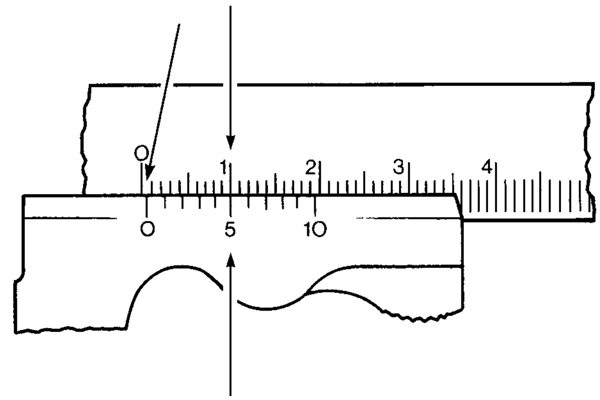
Once we have determined the "crude" part of the measurement in whole millimeters, we shift to the vernier scale and use *it* to count $1/10^{th}$ millimeters. Here's how:

In the first illustration, the caliper reads zero. The "0" pointer is exactly aligned with the "0" on the main scale. Notice, too, that the "0" mark and the "10" mark on the vernier scale are the only marks that line up with a mark on the main scale. Remember that for later reference!

In the second illustration, we have opened the caliper exactly 1 mm. The "0" on the vernier scale no longer reads zero because, of course, it now reads 1 mm. Notice, too, that the "10" on the vernier scale is still lined up with a mark on the main scale, but it is a different mark.

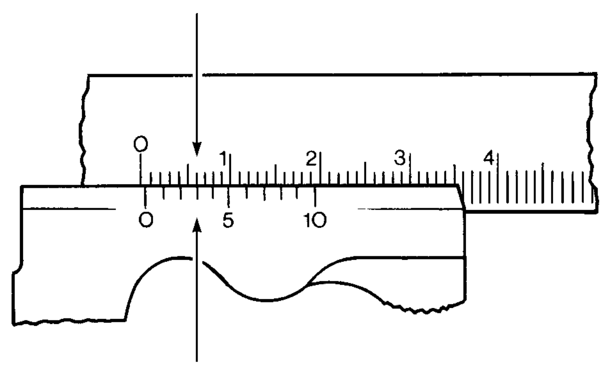
To make sense of this, let's look at a third illustration. The caliper is open exactly ½ mm (0.5). The "0" pointer line on the vernier scale lies, as we expected, halfway between 0 and 1 mm (left arrow).

To count 10^ths^ of millimeters, find the *one* line on the vernier scale that lines up, exactly, with any line on the main scale. In this example, it is the line at the "5" marking (right arrows), representing 5/10^ths^ millimeter, or 0.5 mm.

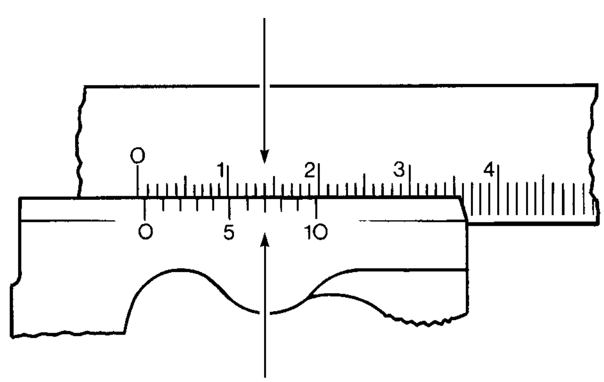


Let's try two other examples. These two appear to be, at first glance, almost identical. They are, however, indicating accurate readings of two very different measurements.

The first example indicates 0.3 mm. The line on the vernier scale that lines up with one on the main scale is the third one (arrows), indicating to 3/10ths or 0.3 mm.



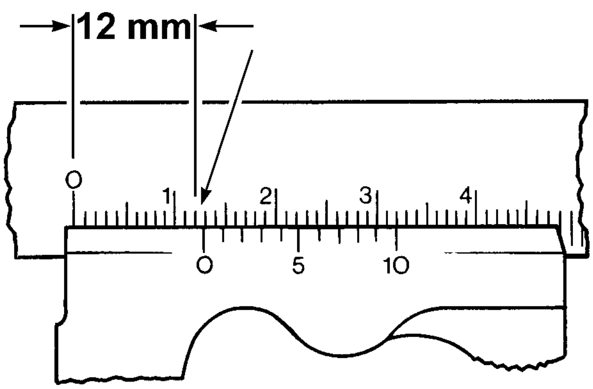
In the next example, we find that two different lines are in alignment (arrows). If we count the lines on the vernier scale, we can see that this example is indicating 7/10^ths^ or 0.7 mm.



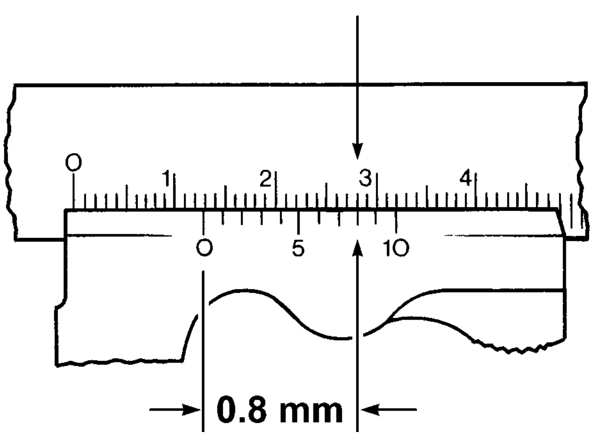
Step 3 — The complete reading

OK, now let’s put it all together to make a complete reading. We will go over the complete process, from beginning to end, using a new example.

First, we determine the “crude” part of the reading: what is the measurement to the nearest whole millimeter. Remember to always use the “0” mark on the vernier scale as a pointer to read the main scale. Count the lines between “0” on the main scale and “0” on the vernier scale.



Each line on the main scale is one millimeter. In this example, we count ten millimeters or one centimeter, indicated by the “1” on the main scale, plus two more for a total of 12. Our measurement lies between 12 mm and 13 mm (arrow).



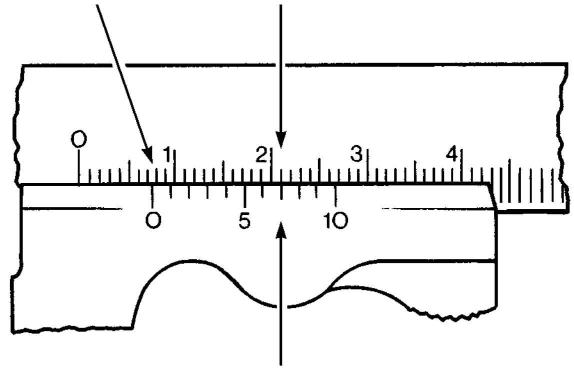
Next, we determine what fractional part of a millimeter remains, using the vernier scale. Looking closely, we see that just one line on the vernier scale lines up with just one line on the main scale (arrows). Counting on the vernier scale now, we count that as the eighth line. Each line indicates $1/10^{th}$ millimeter, so our vernier scale is indicating $8/10^{ths}$ or 0.8 mm.

Finally, we add those two values together to get the total measurement. 12 whole millimeters, plus $8/10^{th}$ millimeter, makes a total of 12.8 mm.

12 mm + 0.8 mm = 12.8 mm

Example:

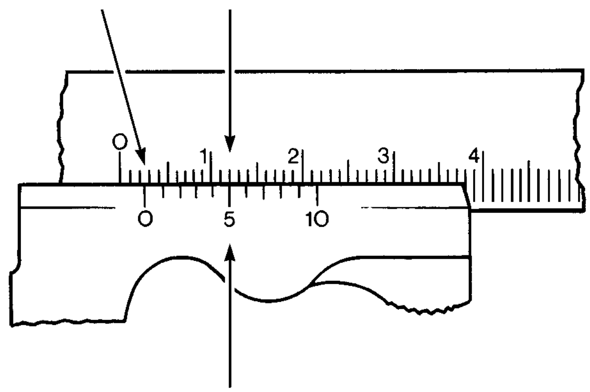
Using the “0” mark on the vernier scale as a pointer, we count seven millimeters on the main scale (left arrow). Then, we look for the one line on the vernier scale that matches up with a line on the main scale (right arrows). On the vernier scale, we count that as the seventh line. Each of the 10 lines on the vernier scale indicates 1/10th millimeter, so our vernier scale is indicating 7/10^{ths} or 0.7 mm.



7 mm + 0.7 mm = 7.7 mm

Example:

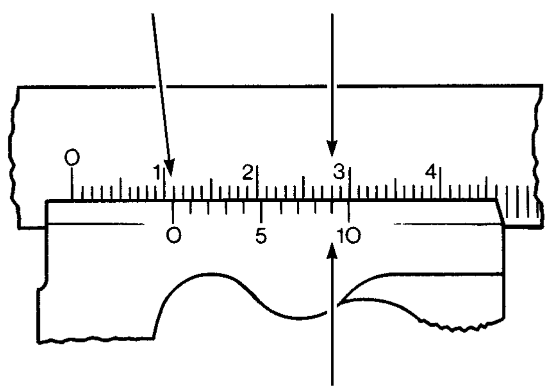
We count two whole millimeters on the main scale (left arrow). Then, we see that the fifth line on the vernier scale, labeled “5,” is the one that lines up with a line on the main scale, so our vernier scale is indicating 5/10^{ths} or 0.5 mm.



2 mm + 0.5 mm = 2.5 mm

Example:

The “0” pointer falls just past the 1 cm mark on the main scale, so we are reading 1 cm or 10 whole millimeters (left arrow). Turning to the vernier scale, we see that the ninth mark lines up with the main fractional scale, for a reading of 0.9 mm.



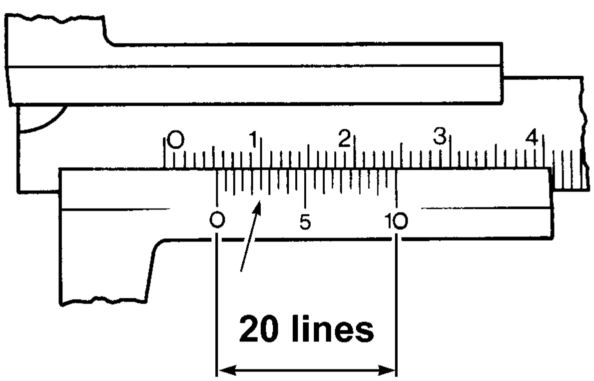
10 mm + 0.9 mm = 10.9 mm

Many vernier calipers are marked in both English and metric units. As you have seen, multiple steps are required to read a vernier caliper. Avoid getting confused about what scale you are using.

Reading other vernier scales

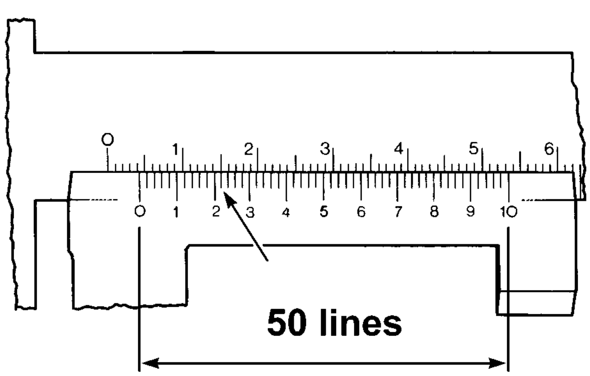
Different types of vernier calipers are capable of different degrees of precision. We have just seen an explanation of one common type, which is accurate to the nearest 1/10th millimeter. Others are capable of greater precision because of their design, and the scales they use.

To review, the short vernier scale always represents one whole millimeter. In our earlier examples, that one-millimeter scale was divided up into ten equal parts, so each part represents 1/10th millimeter. Another caliper might feature a one-millimeter scale divided into 20 or 50 equal parts.



In this case, the "0" to "10" vernier scale still represents one millimeter, but it is divided into 20 equal parts instead of ten. The ten lines representing 0.1 mm are each subdivided by a smaller line. Each of these represents 1/20th millimeter (0.05).

Knowing this, of course, becomes important when we are counting lines on the vernier scale. We have to know what part of a millimeter each line represents. With this more precise vernier scale, we have a way to read values like 5.25 mm, which fall midway between 5.2 mm and 5.3 mm, as shown (arrow).



Vernier scale represents 1 mm
Each mark is 1/50th or 0.02 mm

Let’s look at one more type of vernier scale. The complete "0" to "10" vernier scale *still* represents just one millimeter, but it is divided into 50 equal parts. Each line now represents 1/50th millimeter (0.02), so we can read to the nearest 0.02 mm, reading values like 4.22 mm in the example shown (arrow).

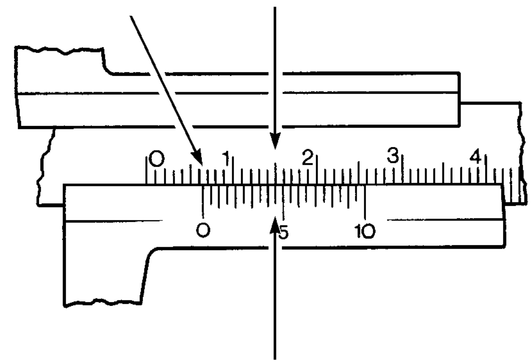
We take measurements with any precision vernier caliper the same way, as long as we translate the lines on the vernier scale correctly.

Example:

The main scale remains the same. Each line marked on the main scale indicates one millimeter. In this example, we count six whole millimeters (left arrow).

Again, just one line on the vernier scale is aligned with another on the main scale. Counting on the vernier scale now, we count that as the ninth line. The difference is, there are now 20 lines on the vernier scale representing 1 mm. Each line indicates $1/20^{th}$ millimeter, or 0.05 mm, so our nine lines on the vernier scale indicate 9 x 0.05, or 0.45 mm.

6 mm + 0.45 mm = 6.45 mm

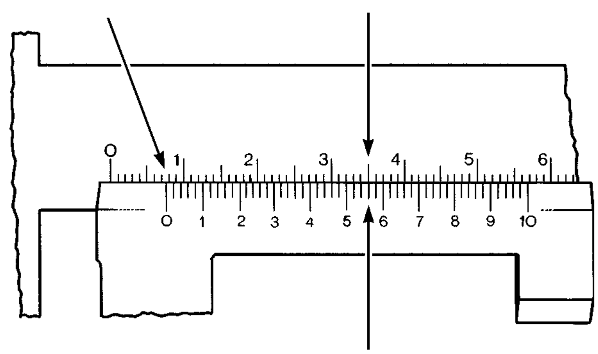


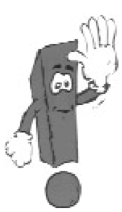
Example:

The main scale is the same. Each line marked on the main scale indicates one millimeter. In this example, we count seven whole millimeters (left arrow).

Again, just one line on the vernier scale lines up with a line on the main scale. Counting on the vernier scale now, we read 0.5 mm plus three more lines. Since each line indicates $1/50^{th}$ millimeter, or 0.02 mm, those three lines on the vernier scale indicate 3 x 0.02, or 0.06 mm.

7 mm + 0.5 + 0.06 mm = 7.56 mm



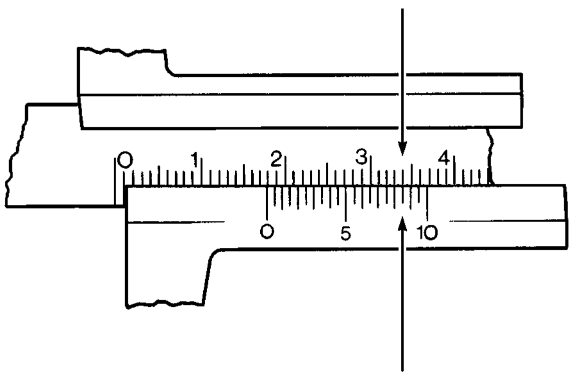


Any measurement using a vernier caliper must be made with the jaws or the depth gauge exactly perpendicular—at right angles—to the measuring surfaces. Otherwise, they will be inaccurate.

Review/Quiz

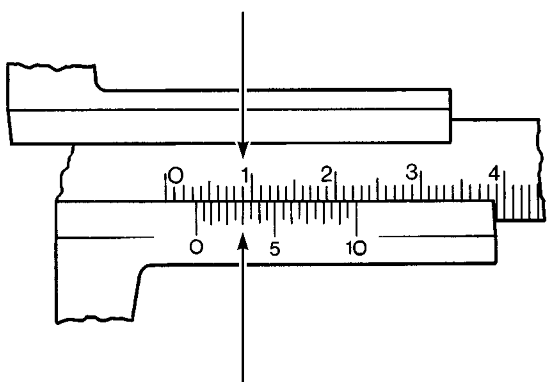
Use the examples on this page to test your understanding of how to read a vernier caliper. For clarity, the marks on the two scales that line up are indicated by the vertical reference lines.

Correct answers are included at the back of the booklet (see page 52).



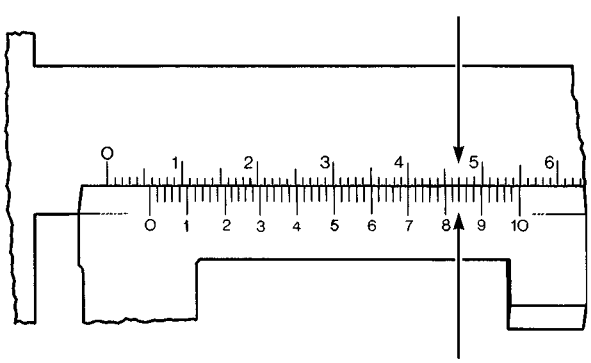
Example 1

The vernier caliper reads __________ mm



Example 2

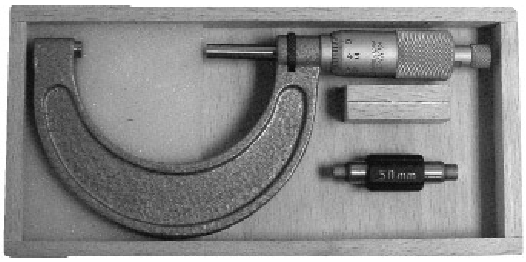
The vernier caliper reads __________ mm



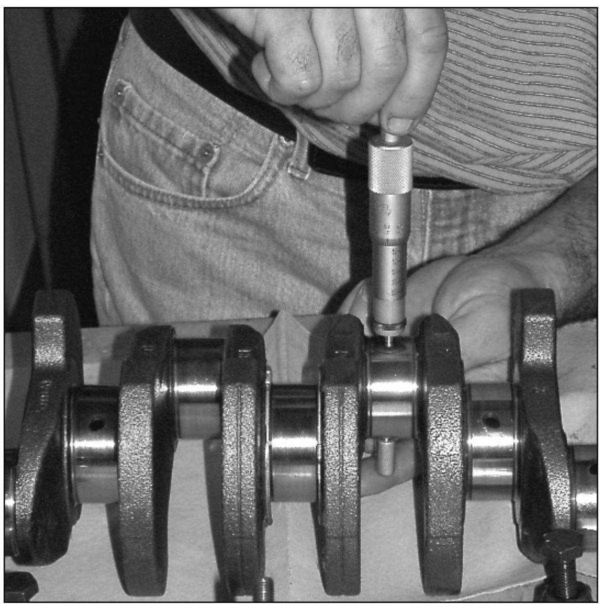
Example 3

The vernier caliper reads __________ mm

Micrometer



A typical outside micrometer



An outside micrometer being used to measure crankshaft journal diameter.

Micrometer

Types of micrometers

A micrometer, like a vernier caliper, is used to make precise measurements of length. Most are capable of measuring to the nearest 1/100th of a millimeter (0.01 mm or 0.0004 in.).

There are three common types: outside, inside, and depth micrometers.

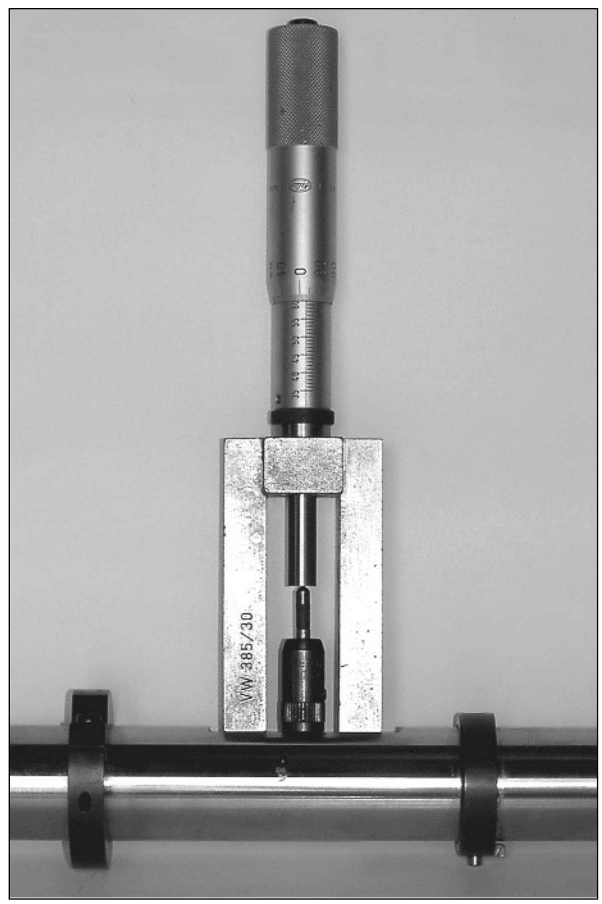
An *outside micrometer* measures outside dimensions. It may be used for precise measurement of thickness, or to measure the outside diameter (OD) of a cylindrical shape like a crankshaft journal or a piston.

An *inside micrometer* measures length or distance between two parallel surfaces. That may be a space between two components, or the inside diameter (ID) of a nominally round component, such as a connecting rod bore. It is a bit more difficult to use than an outside micrometer. The tool must be exactly perpendicular to the measured surfaces. Any deviation from perpendicular, caused by holding the tool at an angle, will produce a reading that is too large.

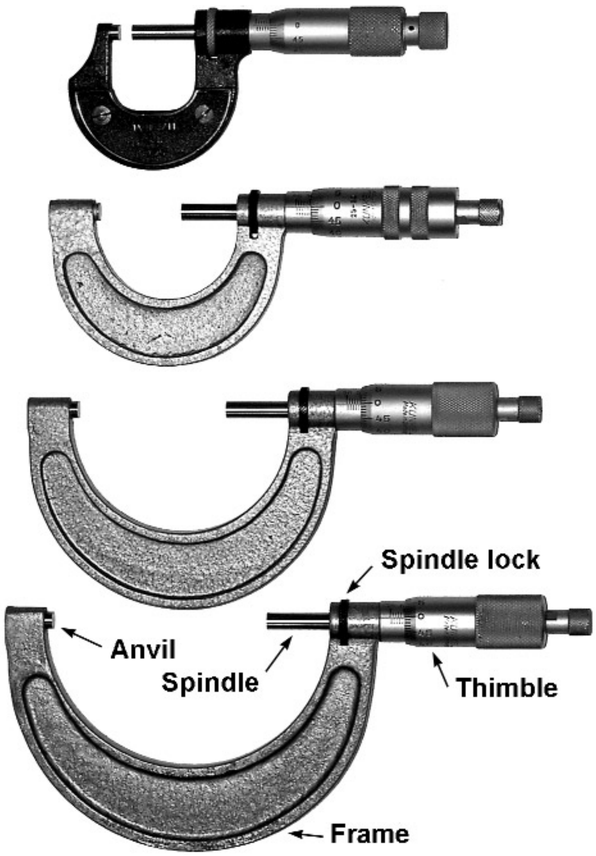
Even with the inside micrometer at the correct perpendicular angle, it can be difficult to get an accurate measurement. You are trying to measure at the largest dimension at any particular point. Any deviation from this true diameter will produce a reading that is too small.

A *depth micrometer* measures dimensions such as the position of a valve seat in a cylinder head. The term “depth” refers to any type of distance measured from a flat reference surface. In the case of a valve seat position, the reference surface is the flat surface of the cylinder head.

Typical inside micrometer, most often used to measure inside dimensions such as bore diameter. Note: the micrometer shown reads in non-metric units.



Volkswagen special tool VW385/30 is a type of depth micromter used in the set-up of final drive assemblies.

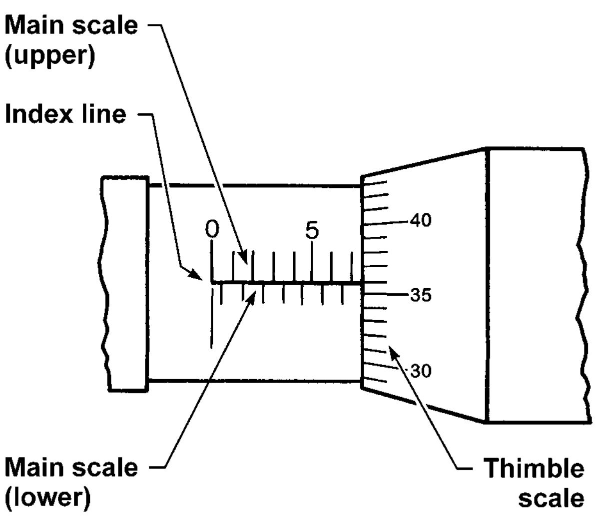


Micrometers have a relatively small range. Choose the right one for a particular job, making sure that the nominal dimension you want to measure falls within the range of the tool. Micrometers are available in various sizes, to measure from less than a millimeter to over 100 mm (approx. 4 in.).

Anatomy of an outside micrometer

The horseshoe-shaped frame holds the anvil and spindle, a spindle lock, the sleeve and the thimble. Measurements are determined by the distance between the moving spindle and the fixed anvil. The thimble rotates to move the spindle back and forth over very precise distances.

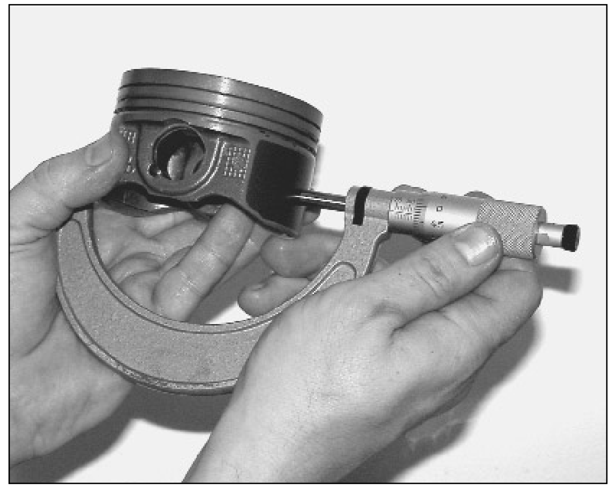
Measurements are made using scales marked on the sleeve and thimble. The main scale on the sleeve is actually an upper scale marked in 1 mm increments, and a lower scale that effectively indicates ½-millimeter increments. The position of the thimble along these two parts of the main scale indicates measurements to the nearest 0.5 mm.



The *index line* on the main scale is used to read the even more precise 1/100th mm (0.01 mm) increments of the scale marked around the diameter of the thimble. The thimble scale is evenly divided into 50 increments corresponding to 0.01 mm each. One complete revolution of the thimble equals 0.5 mm, one ½-mm increment on the sleeve, and a ½-mm movement of the spindle.

Operating a micrometer

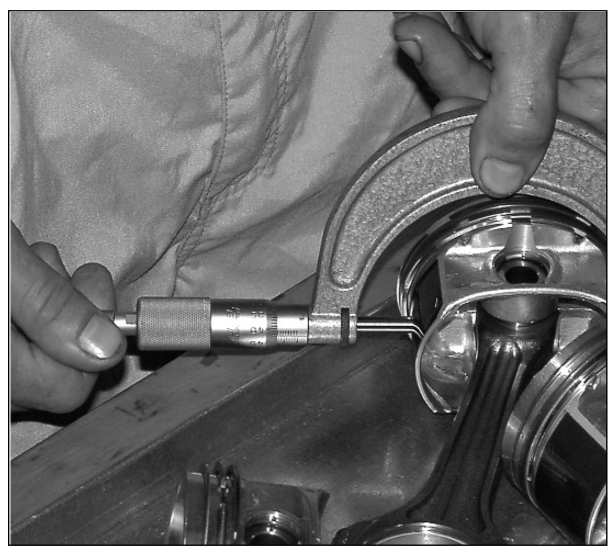
When the thimble is turned so that the spindle is just making light contact with the anvil, the micrometer should read zero. The end of the thimble should be precisely aligned with the “0” mark on the sleeve, and the index line should be precisely aligned with the “0” mark on the thimble.



To measure an object, hold it against the anvil with one hand, while rotating the thimble to move the spindle toward the object with your thumb and forefinger. Continue turning until the spindle makes light contact with corresponding side of the object.

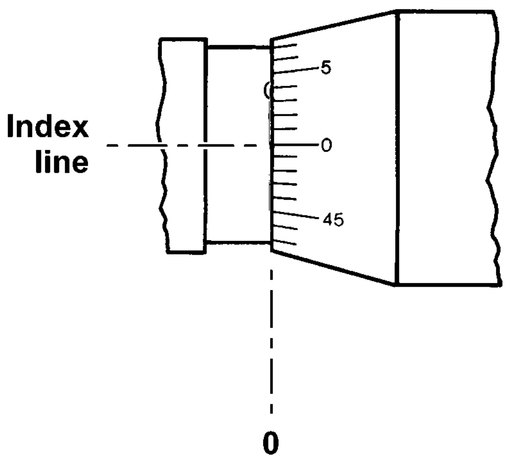
Do not tighten the spindle too forcefully against the measured object. It may damage the micrometer frame and/or destroy its calibration.

Tighten the micrometer just enough that it drags slightly as you try to shift or remove the object. Some micrometers have a small knob on the end of the thimble, connected to a clutch mechanism. Tightening the micrometer using this knob rather than the thimble will ensure that you are applying just the right amount of force. If you apply too much force, the clutch will slip to prevent damage.



Reading a micrometer

A combination of steps is used to arrive at the final, most precise reading. With practice, the sequence will become second nature. For now, however, we will exaggerate the details of each, and treat them as separate steps to make sure the process is clear.



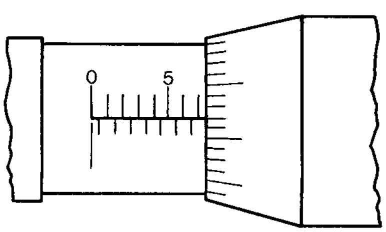
Step 1 — Whole and half millimeters

First, use the main scale to determine the part of the measurement expressed in whole millimeters. The micrometer reads zero when the edge of the thimble is exactly aligned with the “0” on the main scale.

Opening the micrometer to take a measurement, the edge of the thimble moves along the main scale. To read the first part of a measurement—the number of whole millimeters—count the lines that appear between the edge of the thimble and the “0” on the main scale.

Remember that the top of the scale on the sleeve is marked in 1 mm increments. The marks on the bottom scale subdivide the marks on the top, and these bottom marks indicate ½-millimeter increments. Count whole millimeters using the top of the main scale.

Example:



In this example, the thimble is indicating a measurement between 7 mm and 8 mm. We know this, because we can count seven lines on the upper part of the main scale. From this, we determine that the measurement is at least 7 mm.

Compared to a vernier caliper, we are now adding an extra step. The bottom part of the main scale on the sleeve allows us to make this initial reading to the nearest *half* millimeter. Once the initial number of whole millimeters is known (seven in the example above), look to see if another line is visible on the bottom part of the scale. If so, this indicates that another ½-millimeter should be added.

Example:

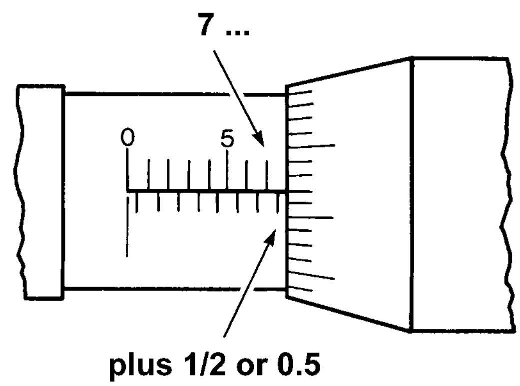
In this example, we count seven lines on the upper part of the main scale, but we can also see an additional line on the bottom part of the main scale. From this, we determine that the measurement is at least 7-½ or 7.5 mm.

7 mm + 0.5 mm = 7.5 mm

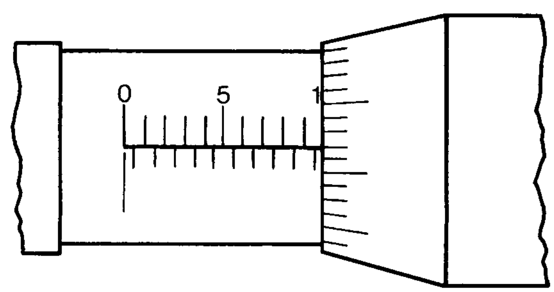
Try this initial reading, using the next two examples as exercises.

What is the first part of the measurement, the whole millimeter (mm) value, in each case?

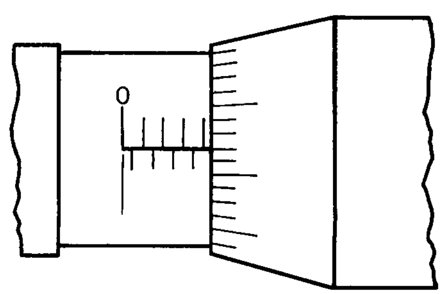
Using the bottom part of the scale, should we add ½ mm to the whole millimeter value?



In the first exercise, we can count nine lines on the main scale. There is an additional line visible just past that, on the bottom part of the scale. From this preliminary reading, we can tell that the measurement will be at least 9.5 mm, but less than 10 mm.



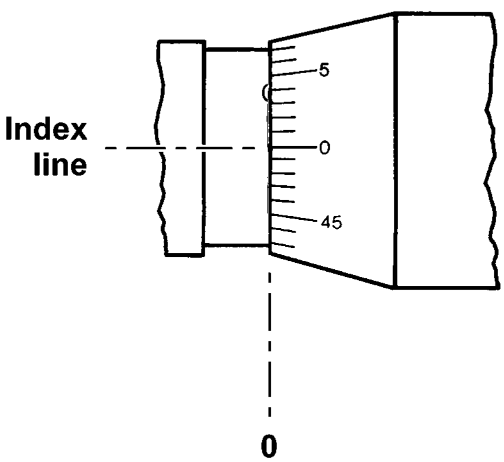
In this next exercise, we count lines and find that the edge of the thimble falls between the fourth and fifth lines on the main scale. In this case, however, no additional line is visible below the index line. From this preliminary reading, we can tell that the measurement will be at least 4 mm, but less than 4.5 mm.



Step 2 — Smaller fractions of millimeters

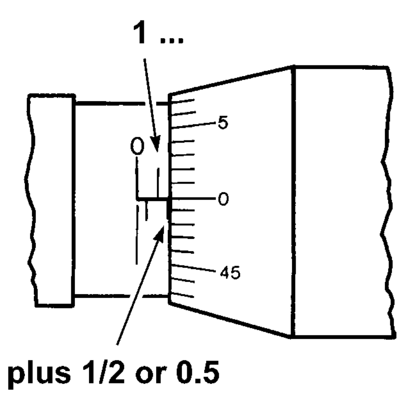
After that initial reading, which is "a little more than" the nearest ½-millimeter, we need to find out how *much* more. We will read the more precise fractions of a millimeter from the scale on the rotating spindle. The thimble and spindle turn on very fine, precisely machined threads, and accurately indicate 100^{ths} of a millimeter.

The entire circumference of the thimble is inscribed with a scale, divided into fifty equal parts, and marked from "0" to "50." Each of the fifty increments of rotation equals 1/100th millimeter of spindle movement. A full rotation equals 50/100^{ths} or ½ mm (0.5)—the distance between a millimeter mark on the main scale (top) and the next ½ mm mark on the bottom main scale.



The reading from the thimble tells us how much, in 100^{ths} of a millimeter, to add to the initial measurement. Here's how.

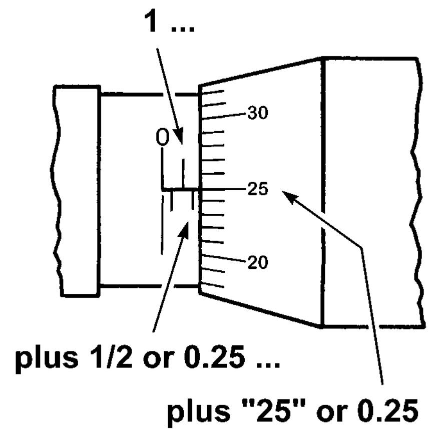
In the first illustration, the micrometer reads zero. The edge of the thimble is aligned with the "0" on the main scale, and the "0" on the thimble scale is aligned with the index line on the sleeve.



In the second illustration, we have opened the micrometer exactly 1.5 mm. The edge of the thimble no longer aligns with "0" because, of course, it now reads 1.5 mm. Note that the thimble has made three complete rotations (3 x 50/100^{ths} = 150/100^{ths} or 1.5). The "0" on the thimble scale is *still* exactly aligned with the index line on the sleeve.

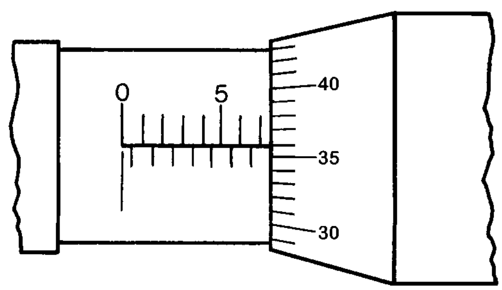
To make sense of this, let's look at the third illustration. The caliper is open exactly 1-¾ mm (1.75). The edge of the thimble lies, as we would expect, halfway between 1.5 mm and 2 mm. To count 100^{ths} of a millimeter, find the line on the thimble scale that lines up with the index line on the main scale. In this example, we see that it is the line at the "25" mark, representing $25/100^{\text{ths}}$ millimeter, or 0.25 mm.

1 mm + 0.5 mm + 0.25 mm = 1.75 mm



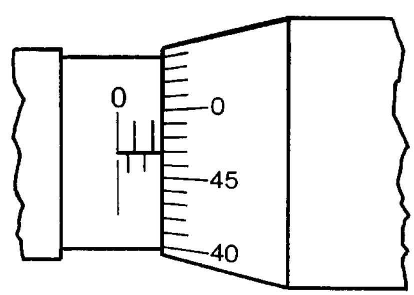
Let's try two other examples. The first indicates 7.36 mm. The edge of the thimble lies just past the seventh line on the upper scale. There is no extra line visible on the lower scale, so our initial reading is between 7 mm and 7.5 mm. On the thimble scale, the index line lines up one mark higher than "35" for a reading of "36" or 0.36 mm. Our initial reading of 7 mm *plus* 0.36 mm = 7.36 mm.

7 mm + 0.36 mm = 7.36 mm

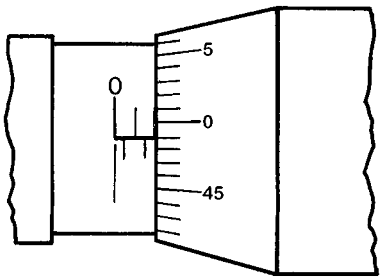


In the next example, the edge of the thimble is indicating just 2 mm, but very close to 2-½ mm. It is no surprise, then, to find the thimble scale reading 0.47 mm—almost 0.50. Our reading is 2 mm *plus* 0.47 mm, for a total of 2.47 mm.

2 mm + 0.47 mm = 2.47 mm



At measurements that are very close to the nearest ½ millimeter, the next line on the main scale may start to become visible. Be careful not to misinterpret this and add an extra 0.5 mm by mistake, as in the next example.



In this example, one might assume that we should count 2 mm on the main scale, and add 0.49 mm from the thimble scale to get a total of 2.49 mm. Looking more closely, we can see that this would be wrong, since the entire reading is very near 2 mm. The reading from the thimble scale is “49” instead of “0,” indicating that the correct reading is 1.99 mm.

1 mm + 0.5 mm + 0.49 mm = 1.99 mm

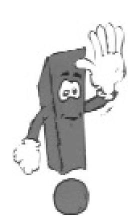
Inside and depth micrometers operate much the same way, although their scales may be graduated in slightly different ways. Determine the most accurate measurement you can make on the main scale, and make sure you understand the relationship between the main scale and the thimble scale.

A 50 mm standard being used to calibrate a 50-75 mm outside micrometer. With 50 mm between the anvil and spindle, the micrometer should read exactly 50.00 mm.

Calibration

A good quality micrometer is furnished with a calibration standard of a precise, known dimension. It should read exactly 0.00 mm when closed, and it should read precisely the specified dimension when measuring the standard—50.00 mm in the example shown.

If it does not read correctly, the calibration of the micrometer should be adjusted. If it cannot be adjusted to read accurately under *both* conditions, the micrometer is excessively worn and should be replaced.



Never store an outside micrometer in the fully closed or “zero” position. Changes in temperature may cause enough thermal expansion to increase stress on the components and warp the frame or damage the sensitive mechanism.

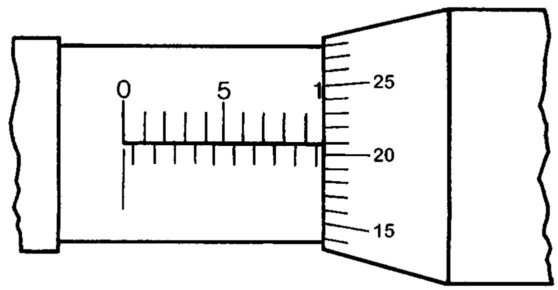
Review/Quiz

Use the examples on this page to test your understanding of how to read a micrometer.

Correct answers are included at the back of the booklet (see page 52).

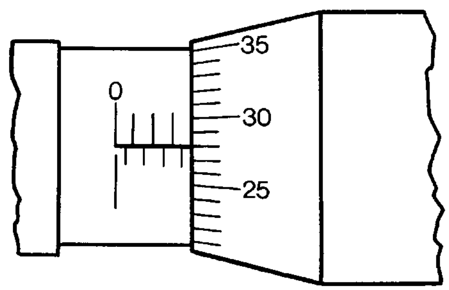
Example 1

This micrometer reads __________ mm



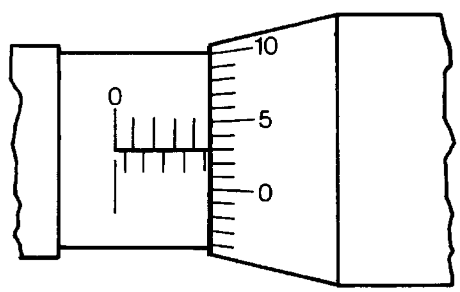
Example 2

This micrometer reads __________ mm

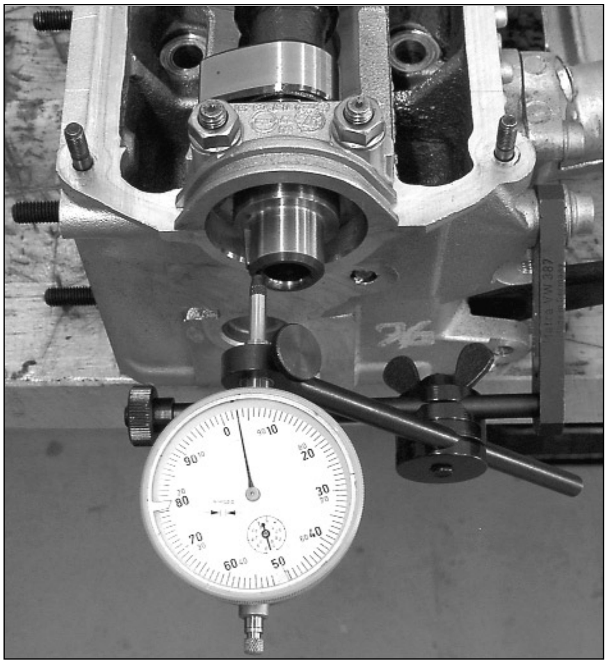


Example 3

This micrometer reads __________ mm



Dial Indicator

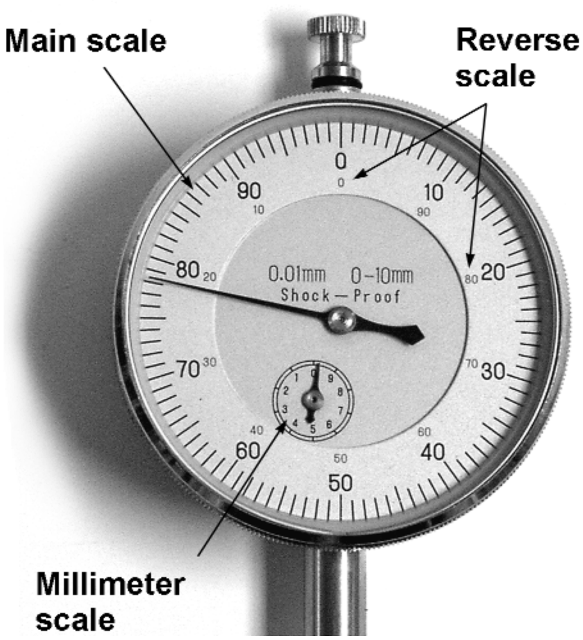


Dial indicator being used to measure camshaft end play.

Dial Indicator

A dial indicator is another instrument used to make very precise measurements of distance, accurate to the nearest 1/100th of a millimeter (0.01 mm or 0.0004 in.). Where a vernier caliper or a micrometer measures fixed dimensions of parallel surfaces, a dial indicator is most often used to measure a range of movement or making minimum/maximum comparisons. Properly set up in one measuring position, it can accurately measure range of free play, limits of movement, run-out, etc.

In the workshop, a dial indicator may be typically used to evaluate the condition of moving parts—run-out measurements on rotating parts, crankshaft or camshaft end play, gear backlash and the like. A dial indicator can also be used to indicate the precise maximum and minimum points in a range of movement, such as camshaft timing based on valve lift, diesel injector pump timing and stroke, etc.



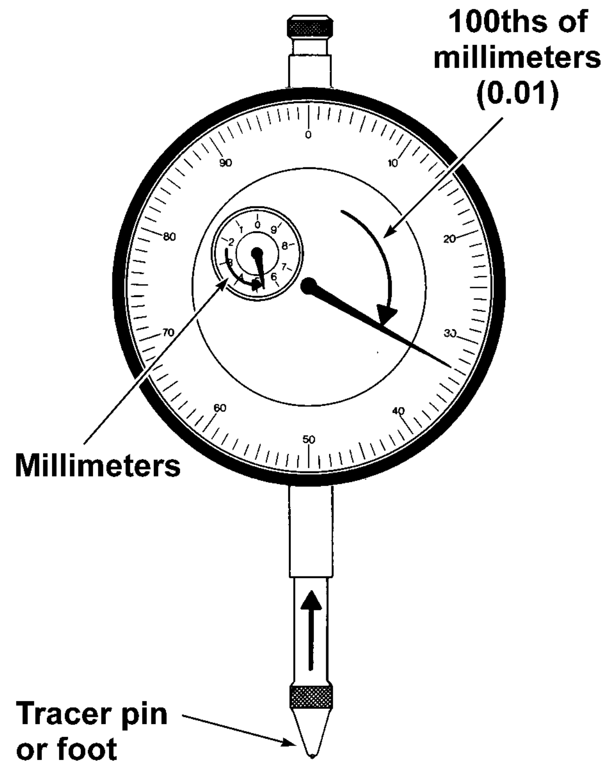
A typical dial indicator has two scales. The larger main scale is marked in increments of 1/100th of a millimeter or 0.01 mm. With 100 of these increments marked on the main scale, one complete revolution of the large needle is equal to 1 mm.

Many dial indicators also have an inner or “reverse” scale that counts travel in the other direction, usually marked in red. It is useful when, for example, you want to set zero as a midpoint and make direct readings of a range of values on both sides of that midpoint.

A smaller indicator, inside the large outer dial, counts whole millimeters.

The smallest movements are recorded by the movement of the large needle. When the tracer *pin* or *foot* is displaced and moves toward the indicator, the large needle rotates clockwise. It will make one complete revolution for each millimeter the pin moves.

Because the dial is very sensitive and will move very quickly, it can be difficult to notice if it has gone around the dial more than once. The small needle turns counter clockwise to count whole millimeters—full revolutions of the larger needle.

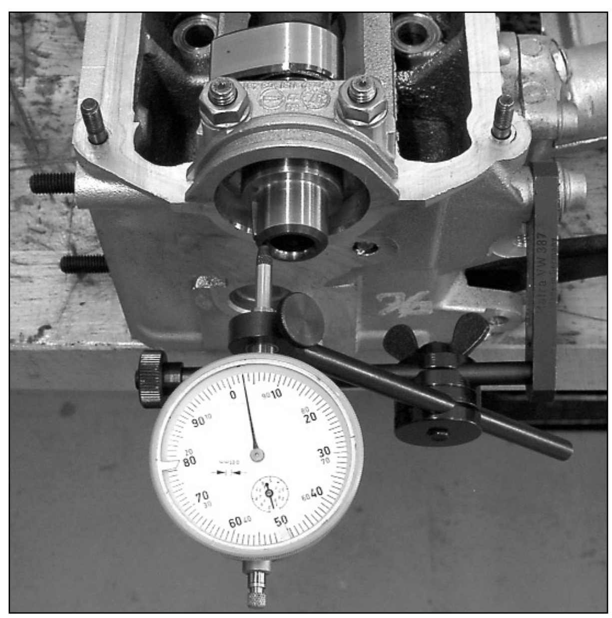


Mounting a dial indicator

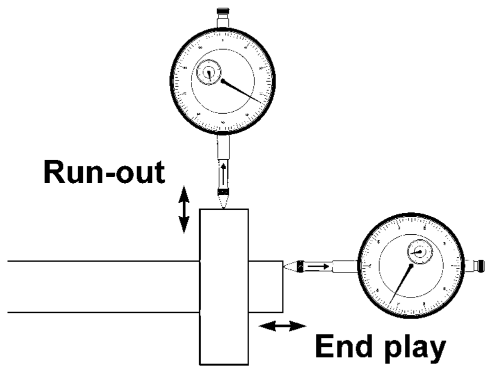
A dial indicator is always used with a mounting fixture that allows it to be aligned at the proper angle, and rigidly mounted in that position. Most mount directly to the work piece with slotted holes and pivot points for adjustment. Another popular mount has a magnetic base that can be attached to any flat iron or steel surface without fasteners.

We typically use dial indicators to make very small measurements. There are two main requirements for making accurate measurements with a dial indicator:

1. Rigid mounting to the work — when measuring, for example, crankshaft end play in a cylinder block, the dial indicator must be mounted directly to the block. Only this way can you be sure that you are measuring *only* the movement you intend to measure. Make sure *all* of the mounting fixture's fasteners and pivot points are tight.



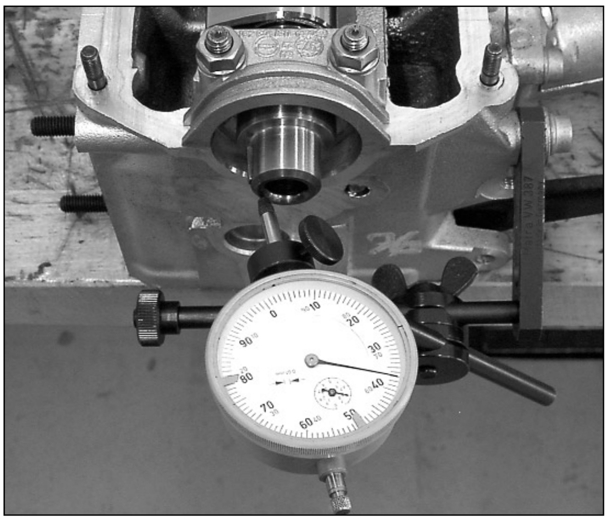
Typical dial indicator mounting, bolted to cylinder head using highly adjustable mounting fixture.



2. Mounting in direction of travel — the tracer pin must be exactly aligned with the dimension being measured.

   When measuring shaft end play or thrust bearing clearance, for example, the tracer pin's movement must be *parallel* to the shaft.

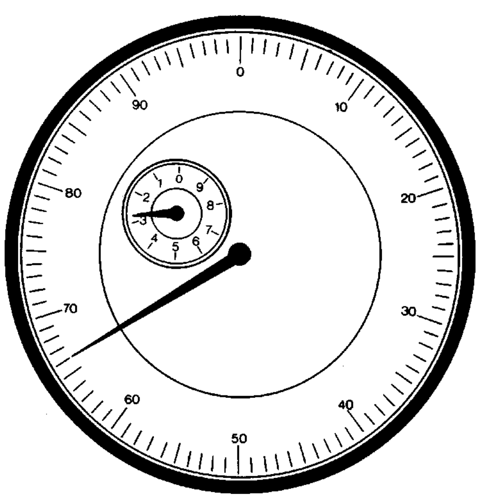
   For measuring run-out, the tracer pin's movement must be *perpendicular* to the shaft or surface being measured.



Improper dial indicator mounting (exaggerated in this view). The tracer pin is not in line with the direction in which play is being measured.

Reading a dial indicator

The main scale is divided into 100 equal parts. We read values to the nearest 1/100th millimeter (0.01 mm) directly on the main scale. A full revolution is equal to one whole millimeter.



Each millimeter—each full revolution of the larger needle—is shown on the smaller indicator. In this example, it shows that we have measured two whole millimeters, plus the 0.66 mm indicated on the main scale.

2 mm + 0.66 mm = 2.66 mm

This is a simple example. In practice, we cannot use the mechanical limit of the dial indicator as zero. There must always be at least some travel, some *pre-load* on the tracer pin, to ensure an accurate reading.

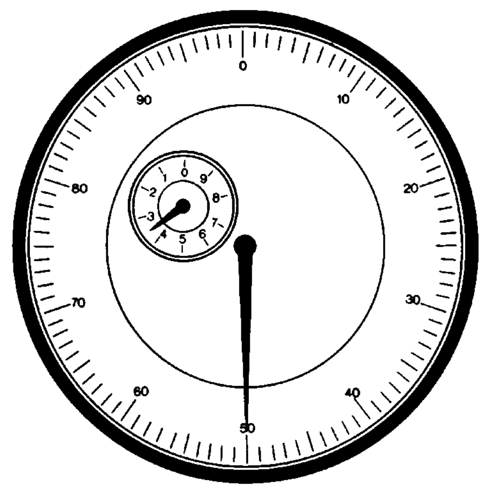
Any dial indicator will have some play in the mechanism. Pre-load means slightly loading the mechanism in one direction to take up that play, so that it does not affect the accuracy of the measurement.

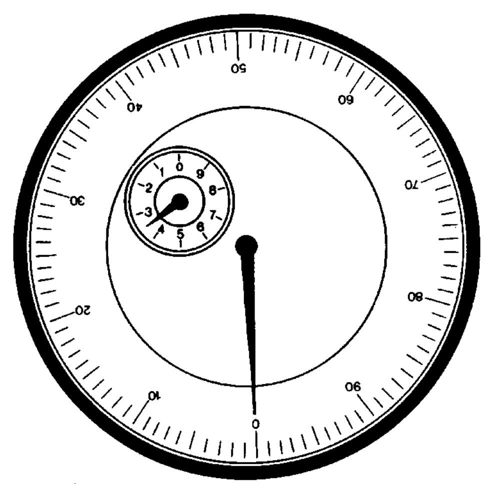
Mount the dial indicator so it reads greater than zero at the minimum point. One millimeter of pre-load is a good “rule of thumb” for most measurements. Initially, near the minimum point, the dial indicator should read about 1 mm.

To measure a range of values such as run-out, read the minimum value, and then subtract it from the maximum value. The actual minimum value may be less than 1 mm, and this is the reason for the pre-load—to make certain that the tracer pin never reaches the end of its travel. Measuring a larger range of values may require more pre-load.

To make it easier to subtract, the outer scale can be moved. Once we establish the precise minimum point, we can rotate the scale and actually make *that* point read exactly zero.

In the top illustration, the minimum value with pre-load reads 3.50 mm. In the bottom illustration, we have rotated the outer scale until the needle reads zero. We have moved *only* the outer scale, so we can make an accurate reading more easily. The needle itself has not moved.





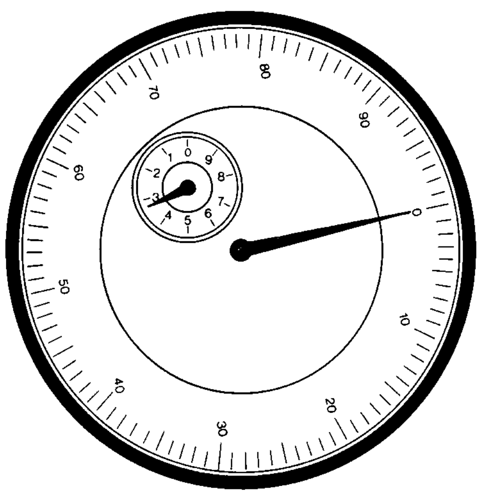
- For accurate measurements, the scale must be set so that the indicator reads exactly zero at the minimum point (lowest reading).
- After adjusting the scale, move the tracer by hand to recheck the zero point.

From this point, reading the measurement on the dial indicator becomes a matter of reading the difference between zero and the other (maximum) value.

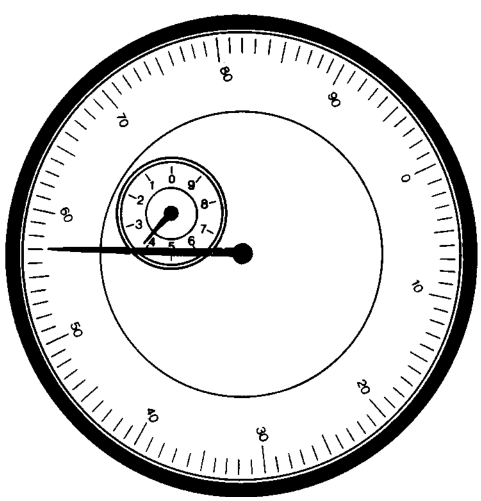
Let’s look at some examples:

Measurement: pump stroke
Specification: approx. 3 mm
Pre-load: 3.50 mm

In this case, we have chosen a pre-load that corresponds to the larger range of values that we expect to measure. With 3.5 mm pre-load, a 3 mm measurement should never exceed the range of travel of the tracer pin.



In the first illustration, we have set the pre-load at 3.5 mm. Then, with the tracer pin at the minimum point, the outer scale has been reset to zero. Notice that the reading has dropped below 3.50 mm.

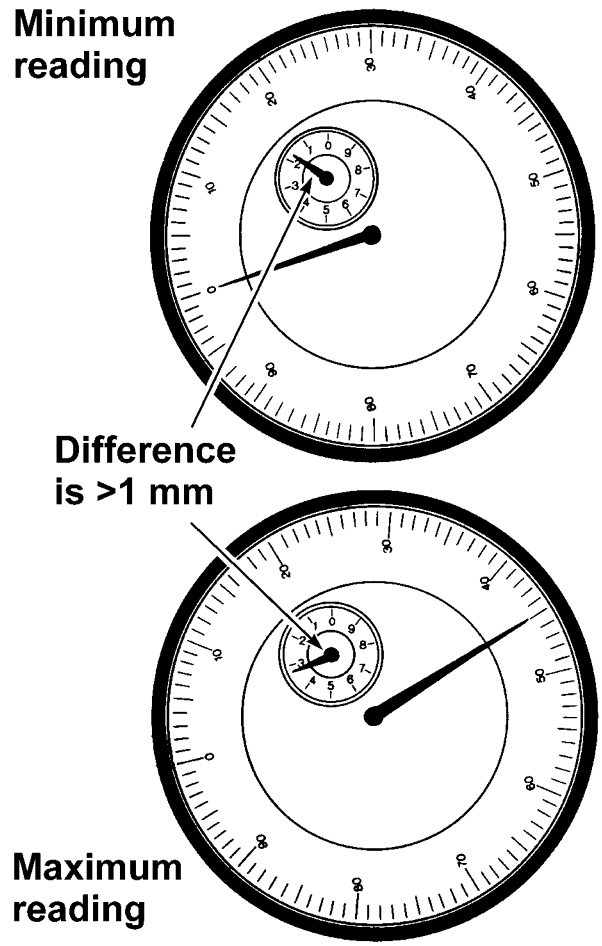


The second illustration shows the reading at the maximum point. The difference on the outer scale is 0.57 mm, and the small scale shows that the total change is less than 1 mm. The measurement in this case, the difference between minimum and maximum, is 0.57 mm.

Measurement: end play
Specification: approx. 1.5 mm
Pre-load: 2 mm

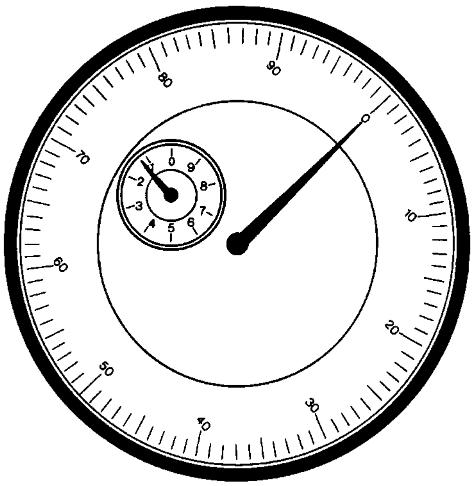
The top of the illustration shows the initial reading at the minimum point, after the outer scale has been reset to zero. The reading has dropped slightly below the 2.00 mm pre-load value.

The bottom part of the illustration shows the reading with the tracer pin at the point of maximum travel. The difference on the outer scale is 0.45 mm, but the inner dial also shows an increase. The large needle has made more than one rotation (1 mm), but less than two.



The measurement in this case, the difference between the minimum and maximum points, is 1.45 mm.

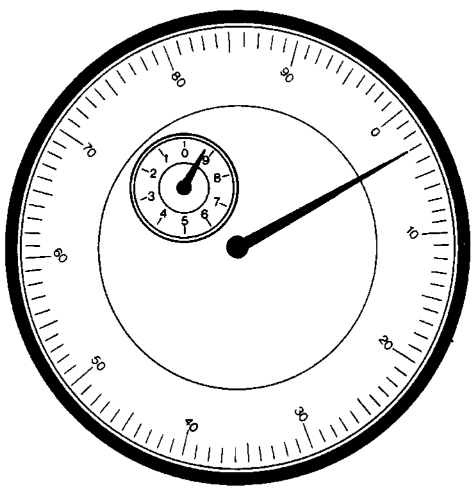
1 mm + 0.45 mm = 1.45 mm



Measurement: actuator movement
Specification: unknown
Pre-load: approx. 5 mm

The first illustration shows the reading after the outer scale has been reset to zero, with the tracer pin at the point of minimum travel. Notice that the indicator reading has dropped *far* below the 5 mm pre-load, but *not* as far as zero. This suggests that 5 mm pre-load is barely enough.

If the initial (minimum) reading dropped below zero, we would want to start again with more pre-load.



The second illustration shows the reading with the tracer pin at the maximum point. The difference on the outer scale is only 0.03 mm, but the inner dial shows that the needle has also moved about eight times around.

The measurement in this case, the difference between the minimum and maximum points, is 8.03 mm.

8 mm + 0.03 mm = 8.03 mm

Review/Quiz

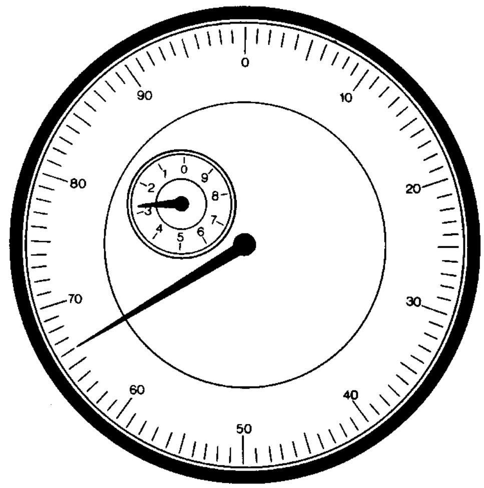
Use the examples on this page to test your understanding of how to read a dial indicator. After answering Example 1, use that result to derive the answers to Examples 2 and 3 as described below.

Correct answers are included at the back of the booklet (see page 52).

Example 1

Assume that we are measuring from a reading of exactly zero.

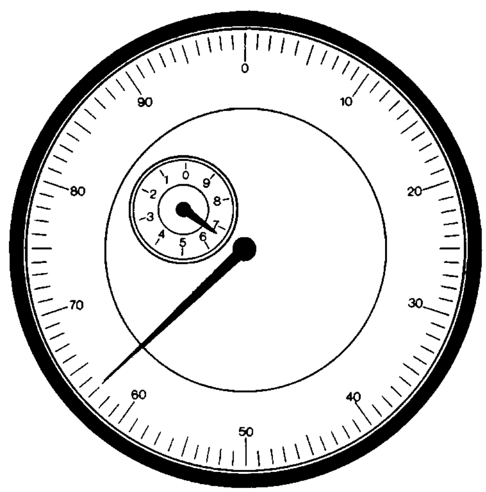
The dial indicator now reads _______ mm



Example 2

Assume that the first reading (above) is a minimum value, and the reading shown at right is the maximum.

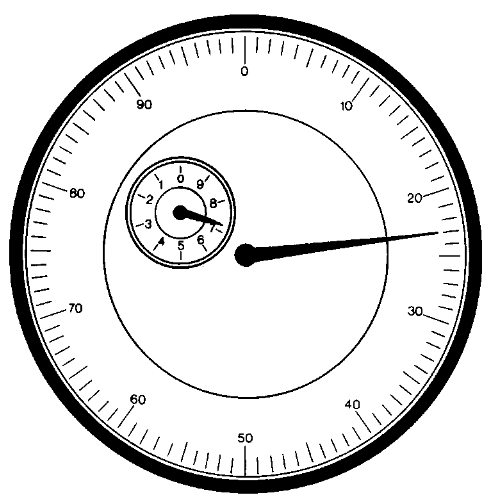
The measurement, difference between minimum and maximum, is ________ mm



Example 3

Assume that the first reading (top) was the minimum reading. Then, the outer scale was adjusted to read zero. The final reading shown at right is the maximum.

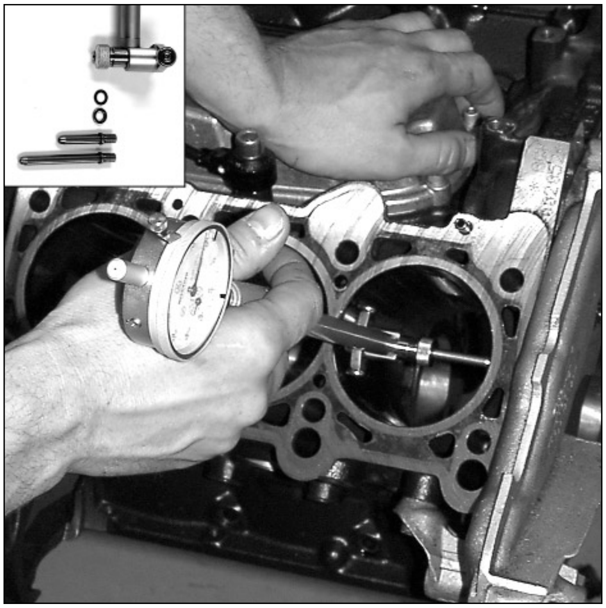
The true measurement is _________ mm



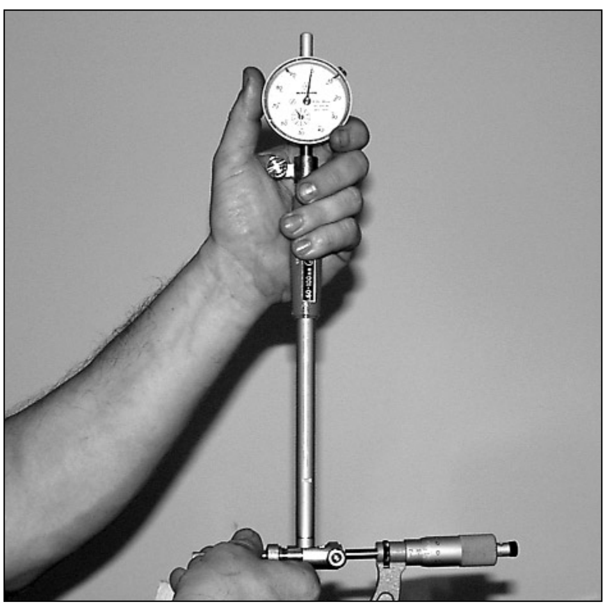
Dial Bore Gauge

Feeler Gauge

Torque Wrench



Dial bore gauge being used to measure cylinder bore diameter. This particular gauge uses precise shims and extensions to adapt to required measuring range (inset).



This outside micrometer clamped in a vise is pre-set to the nominal bore diameter, and the dial bore gauge is being set to read zero at that dimension. Any reading greater than zero translates directly into a measurement of increased cylinder diameter.

Dial Bore Gauge

A dial bore gauge is a special type of dial indicator, with a mechanism designed for measuring cylinder bores and similar inside diameters. By comparing bore diameter measurements at different points around the circumference, we can determine whether, or to what extent, the cylinder is out-of-round. By comparing measurements made at the top and bottom of the bore, we can determine cylinder taper. Both are important ways of evaluating the condition of the pistons and cylinders, possible causes of symptoms such as low compression or oil consumption, and whether or not the cylinder block can be reconditioned.

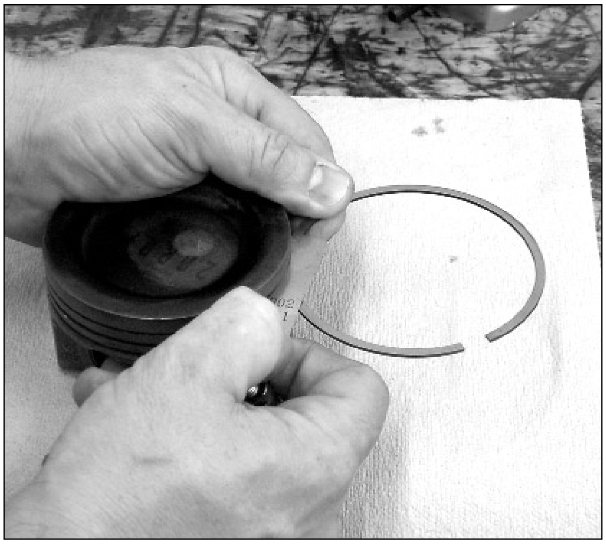
The dial indicator portion of a dial bore gauge functions just like any other dial indicator. The zero point on the scale can be adjusted as necessary as an aid to making a particular measurement.

In the example illustrated here, the zero point on the gauge is being pre-set to the nominal dimension specified for the bore. This way, the gauge will directly read the difference between the actual diameter at any point in the bore, and the nominal value.

The critical thing to remember about using a bore gauge is that it must be positioned precisely in line with the bore, to measure true diameters at any point in the bore. Tipping the gauge even slightly will cause the dial bore gauge to measure a value larger than the actual diameter.

The cylinder block must not be mounted to the assembly stand when measuring bore diameter. The block is deformed by its own weight under these conditions, and that stress will result in false measurements.

Dial bore gauge measurements must be made perpendicular to the cylinder bore. If misaligned, as shown, the values measured will be larger than the actual diameter and, therefore, inaccurate.



Flat-blade feeler gauge being used to measure piston ring clearance.

Feeler Gauge

A single feeler gauge is a strip of metal manufactured to a precise thickness. For convenience, a typical feeler gauge set is made up of multiple strips of varying thickness increments. They are often labeled in both millimeters and inches.

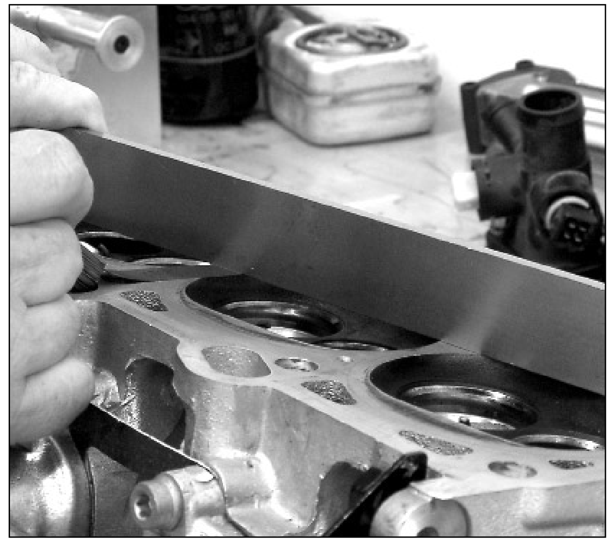
A flat-blade feeler gauge can be used for a variety of measurements including, for example, piston ring end gap, connecting rod side clearance, or valve adjustment (where applicable). For an accurate measurement, the feeler gauge should slip in and out of the gap being measured with a slight amount of drag or resistance.

If there is *no* resistance, the gap is probably slightly bigger than the gauge being used. If it is too difficult to get the gauge in and out of the gap, the gauge is probably just slightly too large. Guard against forcing a gauge into a gap. Doing so may change the gap you are trying to measure, damage the component(s), or damage the feeler gauge itself.

A wire-type feeler gauge or gap gauge is used to measure spark plug gaps. Some flat-blade feeler gauges are made of brass to allow clearance measurements between parts that may be otherwise influenced by magnetic attraction.

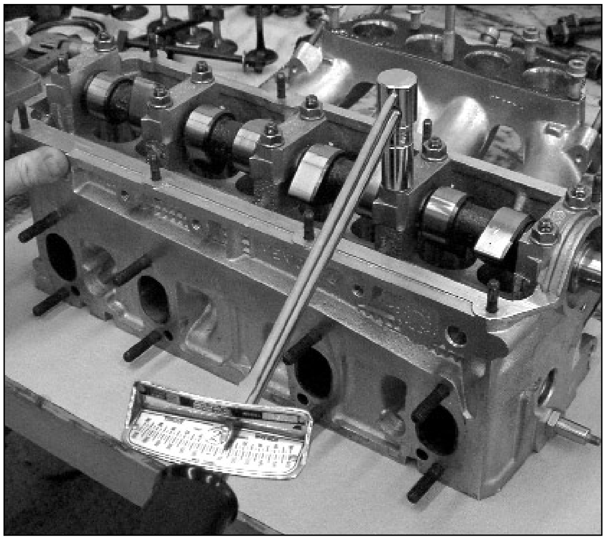
Feeler gauge and straight-edge

Used in conjunction with a straightedge, a flat-blade feeler gauge can be used to check a flat machined surface for warping or other deformation. A straightedge is a precisely machined bar, designed to be almost perfectly flat and very resistant to bending, warping or other distortion. As such, it is used as standard for judging the relative flatness of other components. Without a doubt, the most common application of this tool is in evaluating the condition of aluminum cylinder heads.



A straightedge is used in conjunction with a feeler gauge to measure whatever gap may exist at various points between the straightedge and the surface being checked. Ideally, of course, there are no gaps, and the cylinder head is perfectly flat. Factory repair information usually lists the maximum allowable gap with which the cylinder head can be safely re-used without machining or replacing it.

- Several other factors must be considered when evaluating a cylinder head to determine whether it can be machined to correct problems with flatness or warping.
- The factory repair information will usually list, for example, a minimum cylinder head thickness dimension that is required for proper operation of the hydraulic cam followers. Refer to that information and carry out those additional measurements as necessary.



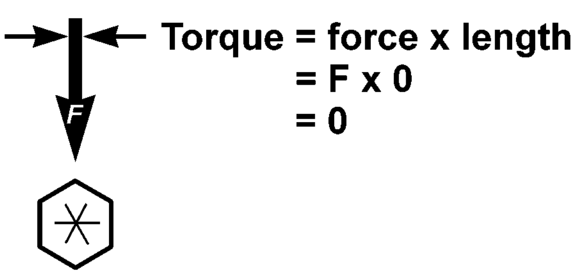
Torque Wrench

While a torque wrench is not strictly a measuring tool, we use tightening torque as an indirect way to measure something that we cannot measure any other way.

A threaded fastener generates a clamping or compression force that will hold two components together. In turn, there is an equal and opposite tension or tensile force that actually stretches the bolt. With a torque wrench, we are measuring the bolt's resistance to being stretched and, indirectly, the force that it exerts to hold the components together.

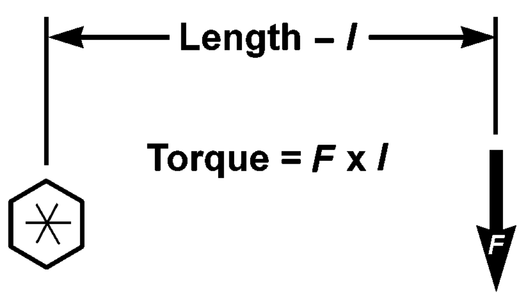
A properly installed fastener must be tight enough to stay in tension under vibration, thermal expansion and contraction and other mechanical loads, but not so tight that the bolt itself "yields" to the tensile force and stretches permanently, strips threads or breaks.

To get bolt tension right, we want to be able to measure bolt length—how much the bolt is being stretched. We could, too, except that usually we can't get to the bolt to measure it! So, we settle for the next best thing—measuring the twisting force or torque required to turn the bolt.



Tightening torque

Tightening torque is like any other kind of torque. It is a twisting force, defined as force times distance. Force by itself is not torque. A torque wrench measures the twisting force acting on a fastener—the amount of force you are applying at the handle, multiplied by the leverage you get from the length of the handle.



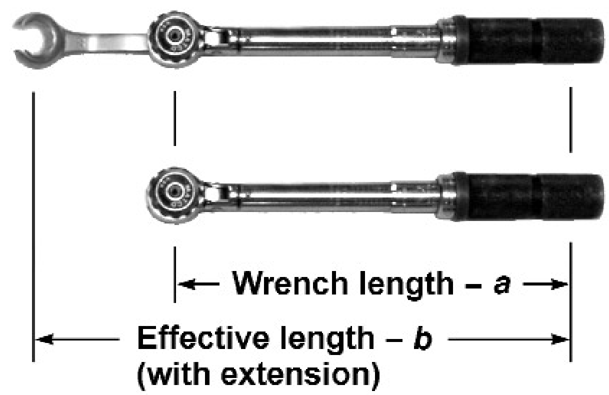
Torque wrenches are calibrated according to their length, according to the leverage they will exert on a fastener. Anything that changes that length, like the addition of a "crow's-foot" extension, will effectively change the calibration.

With an extension, the applied force is acting through a moment arm of greater length. The torque wrench will indicate torque only according to its length, so it will read less than the actual torque being applied to the fastener.

To calculate the actual torque:

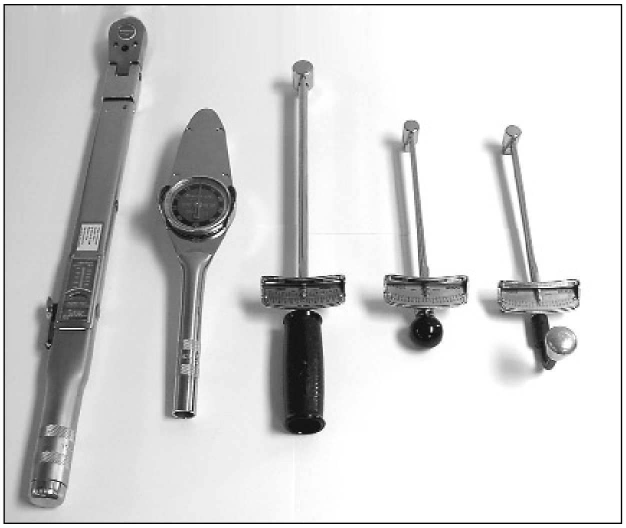
$$\textbf{Reading on torque wrench} = \frac{\textbf{Desired torque} \times \textbf{Torque wrench length}}{\textbf{Total length (w/extension)}}$$

Note that we are talking about tools that extend the effective *length* of the wrench. Ordinary socket extensions that give the wrench a longer reach (without increasing its effective length) have no significant effect on torque readings.



Correct use of a torque wrench

1. To ensure correct torque, make sure you are applying force at the center of the hand grip.
2. Avoid irregular, jerky movements. Apply steady force to reach the desired torque. To re-check a value, relax the wrench momentarily, then apply force again.
3. Do not try to apply torque values that exceed the rated capacity of the torque wrench.
4. With an adjustable torque wrench, such as a "click" type, always store it at its lowest torque setting.



Types of torque wrenches include, from left, "click" type, dial type, and three versions of the basic beam-type.

Types of torque wrenches

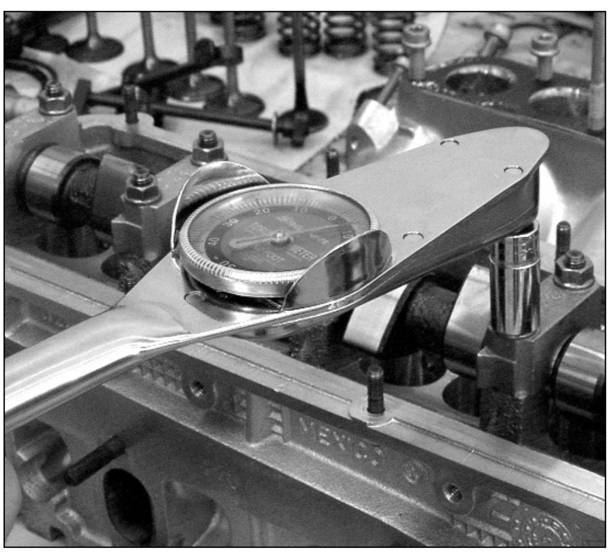
Beam-type

The most basic torque wrench is a beam type. The torque is indicated by simple mechanical deflection. As twisting force (torque) on the fastener is increased, the beam indicated the deflection on a scale attached to the wrench handle. Different size beams and different overall lengths produce torque wrenches with different operating ranges.

Typical wrenches measure torque in Newton•meters (N•m) or foot•pounds (ft•lb), while smaller ones are used for torque values in Newton•centimeters (N•cm) or inch•pounds (in•lb).

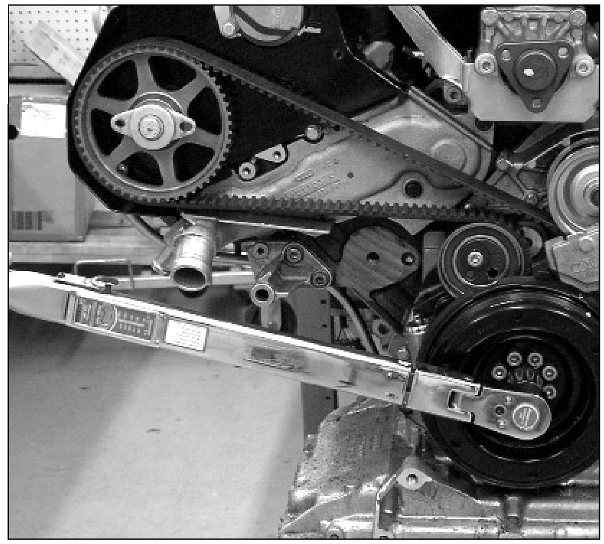
A beam-type torque wrench is preferred for most tasks requiring a torque wrench because it is more reliable. As long as it is properly maintained—protected against bending and corrosion—it is simple and accurate and does not require calibration.

Dial-type



The advantage of a dial-type torque wrench is like the advantage of a dial caliper over a vernier caliper—it is very easy to read. It is, however, more complex and more expensive. The complex mechanism is less reliable and must be calibrated periodically to ensure accuracy.

“Click”-type



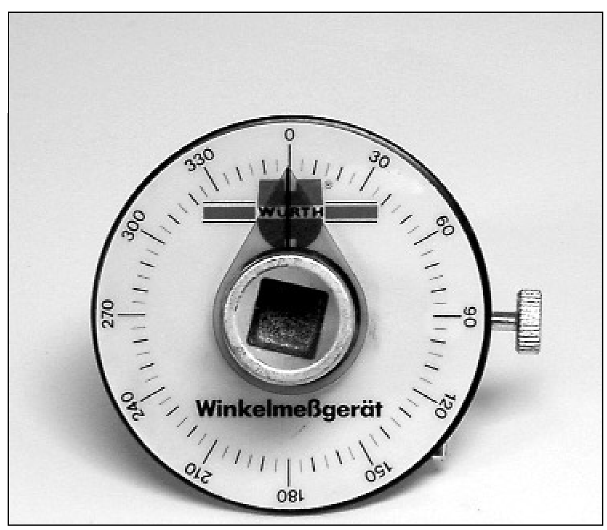
A "click" type torque wrench does not need to be read at all. At a predetermined torque value, the handle will move freely for a few degrees and make an audible "click." This combination signals that the desired torque has been reached.

This type of wrench is especially useful when working in tight quarters, when it would otherwise be difficult to read a dial or otherwise determine when the proper torque value has been reached. Like the dial type, there are some concerns about accuracy and calibration.

This type also has an advantage when doing non-critical, repetitive jobs like tightening wheel lugs. One might, for instance use it for the staged tightening of cylinder head bolts, and then tighten to a final value using a more precise tool.

Because a "click" type torque wrench uses a kind of pre-load to determine the indicating value, it must always be reset to its lowest setting for storage. This will help preserve its calibration.

Torque angle gauge



Some tightening torque specifications are expressed as a conventional torque value (e.g. 100 N•m) plus an additional step, measured as an angle or rotation. This calls for being able to accurately measure the specified angle. To do so, use a torque angle gauge.

Review / Quiz Answer Key

Vernier caliper (page 20)

Example 1:	17.85 mm
Example 2:	3.3 mm
Example 3:	5.84 mm

Micrometer (page 31)

Example 1:	9.71 mm
Example 2:	3.78 mm
Example 3:	4.53 mm

Dial indiator (page 41)

Example 1:	2.66 mm
Example 2:	3.97 mm
Example 3:	4.23 mm

Appendix

Unit conversions — Length/Distance

To calculate: mm x 0.03937 = in.

mm	in.	mm	in.	mm	in.	mm	in.
0.002	0.00008						
0.004	0.00016						
0.006	0.00024						
0.008	0.00031						
0.010	0.00039	0.01	0.0004				
0.020	0.00079	0.02	0.0008				
0.030	0.00118	0.03	0.0012				
0.040	0.00157	0.04	0.0016				
0.050	0.00197	0.05	0.0020				
0.060	0.00236	0.06	0.0024				
0.070	0.00276	0.07	0.0028				
0.080	0.00315	0.08	0.0031				
0.090	0.00354	0.09	0.0035				
0.100	0.00394	0.10	0.0039	0.1	0.004		
0.200	0.00787	0.20	0.0079	0.2	0.008		
0.300	0.01181	0.30	0.0118	0.3	0.012		
0.400	0.01575	0.40	0.0157	0.4	0.016		
0.500	0.01969	0.50	0.0197	0.5	0.020		
0.600	0.02362	0.60	0.0236	0.6	0.024		
0.700	0.02756	0.70	0.0276	0.7	0.028		
0.800	0.03150	0.80	0.0315	0.8	0.031		
0.900	0.03543	0.90	0.0354	0.9	0.035		
1.000	0.03937	1.00	0.0394	1.0	0.039	1	0.04
2.000	0.07874	2.00	0.0787	2.0	0.079	2	0.08
3.000	0.11811	3.00	0.1181	3.0	0.118	3	0.12
4.000	0.15748	4.00	0.1575	4.0	0.157	4	0.16
5.000	0.19685	5.00	0.1969	5.0	0.197	5	0.20
6.000	0.23622	6.00	0.2362	6.0	0.236	6	0.24
7.000	0.27559	7.00	0.2756	7.0	0.276	7	0.28
8.000	0.31496	8.00	0.3150	8.0	0.315	8	0.31
9.000	0.35433	9.00	0.3543	9.0	0.354	9	0.35
10.000	0.39370	10.00	0.3937	10.0	0.394	10	0.39
20.000	0.78740	20.00	0.7874	20.0	0.787	20	0.79
30.000	1.18110	30.00	1.1811	30.0	1.181	30	1.18
40.000	1.57480	40.00	1.5748	40.0	1.575	40	1.57
50.000	1.96850	50.00	1.9685	50.0	1.969	50	1.97
60.000	2.36220	60.00	2.3622	60.0	2.362	60	2.36
70.000	2.75591	70.00	2.7559	70.0	2.756	70	2.76
80.000	3.14961	80.00	3.1496	80.0	3.150	80	3.15
90.000	3.54331	90.00	3.5433	90.0	3.543	90	3.54
100.000	3.93701	100.00	3.9370	100.0	3.937	100	3.94

Unit conversions — Tightening torque

N·m -to- lb·ft (ft·lb)

To calculate: N·m x 0.738 = lb·ft

N·m	lb·ft (ft·lb)	N·m	lb·ft (ft·lb)	N·m	lb·ft (ft·lb)
10	7	55	41	100	74
11	8	56	41	105	77
12	9	57	42	110	81
13	10	58	43	115	85
14	10	59	44	120	89
15	11	60	44	125	92
16	12	61	45	130	96
17	13	62	46	135	100
18	13	63	46	140	103
19	14	64	47	145	107
20	15	65	48	150	111
21	15	66	49	155	114
22	16	67	49	160	118
23	17	68	50	165	122
24	18	69	51	170	125
25	18	70	52	175	129
26	19	71	52	180	133
27	20	72	53	185	136
28	21	73	54	190	140
29	21	74	55	195	144
30	22	75	55	200	148
31	23	76	56	205	151
32	24	77	57	210	155
33	24	78	58	215	159
34	25	79	58	220	162
35	26	80	59	225	166
36	27	81	60	230	170
37	27	82	60	235	173
38	28	83	61	240	177
39	29	84	62	245	181
40	30	85	63	250	184
41	30	86	63	260	192
42	31	87	64	270	199
43	32	88	65	280	207
44	32	89	66	290	214
45	33	90	66	300	221
46	34	91	67	310	229
47	35	92	68	320	236
48	35	93	69	330	243
49	36	94	69	340	251
50	37	95	70	350	258
51	38	96	71	360	266
52	38	97	72	370	273
53	39	98	72	380	280
54	40	99	73	390	288
55	41	100	74	400	295

N·m -to- lb·in (in·lb), kg·cm

To calculate: N·m x 8.85 = lb·in
N·m x 10.20 = kg·cm

N·m	lb·in (in·lb)	kg·cm
1	9	10
2	18	20
3	27	31
4	35	41
5	44	51
6	53	61
7	62	71
8	71	82
9	80	92
10	89	102
11	97	112
12	106	122
13	115	133
14	124	143
15	133	153
16	142	163
17	150	173
18	159	184
19	168	194
20	177	204
21	186	214
22	195	224
23	204	235
24	212	245
25	221	255

N·m	lb·in (in·lb)	kg·cm
25	221	255
26	230	265
27	239	275
28	248	286
29	257	296
30	266	306
31	274	316
32	283	326
33	292	337
34	301	347
35	310	357
36	319	367
37	327	377
38	336	387
39	345	398
40	354	408
41	363	418
42	372	428
43	381	438
44	389	449
45	398	459
46	407	469
47	416	479
48	425	489
49	434	500
50	443	510

N·cm -to- lb·in (in·lb), kg·cm

To calculate: N·cm x 0.089 = lb·in
N·cm x 0.102 = kg·cm

N·cm	lb·in (in·lb)	kg·cm
50	4	5
60	5	6
70	6	7
80	7	8
90	8	9
100	9	10
110	10	11
120	11	12
130	12	13
140	12	14
150	13	15
160	14	16
170	15	17
180	16	18
190	17	19
200	18	20

N·cm	lb·in (in·lb)	kg·cm
200	18	20
250	22	25
300	27	31
350	31	36
400	35	41
450	40	46
500	44	51
550	49	56
600	53	61
650	58	66
700	62	71
750	66	76
800	71	82
850	75	87
900	80	92
950	84	97
1000	89	102

kg·cm -to- lb·in (in·lb), N·cm

To calculate: kg·cm x 0.868 = lb·in
kg·cm x 9.81 = N·cm

kg·cm	lb·in (in·lb)	N·cm
5	4	49
6	5	59
7	6	69
8	7	78
9	8	88
10	9	98
20	17	196
30	26	294
40	35	392
50	43	490
60	52	588
70	61	686
80	69	785
90	78	883
100	87	981

kg·cm	lb·in (in·lb)	N·cm
100	87	981
110	95	1079
120	104	1177
130	113	1275
140	122	1373
150	130	1471
160	139	1569
170	148	1667
180	156	1765
190	165	1863
200	174	1961
210	182	2059
220	191	2157
230	200	2256
240	208	2354
250	217	2452

An on-line Knowledge Assessment (exam) is available for this Self-Study Program

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4. Click "Launch Assessment"

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