Angle Measurement

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Angle Measurement

Sections:

Overview

All length and angle standards are arbitrary human inventions—even the light wave standard (2.99796×10^8 m/s or 186,284 mi/s)—because even though light is a natural phenomenon, man created a length standard out of it. One standard, however, is not an arbitrary creation of man: it actually exists in nature— the **circle**.

The circle can be the path of an electron around the nucleus of its atom or the circumference of a planet, but its geometry is always the same. The parts of the circle always have the same relationships to each other; therefore, the circle is a universal standard that we can re-create anywhere at any time to measure angles. Angular measurement is inescapable in all technical endeavors, used in every phase of life, from botany and carpentry to billiards and marbles. Squares, in all of their diverse forms, are the most basic of the angle-measurement instruments

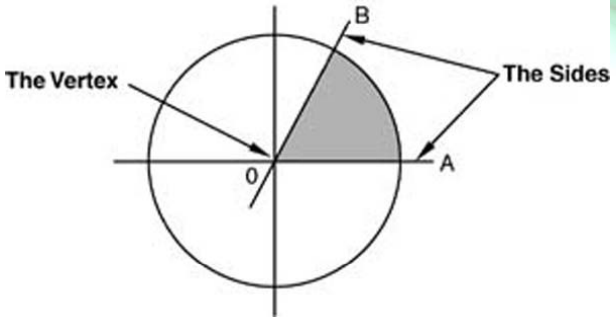
Background

<u>The Circle</u>

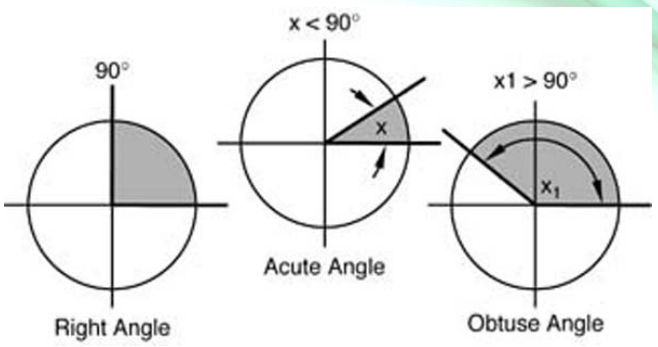
A circle is a curve consisting of points in a plane all equally distant from a center point. It is different from all other curves because it is the same at all points. If we turn a circle around its center in the same plane, the circle appears exactly the same as it did before we turned it: all new positions are exactly like the original position, which is a characteristic of circles called roundness.

We form a circle by continuous motion of fixed length around a point; therefore, the perfection of the circle is independent of the instrument we use to scribe it. In contrast, when we use a straightedge to create a line, we duplicate all the errors of the straightedge in the line.

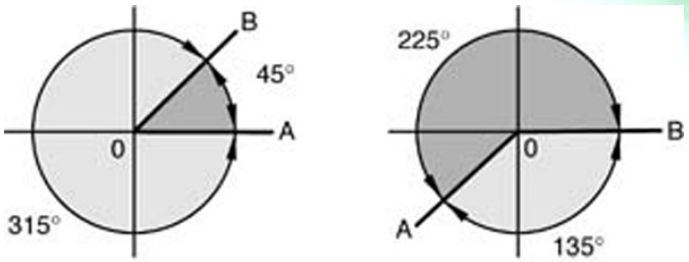
Angles



Angles

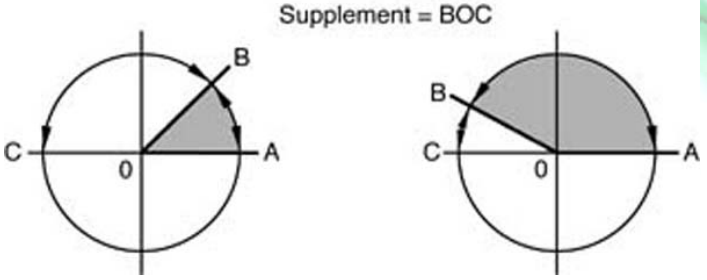


Angles

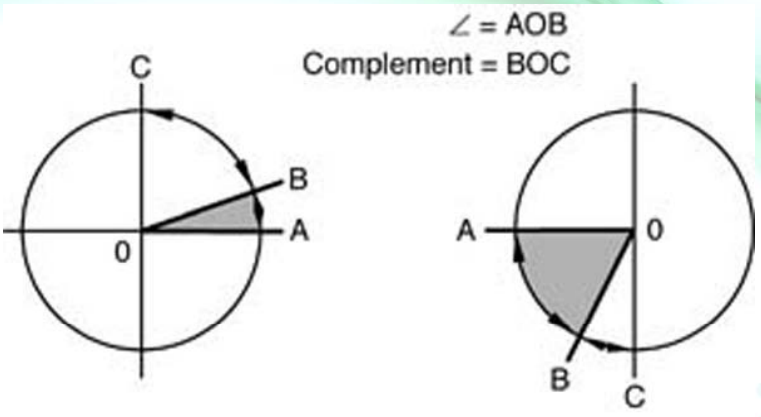


Angles

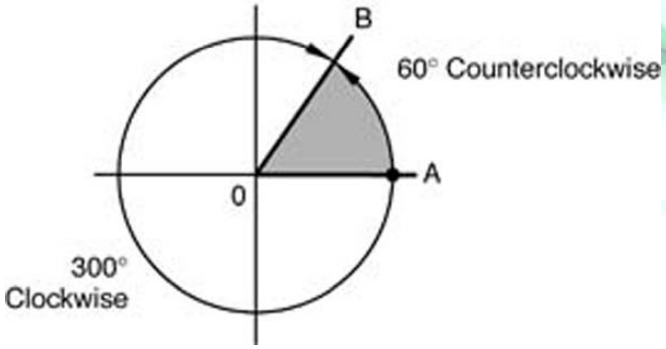
∠ = AOB
Supplement = BOC



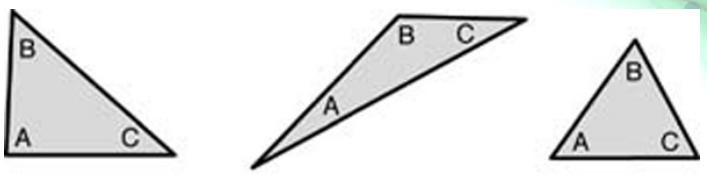
Angles



Angles

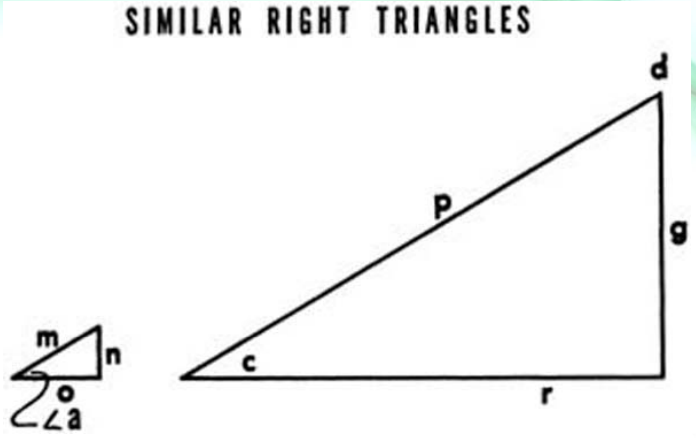


Angles

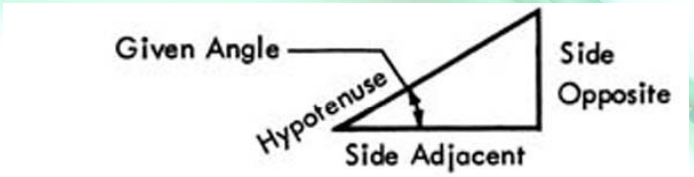


The sum of ∠a, ∠b and ∠c equals 180°

Angles



Angles



$$\frac{\text{Side opposite}}{\text{Hypotenuse}} = \text{sine of given angle (sin)}$$

$$\frac{\text{Side adjacent}}{\text{Hypotenuse}} = \text{cosine of given angle (cos)}$$

$$\frac{\text{Side opposite}}{\text{Side adjacent}} = \text{tangent of given angle (tan)}$$

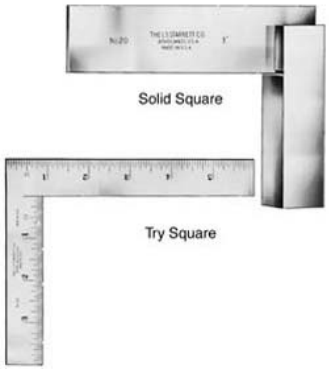
$$\frac{\text{Side adjacent}}{\text{Side opposite}} = \text{cotangent of given angle (cot)}$$

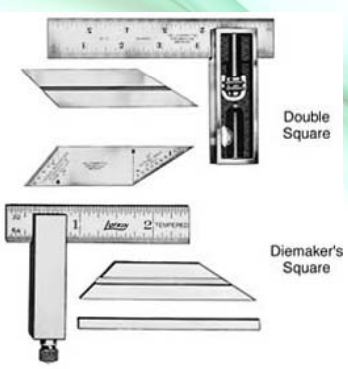
Angle Measurement

Equivalent Instruments

Linear Measurement	Type	Angular Measurement
Steel Rule	scaled	Plain Protractor
Combination Square	scaled	Protractor Head of combination set
Vernier Caliper	vernier	Vernier Protractor
Micrometer	mechanical	Index Heads
Gage Blocks	standards	Angle Blocks
Comparators	comparison	Sine Devices with comparators
Measuring Microscopes	optical	Autocollimators

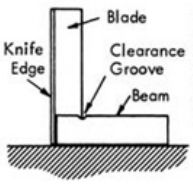
Angle Measurement





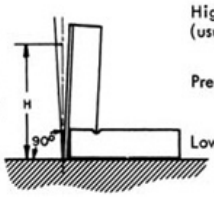
Angle Measurement

FUNCTIONAL FEATURES



NOTE: The maximum deviation of the sides of the blade with the reference surface is 3 times the tolerance of the blade.

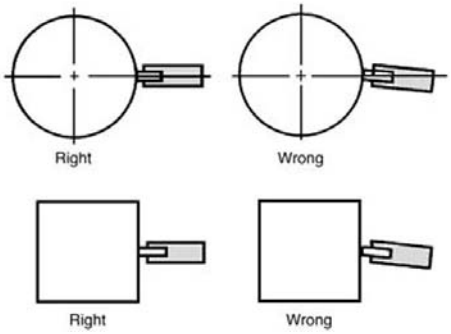
PRECISION SQUARES



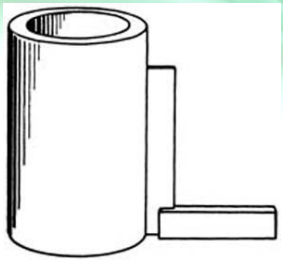
METROLOGICAL FEATURES

Highest Accuracy (usually knife edge)	$\pm .00008 + \frac{H}{100,000}$
Precision Quality	$\pm .0002 + \frac{H}{50,000}$
Lowest Quality	$\pm .0008 + \frac{H}{10,000}$

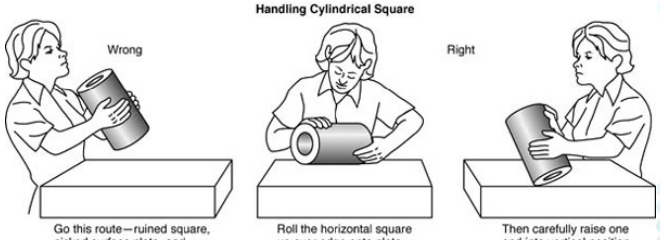
Angle Measurement



Angle Measurement



Handling Cylindrical Square

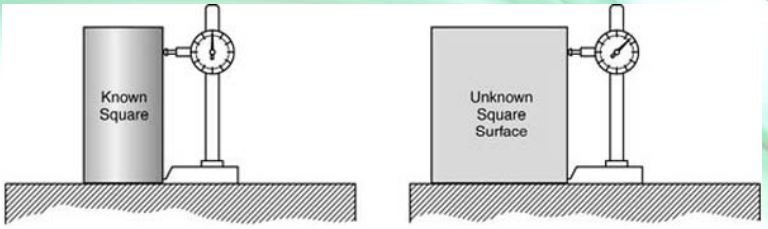


Go this route—ruined square, nicked surface plate, and smashed fingers result.

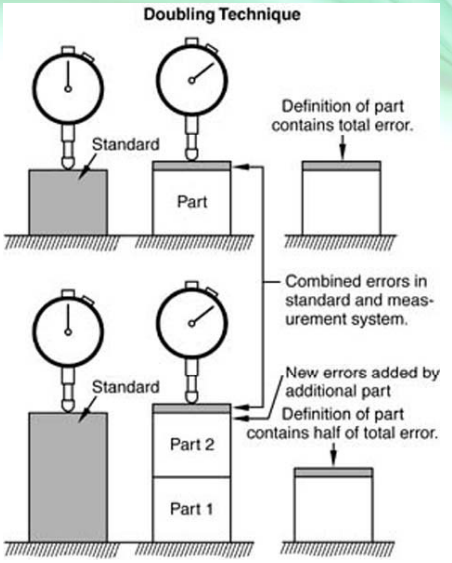
Roll the horizontal square up over edge onto plate.

Then carefully raise one end into vertical position.

Angle Measurement



Angle Measurement



The Level

The Level

The Level

The Level

The Level

Precision Level

Metrological Features	Functional Features
(A) Ground Graduated Level Vial	(C) Screw Adjustment
(B) Reference Plane	(D) Insulating Top Plate
	(E) Cross Test Level

The Level

Reading A Level

Readings:	Values For 10-Second Vial
A	Centered — Level
B	One Division Left — Left high by 0.0005 in. in 12 in. (Negative reading)
C	One Division Right — Right high by 0.0005 in. in 12 in. (Positive reading)
D	Three Divisions Right — Right high by 0.0015 in. in 12 in. (Positive reading)
E	No Bubble — Completely out of range

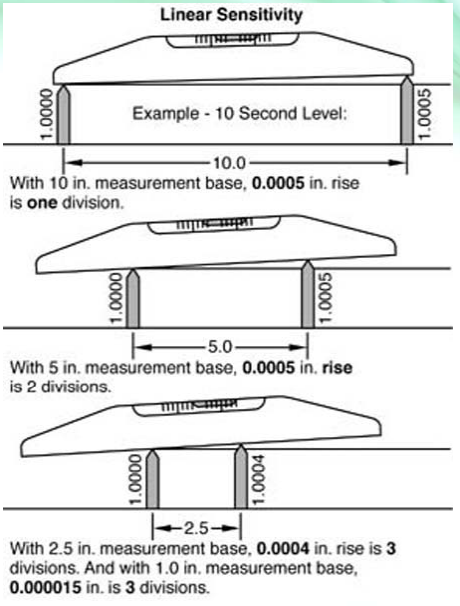
The Level

RELIABILITY WITH LEVELS

For Precise Measurement:

1. Take readings from both ends of the vial.
2. Reverse level.
3. Repeat readings from both ends.
4. Average the four readings.
5. Repeat all steps for critical cases.

The Level

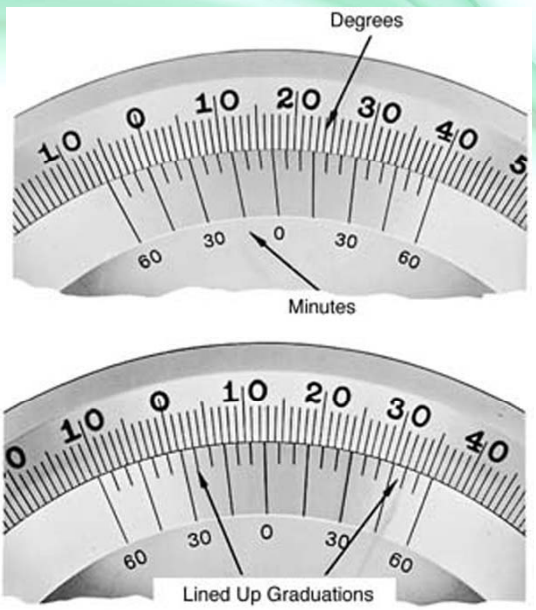


The Level

	Metrological Data For Squares						Reliability	
Instrument	Type of Measurement	Normal Range	Designated Precision	Discrimination	Sensitivity	Linearity	Practical Tolerance for Skilled Measurement	Practical Manufacturing Tolerance
Combination square	comparison	none	none	not applicable	beyond accuracy	not applicable	30′	1°
Precision square	comparison	none	none	not applicable	beyond accuracy	not applicable	30″	1′
Surface plate square	comparison	none	none	not applicable	beyond accuracy	not applicable	10″	30″
Cylindrical square	comparison	none	none	not applicable	beyond accuracy	not applicable	5″	30″
Graduated cylindrical square	comparison	0. to 0.0012″	0.0001″ in 6″	0.0002″ in 6″	beyond accuracy	50 mike within 6″	0.0002″ in 6″	0.0004″ in 6″
Square and transfer stand	All factors limited by metrological data of transfer instrument							
Mechanic's level	direct	6°	1°	1°	30′	30′	1°	2°
Precision level	direct	1′20″	10″	10″	5″	5″	10″	30″
Clinometer (average)	direct	0° to 360°	10″	10″	2″	2″	5″	15″

The Protractor

The Protractor



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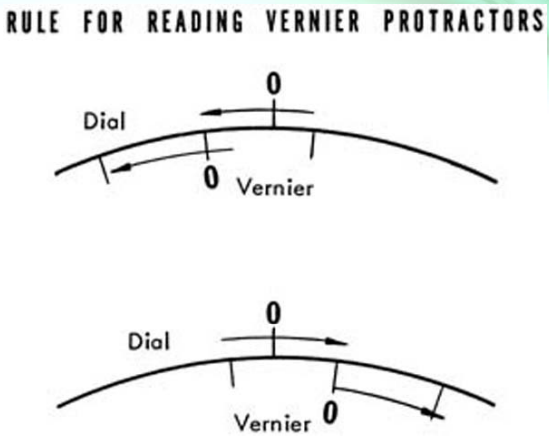

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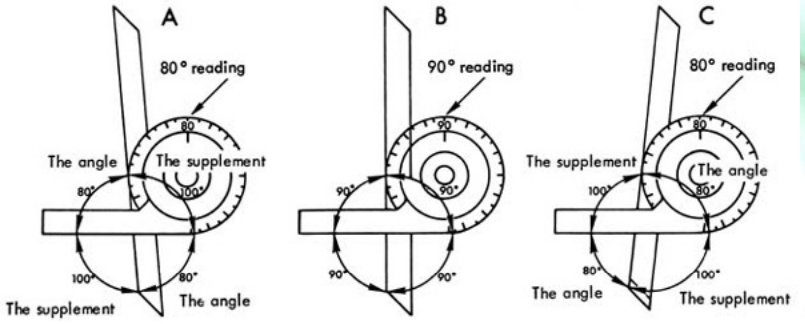

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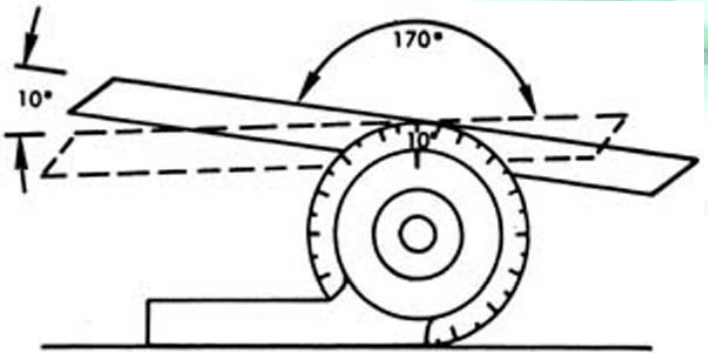

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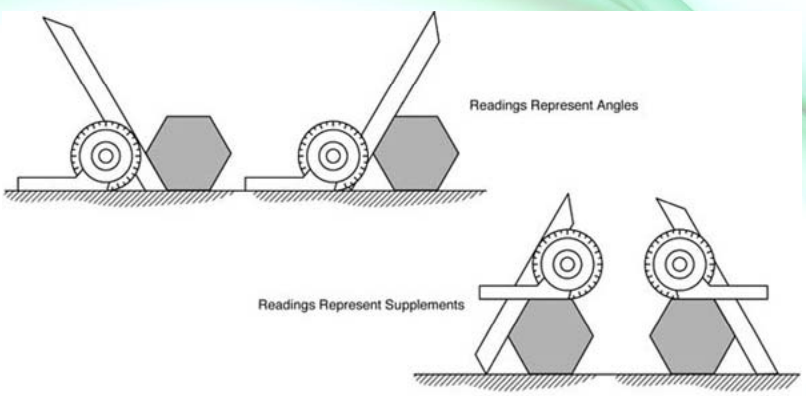

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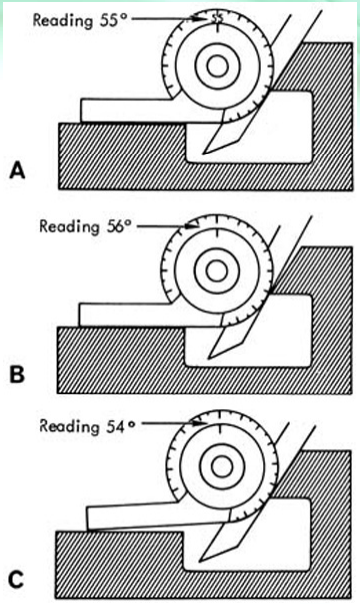


The Protractor

Reliability with Protractors

Mechanical considerations:

1. Can both the base and the blade reach their respective surfaces unobstructed?
2. Is overconstraint causing erroneous contact?
3. Do burrs, dirt, or excessive roughness interfere with intimate contact?

Positional considerations:
(Consider angle in yz plane.)

1. Is the vertical axis of the instrument parallel to the plane of the angle?
2. Is the horizontal axis of the instrument parallel to the plane of the angle?

Observational considerations:

1. Is the reading the complement of the angle being measured?
2. Is the reading the supplement of the angle being measured?
3. Does parallax error exist?
4. Are you conscious of bias?

The Protractor

Care of the Universal Bevel Protractor

Before use:

1. Wipe off dust and oil.
2. Examine for visual signs of damage or abuse.
3. Run fingers along base and blade to detect burrs.
4. Check mechanical movement for freedom.
5. Check clamps for security.
6. Allow instrument to normalize.
7. Determine that the instrument has been recently calibrated.

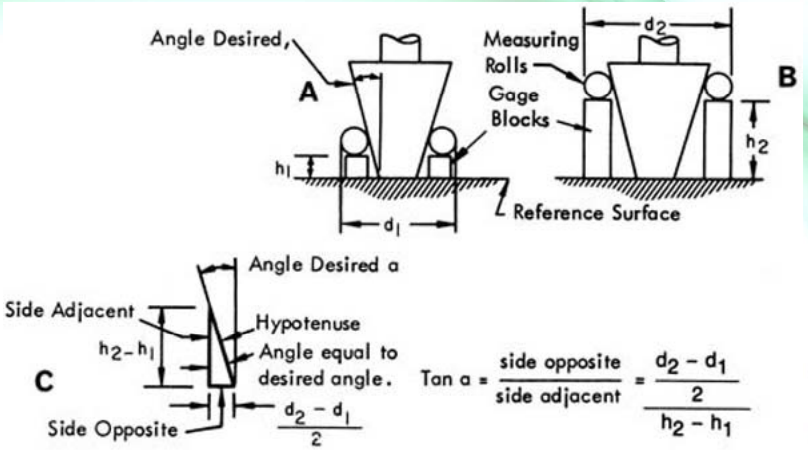
During use:

1. Keep case nearby so that instrument may be placed in case rather than on hard surface when not being used.
2. Avoid excessive handling to minimize heat transfer.
3. Do not slide along abrasive surfaces.
4. Do not overtighten clamps.
5. Do not spring or bend by overconstraint.
6. Take precautions to avoid dropping instrument and to avoid dropping objects on it.
7. Avoid work near heat sources.

After use:

1. Clean thoroughly. Do not use compressed air, which could drive particles into instrument. Dip in solvent and shake dry if exposed to cutting fluids.
2. Lubricate moving parts.
3. Apply thin rust-preventative lubricant.
4. Replace in case.

Trigonometric Functions



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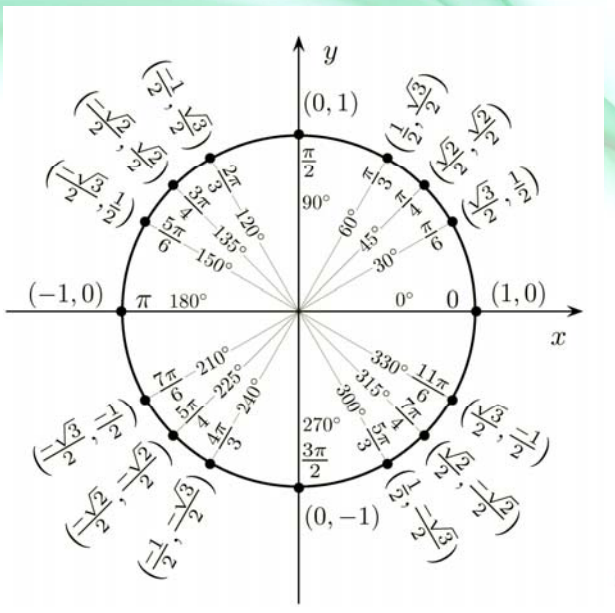

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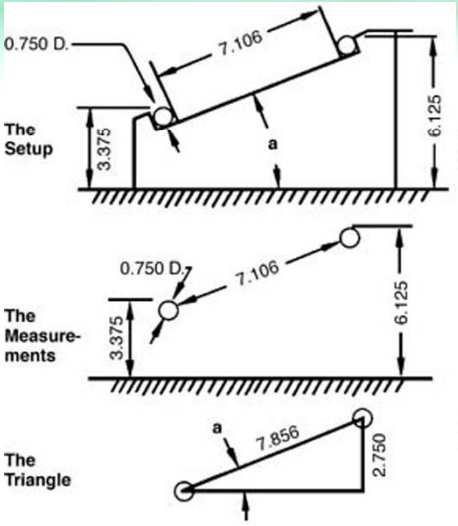
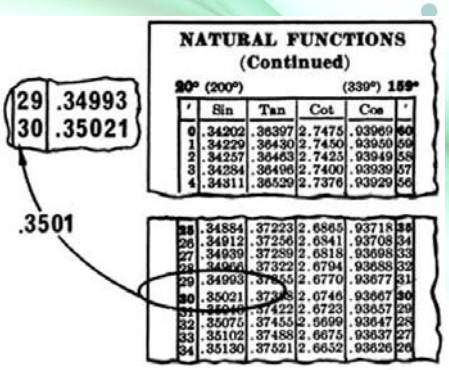




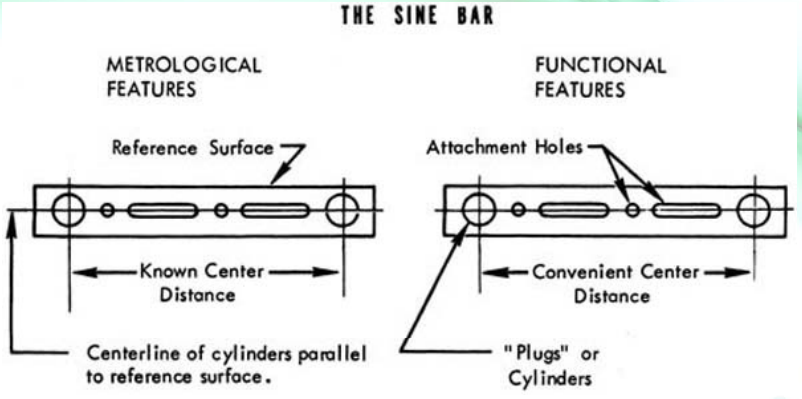
NATURAL FUNCTIONS
(Continued)

20° (200ᵍ) (339ᵍ) 159°

′	Sin	Tan	Cot	Cos	′
0	.34202	.36397	2.7475	.93969	60
1	.34229	.36430	2.7450	.93950	59
2	.34257	.36463	2.7423	.93949	58
3	.34284	.36496	2.7400	.93939	57
4	.34311	.36529	2.7376	.93929	56
25	.34884	.37223	2.6865	.93718	35
26	.34912	.37256	2.6841	.93708	34
27	.34939	.37289	2.6818	.93698	33
28	.34966	.37322	2.6794	.93688	32
29	.34993	.37355	2.6770	.93677	31
30	.35021	.37388	2.6746	.93667	30
31	.35048	.37422	2.6723	.93657	29
32	.35075	.37455	2.6699	.93647	28
33	.35102	.37488	2.6675	.93637	27
34	.35130	.37521	2.6652	.93626	26

Sin A=.3501 Angle A = 20°29′

Sine Bars and Plates



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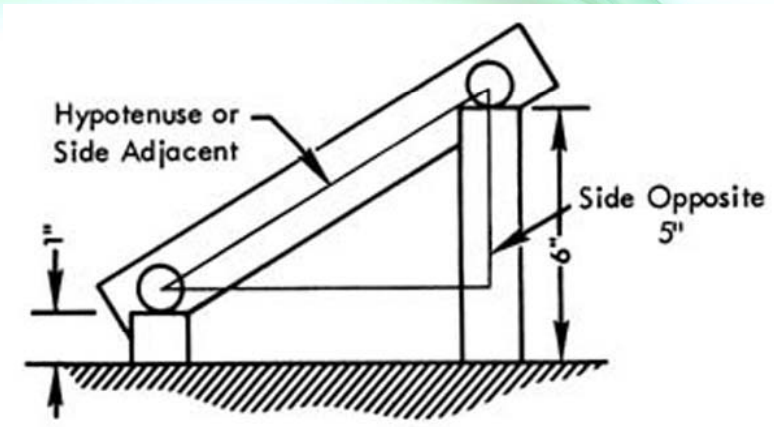


Sine Bars and Plates

Sine Bar Measurement Variables

Geometric:

1. Parallelism of the working surface to the centerline of the cylinders
2. Squareness of the axes of the cylinders to the instrument
3. Roundness of the cylinders

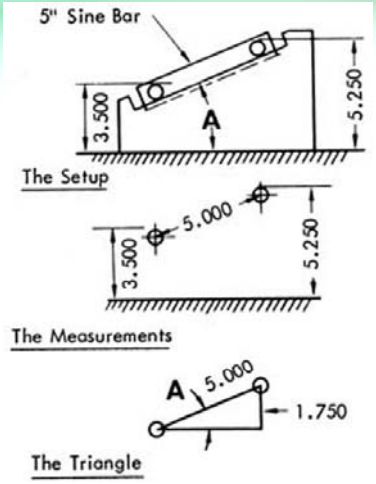
Mechanical:

1. Error in center-to-center distance
2. Differences in cylinder diameters
3. Surface imperfections, such as insufficient flatness of working surface

Setup:

1. Error in **two** sets of height supports
2. Imperfect reference surface

Sine Bars and Plates



29	.7496
30	1.7510

1.750

Angle A = 20° 29′

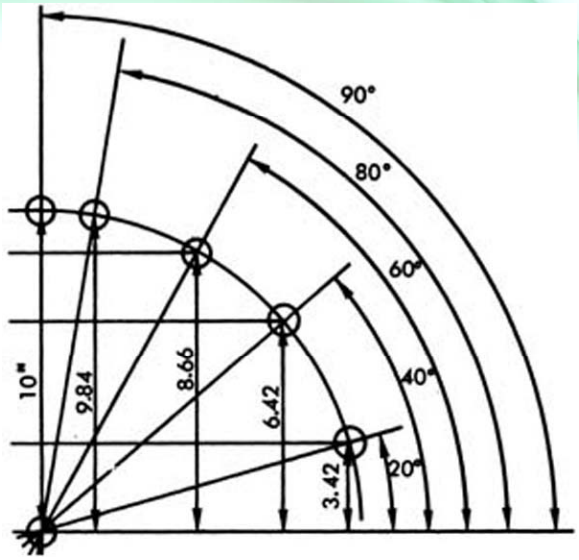
CONSTANTS IN TABLE ARE FOR FIVE INCH SINE BARS OR PLATES
WHEN USING TEN INCH SINE BARS OR PLATES MULTIPLY CONSTANTS BY TWO

Figures are in Inches

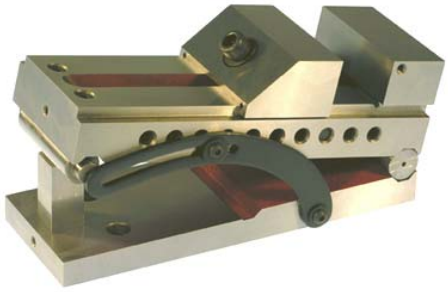
Min.	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	Min.
0	1.7101	1.7918	1.8733	1.9536	2.0337	2.1131	2.1918	2.2699	2.3473	2.4240	0
1	.7114	.7932	.8744	.9550	.0350	.1144	.1931	.2712	.3486	.4253	1
2	.7128	.7946	.8757	.9563	.0363	.1157	.1944	.2725	.3499	.4266	2
3	.7143	.7960	.8771	.9576	.0376	.1170	.1958	.2738	.3512	.4278	3
4	.7157	.7973	.8784	.9589	.0389	.1183	.1971	.2751	.3525	.4291	4
5	1.7169	1.7986	1.8797	1.9602	2.0402	2.1197	2.1984	2.2764	2.3538	2.4304	5
6	.7183	.8000	.8811	.9615	.0416	.1210	.1997	.2777	.3550	.4317	6
7	.7196	.8013	.8824	.9630	.0429	.1223	.2010	.2790	.3563	.4329	7
8	.7210	.8027	.8838	.9643	.0443	.1236	.2023	.2803	.3576	.4342	8
9	.7224	.8040	.8851	.9657	.0456	.1249	.2036	.2816	.3589	.4355	9
10	1.7237	1.8054	1.8865	1.9670	2.0469	2.1262	2.2049	2.2829	2.3602	2.4367	10
11	.7251	.8067	.8878	.9683	.0483	.1276	.2062	.2842	.3614	.4380	11
12	.7265	.8081	.8892	.9697	.0496	.1289	.2075	.2855	.3627	.4393	12
13	.7278	.8094	.8905	.9710	.0509	.1302	.2088	.2868	.3640	.4405	13
14	.7292	.8108	.8919	.9724	.0522	.1315	.2101	.2881	.3653	.4418	14
15	1.7306	1.8121	1.8932	1.9737	2.0536	2.1328	2.2114	2.2893	2.3666	2.4431	15
16	.7319	.8135	.8946	.9750	.0549	.1341	.2127	.2906	.3679	.4444	16
17	.7333	.8149	.8959	.9764	.0563	.1354	.2140	.2919	.3691	.4456	17
18	.7347	.8162	.8973	.9777	.0576	.1368	.2153	.2932	.3704	.4469	18
19	.7360	.8176	.8986	.9790	.0589	.1381	.2166	.2945	.3717	.4482	19
20	1.7374	1.8189	1.8999	1.9804	2.0602	2.1394	2.2179	2.2958	2.3730	2.4494	20
21	.7387	.8203	.9013	.9817	.0615	.1407	.2192	.2971	.3743	.4507	21
22	.7401	.8216	.9026	.9831	.0629	.1420	.2205	.2984	.3756	.4520	22
23	.7415	.8230	.9040	.9844	.0642	.1433	.2218	.2997	.3769	.4533	23
24	.7428	.8244	.9053	.9857	.0655	.1447	.2231	.3010	.3781	.4545	24
25	1.7442	1.8257	1.9067	1.9870	2.0668	2.1460	2.2244	2.3023	2.3794	2.4558	25
26	.7456	.8271	.9080	.9884	.0681	.1473	.2258	.3036	.3807	.4570	26
27	.7469	.8284	.9094	.9897	.0695	.1486	.2271	.3049	.3819	.4583	27
28	.7483	.8298	.9107	.9911	.0708	.1499	.2284	.3061	.3832	.4596	28
29	.7496	.8311	.9120	.9924	.0721	.1512	.2297	.3074	.3845	.4608	29
30	1.7510	1.8325	1.9134	1.9937	2.0734	2.1525	2.2310	2.3087	2.3858	2.4621	30
31	.7524	.8338	.9147	.9951	.0748	.1538	.2323	.3100	.3870	.4634	31
32	.7537	.8352	.9161	.9964	.0761	.1552	.2336	.3113	.3883	.4646	32
33	.7551	.8365	.9174	.9977	.0774	.1565	.2349	.3126	.3896	.4659	33
34	.7565	.8379	.9188		.0787	.1578	.2362		.3909		34

http://www.wisc-online.com/objects/ViewObject.aspx?ID=MSR2202

Sine Bars and Plates



Sine Bars and Plates

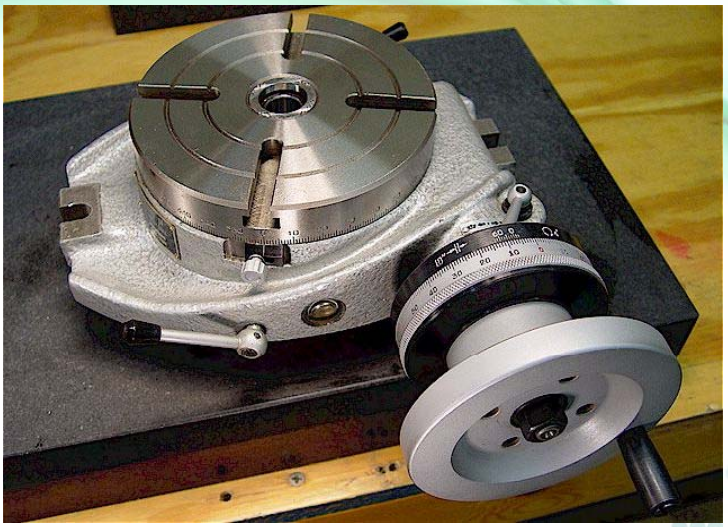


Sine Bars and Plates

Other Instruments for Angle Measurement

Other Instruments for Angle Measurement

Other Instruments for Angle Measurement



Other Instruments for Angle Measurement

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Angle Measurement

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