M 22-24

Highway Engineering
Field Formulas

Washington State Department of Transportation

Metric (SI) or US Units

Unless otherwise stated the formulas shown in this manual can be used with any units. The user is cautioned not to mix units within a formula. Convert all variables to one unit system prior to using these formulas.

Significant Digits

Final answers from computations should be rounded off to the number of decimal places justified by the data. The answer can be no more accurate than the least accurate number in the data. Of course, rounding should be done on final calculations only. It should not be done on interim results.

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CONTENTS

Nomenclature For Circular Curves

POT	Point On Tangent outside the effect of any curve
POC	Point On a circular Curve
POST	Point On a Semi-Tangent (within the limits of a curve)
PI	Point of Intersection of a back tangent and forward tangent
PC	Point of Curvature - Point of change from back tangent to circular curve
PT	Point of Tangency - Point of change from circular curve to forward tangent
PCC	Point of Compound Curvature - Point common to two curves in the same direction with different radii
PRC	Point of Reverse Curve - Point common to two curves in opposite directions and with the same or different radii
L	Total Length of any circular curve measured along its arc
L_c	Length between any two points on a circular curve
R	Radius of a circular curve
Δ	Total intersection (or central) angle between back and forward tangents

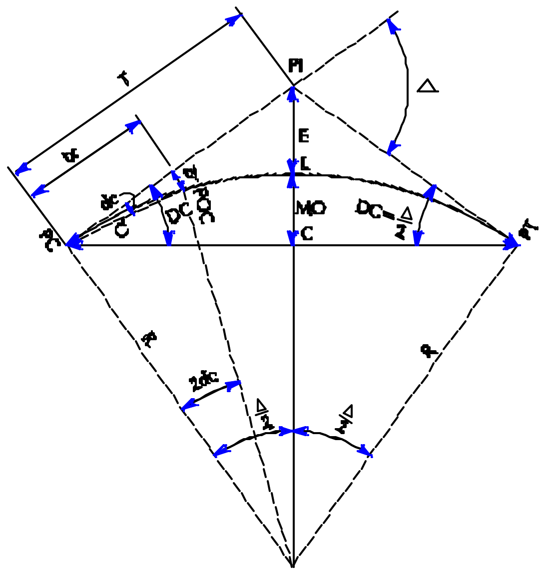
Nomenclature For Circular Curves (Cont.)

DC	Deflection angle for full circular curve measured from tangent at PC or PT
dc	Deflection angle required from tangent to a circular curve to any other point on a circular curve
C	Total Chord length, or long chord, for a circular curve
C´	Chord length between any two points on a circular curve
T	Distance along semi-Tangent from the point of intersection of the back and forward tangents to the origin of curvature (From the PI to the PC or PT)
tx	Distance along semi-tangent from the PC (or PT) to the perpendicular offset to any point on a circular curve. (Abscissa of any point on a circular curve referred to the beginning of curvature as origin and semi-tangent as axis)
ty	The perpendicular offset, or ordinate, from the semi-tangent to a point on a circular curve
E	External distance (radial distance) from PI to midpoint on a simple circular curve

Circular Curve Equations

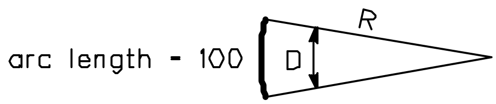
Equations	Units
$\mathbf{R} = \frac{\mathbf{180°}}{\pi} \times \frac{\mathbf{L}}{\Delta}$	m or ft.
$\Delta = \frac{\mathbf{180°}}{\pi} \times \frac{\mathbf{L}}{\mathbf{R}}$	degree
$\mathbf{L} = \frac{\pi}{\mathbf{180}} \times \mathbf{R}\Delta$	m or ft.
$\mathbf{T} = \mathbf{R}\,\mathbf{tan}\frac{\Delta}{\mathbf{2}}$	m or ft.
$\mathbf{E} = \frac{\mathbf{R}}{\mathbf{cos}\frac{\Delta}{2}} - \mathbf{R}$	m or ft.
$\mathbf{C} = \mathbf{2R}\,\mathbf{sin}\frac{\Delta}{\mathbf{2}}, \mathbf{or} = \mathbf{2R}\,\mathbf{sin}\,\mathbf{DC}$	m or ft.
$\mathbf{MO} = \mathbf{R}\left(1 - \mathbf{cos}\frac{\Delta}{2}\right)$	m or ft.
$\mathbf{DC} = \frac{\Delta}{2}$	degree
$\mathbf{dc} = \frac{\mathbf{L_c}}{\mathbf{L}}\left(\frac{\Delta}{2}\right)$	degree
$\mathbf{C'} = 2\mathbf{R}\,\mathbf{sin}(\mathbf{dc})$	m or ft.
$\mathbf{C} = \mathbf{2R}\,\mathbf{sin(DC)}$	m or ft.
$\mathbf{tx} = \mathbf{R}\,\mathbf{sin(2dc)}$	m or ft.
$\mathbf{ty} = \mathbf{R}[\mathbf{1} - \mathbf{cos(2dc)}]$	m or ft.

Simple Circular Curve



Constant for $\pi = 3.14159265$

Degree of Curvature for Various Lengths of Radii

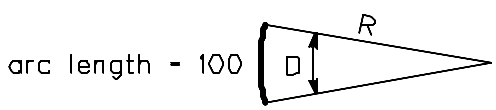


Exact for Arc Definition

$$\mathbf{D} = \frac{\mathbf{100}\left(\frac{\mathbf{180}}{\pi}\right)}{\mathbf{R}} = \frac{\mathbf{18000}}{\pi\mathbf{R}}$$

Where D is Degree of Curvature

Length of Radii for Various Degrees of Curvature



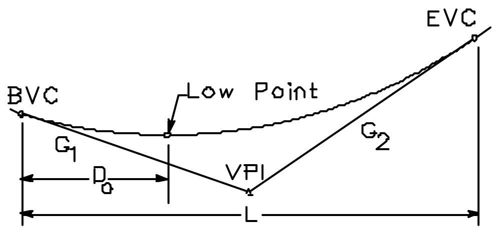
$$\mathbf{R} = \frac{\mathbf{100}\left(\frac{\mathbf{180}}{\pi}\right)}{\mathbf{D}} = \frac{\mathbf{18000}}{\pi\mathbf{D}}$$

Where R is Radius Length

Nomenclature For Vertical Curves

G_1 & G_2	Tangent Grade in percent
A	The absolute of the Algebraic difference in grades in percent
BVC	Beginning of Vertical Curve
EVC	End of Vertical Curve
VPI	Vertical Point of Intersection
L	Length of vertical curve
D	Horizontal distance to any point on the curve from BVC or EVC
E	Vertical distance from VPI to curve
e	Vertical distance from any point on the curve to the tangent grade
K	Distance required to achieve a 1 percent change in grade
L_1	Length of a vertical curve which will pass through a given point
D_0	Distance from the BVC to the lowest or highest point on curve
X	Horizontal distance from P' to VPI
H	A point on tangent grade G_1 to vertical position of point P'
P and P'	Points on tangent grades

Symmetrical Vertical Curve Equations



$$\mathbf{A} = (\mathbf{G_2}) - (\mathbf{G_1})$$

$$\mathbf{E} = \frac{\mathbf{AL}}{\mathbf{800}}$$

$$\mathbf{E} = \frac{\mathbf{1}}{\mathbf{2}}\left(\frac{\mathbf{Elev.BVC} + \mathbf{Elev.EVC}}{\mathbf{2}} - \mathbf{Elev.VPI}\right)$$

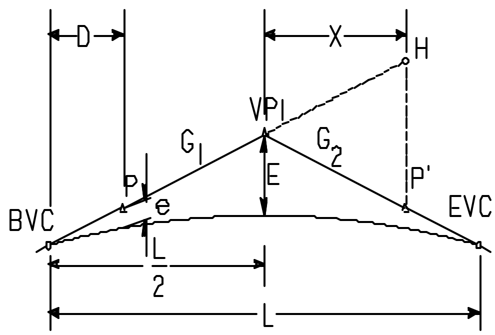
$$\mathbf{e} = \frac{\mathbf{4ED^2}}{\mathbf{L^2}}$$

Notes: All equations use units of length (not stations or increments)

The variable **A** is expressed as an absolute in percent (%)

Example: If $\mathbf{G_1}$ = +4% and $\mathbf{G_2}$ = -2%
Then **A** = 6

Symmetrical Vertical Curve Equations (cont.)



$$e = \frac{AD^2}{200L}$$

$$L_1 = \frac{2(AX + 200e + 20\sqrt{AXe + 100e^2})}{A}$$

$$D_0 = |G_1|\frac{L}{A}$$

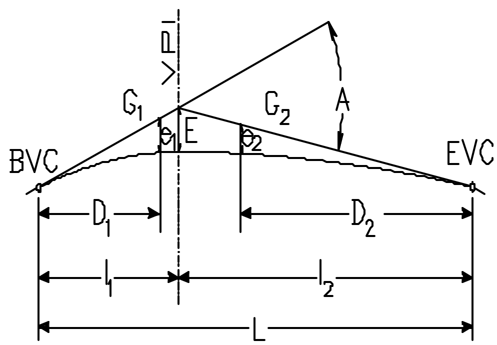
$$X = \frac{100(ElevH - ElevP')}{A}$$

$$K = \frac{L}{A}$$

Nomenclature For Nonsymmetrical Vertical Curves

G_1 & G_2	Tangent Grades in percent
A	The absolute of the Algebraic difference in grades in percent
BVC	Beginning of Vertical Curve
EVC	End of Vertical Curve
VPI	Vertical Point of Intersection
l_1	Length of first section of vertical curve
l_2	Length of second section of vertical curve
L	Length of vertical curve
D_1	Horizontal distance to any point on the curve from BVC towards the VPI
D_2	Horizontal distance to any point on the curve from EVC towards the VPI
e_1	Vertical distance from any point on the curve to the tangent grade between BVC and VPI
e_2	Vertical distance from any point on the curve to the tangent grade between EVC and VPI
E	Vertical distance from VPI to curve

Nonsymmetrical Vertical Curve Equations



$$\mathbf{A} = (\mathbf{G_2}) - (\mathbf{G_1})$$

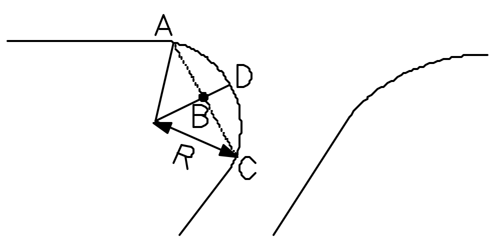
$$\mathbf{L} = \mathbf{l_1} + \mathbf{l_2}$$

$$\mathbf{E} = \frac{\mathbf{l_1 l_2}}{\mathbf{200(l_1 + l_2)}}\mathbf{A}$$

$$\mathbf{e_1} = \mathbf{m}\left\{\frac{\mathbf{D_1}}{\mathbf{l_1}}\right\}^2$$

$$\mathbf{e_2} = \mathbf{m}\left\{\frac{\mathbf{D_2}}{\mathbf{l_2}}\right\}^2$$

Determining Radii of Sharp Curves by Field Measurements



$$\mathbf{R} = \frac{\mathbf{BC}^2}{\mathbf{2BD}} + \frac{\mathbf{BD}}{\mathbf{2}}$$

$$\mathbf{BC} = \frac{\mathbf{AC}}{\mathbf{2}}$$

Note: Points A and C may be any two points on the curve

Example:

Measure the chord length from A to C

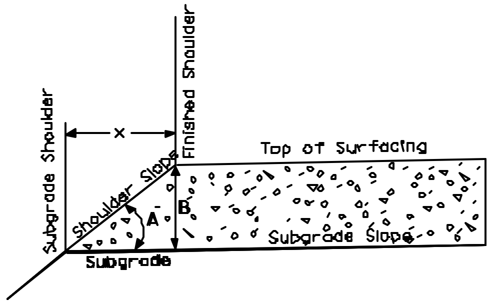
AC = 18.4 then BC = 9.2

Measure the middle ordinate length B to D

BD = 3.5

$$\mathbf{R} = \frac{\mathbf{9.2}^2}{\mathbf{7.0}} + \frac{\mathbf{3.5}}{\mathbf{2}} = \mathbf{13.8}$$

Distance From Finished Shld. to Subgrade Shld. and Slope Equivalents



$$\textbf{Equation: } x = \frac{100B}{A}$$

A = Algebraic difference in % between shld. slope and subgrade slope
B = Depth of surfacing at finished shoulder
x = Distance from finished shld. to subgrade shld.

Shoulder Slope	Equivalent Rate of Grade	Equivalent Vertical Angle
1:1.5	66.67%	33°41'24"
1:1.75	57.14%	29°44'42"
1:2	50.00%	26°33'54"
1:2.5	40.00%	21°48'05"
1:3	33.33%	18°26'06"
1:4	25.00%	14°02'10"
1:5	20.00%	11°18'36"
1:6	16.67%	9°27'44"
1:8	12.50%	7°07'30"
1:10	10.00%	5°42'38"

Subgrade Slope	Equivalent Rate of Grade	Equivalent Vertical Angle
.020 / 1	2.00%	1°08'45"
.025 / 1	2.50%	1°25'56"
.030 / 1	3.00%	1°43'06"
.035 / 1	3.50%	2°00'16"
.040 / 1	4.00%	2°17'26"
.050 / 1	5.00%	2°51'45"

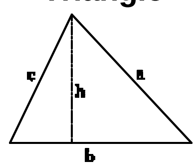
Areas of Plane Figures

Nomenclature

A = Area **h =** Height

R = Radius **P =** Perimeter

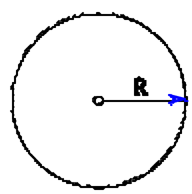
Triangle



$$A = \frac{bh}{2}$$

$$P = a + b + c$$

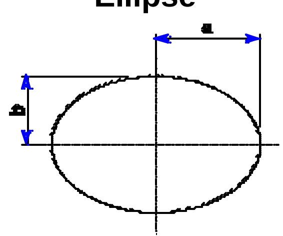
Circle



$$A = \pi R^2$$

$$P = 2\pi R$$

Ellipse



$$A = \pi ab$$

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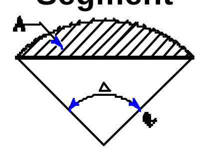
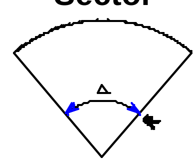
Areas of Plane Figures

Segment



$$A = \pi R^2 \frac{\Delta}{360^0} - \frac{R^2 \sin\Delta}{2}$$

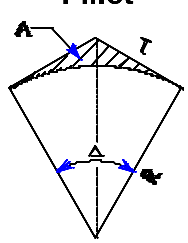
Sector



$$A = \pi R^2 \frac{\Delta}{360^0}$$

$$P = 2R + \frac{\Delta}{360^0}(2\pi R)$$

Fillet

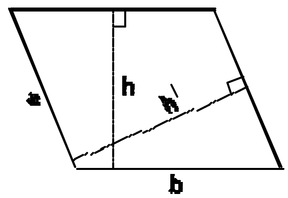


$$A = RT - \left(\frac{\Delta}{360^0}\right)\pi R^2$$

$$\textbf{When: } \Delta = 90^0, A = 0.2146R^2$$

Areas of Plane Figures

Parallelogram



$$A = bh$$

$$A = ah'$$

$$P = 2(a + b)$$

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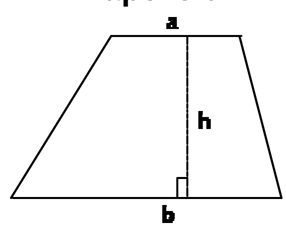
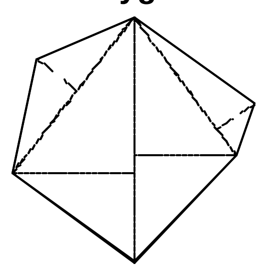
Trapezoid



$$A = \frac{(a + b)h}{2}$$

____

Polygon



Divide into triangles

A = Sum of all triangles

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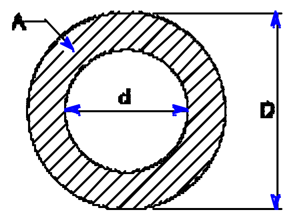
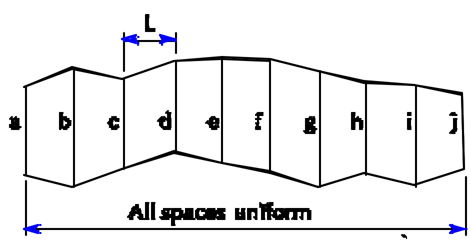
Areas of Plane Figures

Annulus
(Circular Ring)



$$A = \frac{\pi}{4}\left(D^2 - d^2\right)$$

Irregular Figure



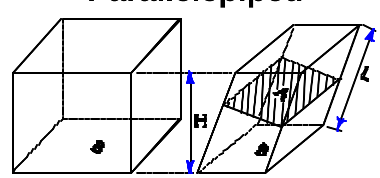
$$A = L\left(\frac{a+j}{2} + b + c + d + e + f + g + h + i\right)$$

Surfaces\Volumes of Solids

Nomenclature

S Lateral surface area
V Volume
A Area of section perpendicular to sides
B Area of base
P Perimeter of base
P_A Perimeter of section perpendicular to its sides
R Radius of sphere or circle
L Slant height or lateral length
H Perpendicular Height
C Circumference of circle or sphere

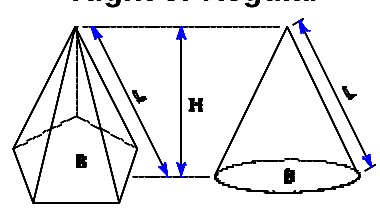
Parallelepiped



$\mathbf{S = PH}$ $\mathbf{S = P_A L}$

$\mathbf{V = BH = AL}$

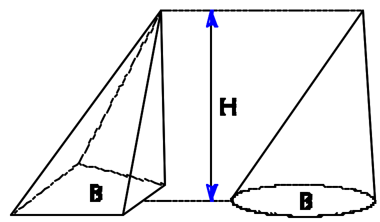
Pyramid or Cone
Right or Regular



$\mathbf{S = \frac{1}{2} PL}$ $\mathbf{V = \frac{1}{3} BH}$

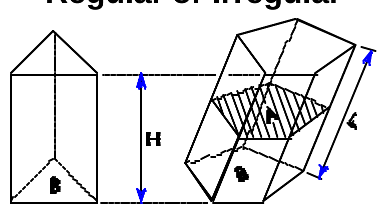
Surfaces\Volumes of Solids

Pyramid or Cone, Right or Oblique, Regular or Irregular



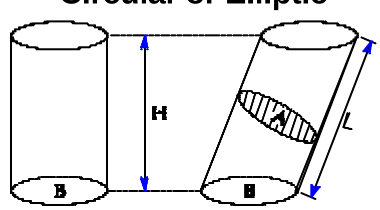
$$V = \frac{1}{3}BH$$

Prism: Right or Oblique, Regular or Irregular



$S = PH = P_A L$ $\qquad$ $V = BH = AL$

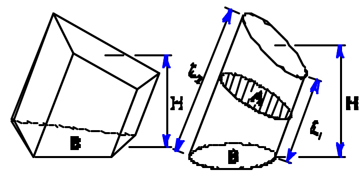
Cylinder: Right or Oblique, Circular or Elliptic



$S = PH = P_A L$ $\qquad$ $V = BH = AL$

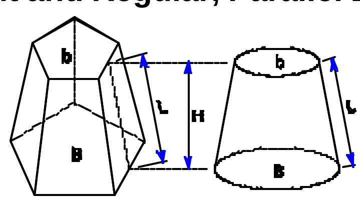
Surfaces\Volumes of Solids

Frustum of any Prism or Cylinder



$$V = BH \qquad\qquad V = \frac{1}{2}A\left(L_2 + L_1\right)$$

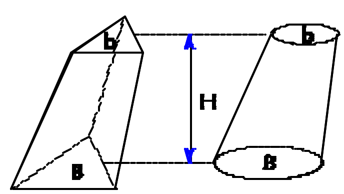
Frustum of Pyramid or Cone
Right and Regular, Parallel Ends



$$S = \frac{1}{2}L\left(P + p\right) \qquad V = \frac{1}{3}H\left(B + b + \sqrt{Bb}\right)$$

p = perimeter of top **b** = area of top

Frustum of any Pyramid or Cone, with Parallel Ends

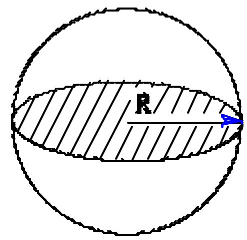


$$V = \frac{1}{3}H\left(B + b + \sqrt{Bb}\right)$$

b = area of top

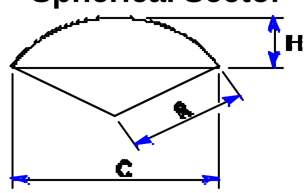
Surfaces\Volumes of Solids

Sphere



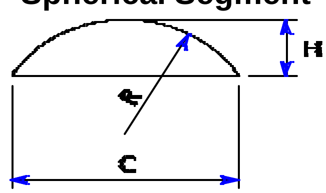
$$S = 4\pi R^2 \qquad V = \frac{4}{3}\pi R^3$$

Spherical Sector



$$S = \frac{1}{2}\pi R(4H + C) \qquad V = \frac{2}{3}\pi R^2 H$$

Spherical Segment

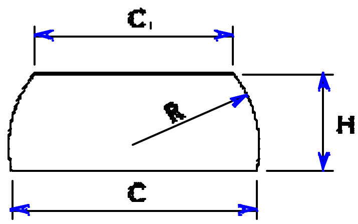


$$S = 2\pi RH = \frac{1}{4}\pi\left(4H^2 + C^2\right)$$

$$V = \frac{1}{3}\pi H^2(3R - H)$$

Surfaces\Volumes of Solids

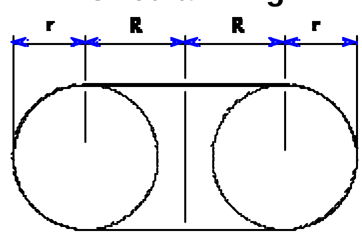
Spherical Zone



$$S = 2\pi RH$$

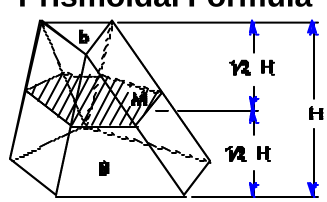
$$V = \frac{1}{24}\pi H\left(3C_1^2 + 3C^2 + 4H^2\right)$$

Circular Ring



$$S = 4\pi^2 Rr \qquad V = 2\pi^2 Rr^2$$

Prismoidal Formula

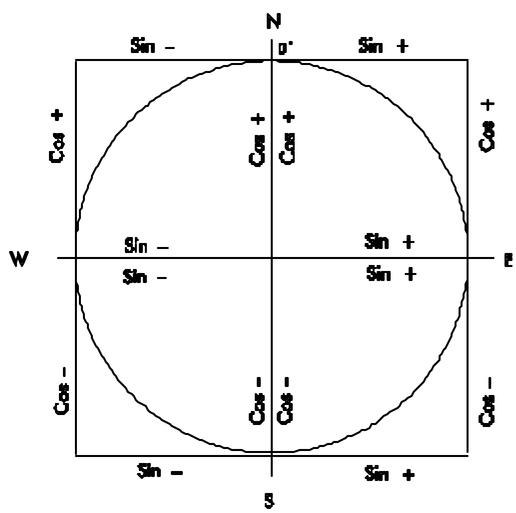


$$V = \frac{H}{6}\left(B + b + 4M\right)$$

M = Area of section parallel to bases,
Midway between them

b = area of top

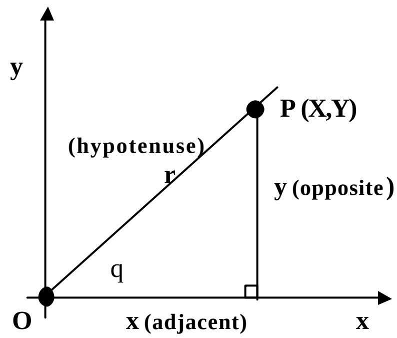
Signs of Trigonometric Functions for All Quadrants



Note:

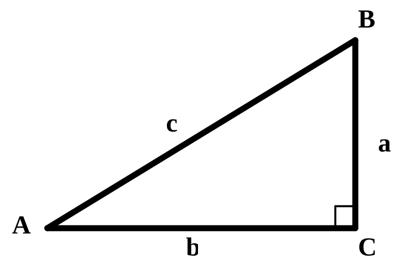
When using a calculator to compute trigonometric functions from North Azimuths, the correct sign will be displayed

Trigonometric Functions



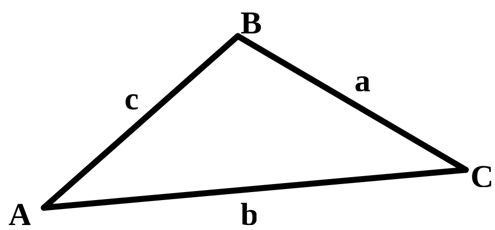
Sine	$\mathbf{Sin}q = \frac{\mathbf{y}}{\mathbf{r}} = \frac{\mathbf{opposite}}{\mathbf{hypotenuse}}$
Cosine	$\mathbf{cos}q = \frac{\mathbf{x}}{\mathbf{r}} = \frac{\mathbf{adjacent}}{\mathbf{hypotenuse}}$
Tangent	$\mathbf{tan}q = \frac{\mathbf{y}}{\mathbf{x}} = \frac{\mathbf{opposite}}{\mathbf{adjacent}}$
Cotangent	$\mathbf{cot}\,q = \frac{\mathbf{x}}{\mathbf{y}} = \frac{\mathbf{adjacent}}{\mathbf{opposite}}$
Secant	$\mathbf{sec}\,q = \frac{\mathbf{r}}{\mathbf{x}} = \frac{\mathbf{hypotenuse}}{\mathbf{adjacent}}$
Cosecant	$\mathbf{csc}q = \frac{\mathbf{r}}{\mathbf{y}} = \frac{\mathbf{hypotenuse}}{\mathbf{opposite}}$
Reciprocal Relations	$\mathbf{sin}\,q = \frac{\mathbf{1}}{\mathbf{csc}}$ $\quad \mathbf{tan}\,q = \frac{\mathbf{1}}{\mathbf{cot}\,q}$ $\mathbf{cos}\,q = \frac{\mathbf{1}}{\mathbf{sec}}$
Rectangular	$\mathbf{X} = \mathbf{r} \times \mathbf{cos}\,q$ $\mathbf{y} = \mathbf{r} \times \mathbf{sin}\,q$
Polar	$\mathbf{r} = \sqrt{(\mathbf{x}^2 + \mathbf{y}^2)}$ $q = \mathbf{arctan}\frac{\mathbf{y}}{\mathbf{x}}$

Right Triangles



$A+B+C=180^0$		K=Area
Pythagorean Theorem		$a^2 + b^2 = c^2$
A and B are complementary angles		
sin A = cos B cos A = sin B	tan A = cot B cot A = tan B	sec A = csc B csc A = sec B
Given	**To Find**	**Equation**
a, c	A, B, b, K	$\sin A = \frac{a}{c}$ $\cos B = \frac{a}{c}$ $b = \sqrt{c^2 - a^2}$ $K = \frac{a}{2}\sqrt{c^2 - a^2}$
a, b	A, B, c, K	$\tan A = \frac{a}{b}$ $\tan B = \frac{b}{a}$ $c = \sqrt{a^2 + b^2}$ $K = \frac{ab}{2}$
A, a	B, b, c, K	$B = 90^0 - A$ $b = a \times \cot A$ $c = \frac{a}{\sin A}$ $k = \frac{a^2 \times \cot A}{2}$
A, b	B, a, c, K	$B = 90^0 - A$ $a = b \times \tan A$ $c = \frac{b}{\cos A}$ $K = \frac{b^2 \times \tan A}{2}$
A, c	B, a, b, K	$B = 90^0 - A$ $a = c \times \sin A$ $b = c \times \cos A$ $K = \frac{c^2 \times \sin 2A}{4}$

Oblique Triangles



Law of Sines		$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
Law of Cosines		$a^2 = b^2 + c^2 - 2bc \cdot \cos A$ $b^2 = a^2 + c^2 - 2ac \cdot \cos B$ $c^2 = a^2 + b^2 - 2ab \cdot \cos C$
Sum of Angles		$A + B + C = 180^0$
K = Area		$s = \frac{a + b + c}{2}$
Given	**To Find**	**Equation**
a, b, c	**A**	$\sin\frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}}$ $\cos\frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$ $\tan\frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$

Oblique Triangles

Given	To Find	Equation
a, b, c	B	$\sin\frac{B}{2} = \sqrt{\frac{(s-a)(s-c)}{ac}}$ $\cos\frac{B}{2} = \sqrt{\frac{s(s-b)}{ac}}$ $\tan\frac{B}{2} = \sqrt{\frac{(s-a)(s-c)}{s(s-b)}}$
a, b, c	C	$\sin\frac{C}{2} = \sqrt{\frac{(s-a)(s-b)}{ab}}$ $\cos\frac{C}{2} = \sqrt{\frac{s(s-c)}{ab}}$ $\tan\frac{C}{2} = \sqrt{\frac{(s-a)(s-b)}{s(s-c)}}$
a, b, c	K	$K = \sqrt{s(s-a)(s-b)(s-c)}$
a, A, B	b, c	$b = \frac{a \times \sin B}{\sin A}$ $\quad c = \frac{a \times \sin(A+B)}{\sin A}$
a, A, B	K	$K = \frac{ab \times \sin C}{2} = \frac{a^2 \times \sin B \times \sin C}{2 \times \sin A}$
a, b, A	B	$\sin B = \frac{b \times \sin A}{a}$
a, b, A	c	$c = \frac{a \times \sin C}{\sin A} = \frac{b \times \sin C}{\sin B}$ $c = \sqrt{\left(a^2 + b^2 - 2ab \times \cos C\right)}$
a, b, A	K	$K = \frac{ab \times \sin C}{2}$
a, b, C	A	$\tan A = \frac{a \times \sin C}{b - a \times \cos C}$
a, b, C	c	$c = \frac{a \times \sin(A+B)}{\sin A}$ $c = \sqrt{\left(a^2 + b^2 - 2ab \times \cos C\right)}$
a, b, C	K	$K = \frac{ab \times \sin C}{2}$

Conversion Factors

Class	multiply:	by:	to get:
Length	in	0.0833	ft
	in	0.028	yd
	ft	12	in
	ft	0.33	yd
	ft	0.06	rods
	yd	36	in
	yd	3	ft
	yd	0.18	rods
	rods	198	in
	rods	16.5	ft
	rods	5.5	yd
	mi	5280	ft
	mi	1760	yd
	mi	320	rods
Area	in^2	0.007	ft^2
	ft^2	144	in^2
	ft^2	0.11	yd^2
	yd^2	1296	in^2
	yd^2	9	ft^2
	yd^2	0.03	$rods^2$
	$rods^2$	272.25	ft^2
	$rods^2$	30.25	yd^2
	acres	43560	ft^2
	acres	4840	yd^2
	acres	160	$rods^2$

Conversion Factors

Class	multiply:	by:	to get:
Volume	ft^3	1728	in^3
	ft^3	0.04	yd^3
	ft^3	7.48	gallons
	yd^3	27	ft^3
	yd^3	202	gallons
	quarts	2	pints
	quarts	0.25	gallons
	gallons	8	pints
	gallons	4	quarts
	gallons	0.13	ft^3
Force	ounces	0.06	pounds
	pounds	16	ounces
	tons (short)	2000	pounds
	tons (metric)	2205	pounds
Velocity	miles/hr	88	ft/min
	miles/hr	1.47	ft/sec

Metric Conversion Factors

Class	multiply:	by:	to get:
Length	in	25.40	mm
	in	2.540	cm
	in	0.0254	m
	ft	0.3048	m
	yd	0.9144	m
	mi	1.6093	km
Area	ft^2	0.0929	m^2
	yd^2	0.8361	m^2
	mi^2	2.590	km^2
Volume	in^3	16.387	cm^3
	ft^3	0.0283	m^3
	yd^3	0.7646	m^3
	gal	3.785	L
	gal	0.0038	m^3
	fl oz	29.574	mL
	acre ft	1233.48	m^3
Mass	oz	28.35	g
	lb	0.4536	kg
	kip (1000 lb)	0.4536	metric ton (1000 kg)
	short ton 2000 lb	907.2	kg
	short ton	0.9072	metric ton

Land Surveying Conversion Factors

Class	multiply:	by:	to get:
Area	acre	4046.8726	m^2
	acre	0.40469	ha 10000 m^2
Length	ft	12/39.37*	m

*** Exact, by definition of the U.S. Survey foot**

Steel Tape Temperature Corrections

$$C = 11.66 \cdot 10^{-6} (T_C - 20) L_m$$

or

$$C = 6.45 \cdot 10^{-6} (T_F - 68) L_f$$

Where:

C = Correction
T_C = Temperature in degrees Celsius
L_M = Length in meters
T_F = Temperature in degrees Fahrenheit
L_f = Length in feet

Temperature Conversion

Fahrenheit to Celsius $\frac{5}{9}(°F - 32)$

Celsius to Fahrenheit $\left(\frac{9}{5}°C\right) + 32$

Less Common Conversion Factors

Class	multiply:	by:	to get:
Density	lb/ft^3	16.0185	kg/m^3
	lb/yd^3	0.5933	kg/m^3
Pressure	psi	6894.8	Pa
	ksi	6.8948	MPa
	lb/ft^2	47.88	Pa
Velocity	ft/s	0.3048	m/s
	mph	0.4470	m/s
	mph	1.6093	km/h

Water Constants

Freezing point of water = 0° C (32° F)
Boiling point of water under pressure of one atmosphere = 100° C (212° F)
The mass of one cu. meter of water is 1000 kg
The mass of one liter of water is 1 kg (2.20 lbs)
1 cu. ft. of water @60° F = 62.37 lbs (28.29 kg)
1 gal of water @60° F = 8.3377 lbs (3.78 kg)

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Cement Constants

1 sack of cement (appx.) = 1 ft^3 = 0.028 m^3
1 sack of cement = 94 lbs. = 42.64 kg
1 gallon water = 8.3453 lbs. @39.2° F
1 gallon water = 3.7854 kg @4° C

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Multiplication Factor Table

Multiple	Prefix	Symbol
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	*****hecto	h
10 = 10^{1}	*****deka	da
0.1 = 10^{-1}	*****deci	d
0.01 = 10^{-2}	*****centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n

***** Avoid when possible

Recommended Pronunciations

Prefix	Pronunciation
giga	jig'a (i as in *jig,* a as in *a*-bout
mega	as in *mega*-phone
kilo	kill' oh
hecto	heck' toe
deka	deck' a (a as in *a*-bout
centi	as in *centi*-pede
milli	as in *mili*-tary
micro	as in *micro*-phone
nano	nan' oh

Reinforcing Steel

Bar Size	Nominal Diameter	Nominal Area	Unit Weight
#3	9.5mm [0.375 in]	$71mm^2$ [$0.110\ in^2$]	0.560kg\m [0.376 lb\ft]
#4	12.7mm [0.500 in]	$127mm^2$ [$0.197\ in^2$]	0.994kg\m [0.668 lb\ft]
#5	15.9mm [0.625 in]	$199mm^2$ [$0.309\ in^2$]	1.552kg\m [1.043 lb\ft]
#6	19.1mm [0.750 in]	$287mm^2$ [$0.445\ in^2$]	2.235kg\m [1.502 lb\ft]
#7	22.2mm [0.875 in]	$387mm^2$ [$0.600\ in^2$]	3.045kg\m [2.044 lb\ft]
#8	25.4mm [1.000 in]	$507mm^2$ [$0.786\ in^2$]	3.973kg\m [2.670 lb\ft]
#9	28.7mm [1.128 in]	$647mm^2$ [$1.003\ in^2$]	5.060kg\m [3.400 lb\ft]
#10	32.3mm [1.270 in]	$819mm^2$ [$1.270\ in^2$]	6.404kg\m [4.303 lb\ft]
#11	35.8mm [1.410 in]	$1007mm^2$ [$1.561\ in^2$]	7.907kg\m [5.313 lb\ft]
#14	43.0mm [1.693 in]	$1452mm^2$ [$2.251\ in^2$]	11.384kg\m [7.650 lb\ft]
#18	57.3mm [2.257 in]	$2579mm^2$ [$3.998\ in^2$]	20.239kg\m [13.600 lb\ft]

Notes

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