Meridian Conversion

Blue Mountain Chapter PLSO
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Jerry Mahun. PLS
jerry.mahun@gmail.com
715-896-3178
jerrymahun.com

Contents

A. Definitions

1. Meridian

A north-south reference line.

"North"

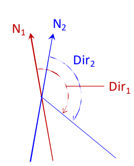
Common Meridians:
- True
- Geodetic
- Magnetic
- Astronomic
- Grid, Grid, Grid
- Assumed

Some ____, others _____.

converge, are parallel
are straight, vary
are constant, change over time

2. Meridian conversion

Changing a direction from one meridian to another.



B. Applications

Traditional
- Magnetic ←→ True
- Traverse ←→ Traverse

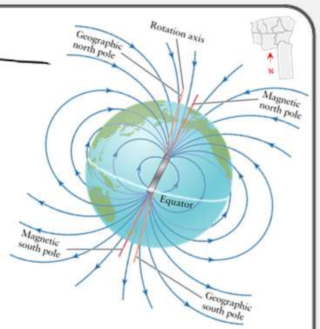
Contemporary
- Grid ←→ Geodetic
- Grid ←→ Grid

C. Magnetic Conversions

1. True North
   - Based on rotational axis of Earth
   - Great circle containing observer and Poles
   - Constant over time.
   - True meridians converge.

C. Magnetic Conversions

2. Magnetic North
   - Based on Earth's magnetic fields.
   - Magnetic meridians converge, but are not straight.
     - Affected by local attractions.
   - Magnetic poles move over time.
     - Movement is not constant.

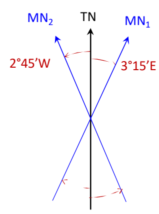


C. Magnetic Conversions

3. Declination, δ

The angle from the true north meridian to the magnetic north meridian at a point.

Measured at the North ends of the meridians.



C. Magnetic Conversions

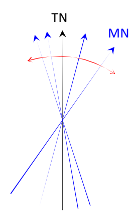
4. Variation

Magnetic north moves over time

Variation is amount and direction declination changes over time

Variation is not constant.

While we can record past declinations, it's not easy to predict future declination.



C. Magnetic Conversions

5. Isogonic Chart

Map of declination at a specific time
- Isogonic line
  - line of equal declination
- Agonic line
  - line of 0° declination

Historic Magnetic Declination

https://www.ncei.noaa.gov/maps/historical_declination/

C. Magnetic Conversions

6. Behavior

True North does not move over time.

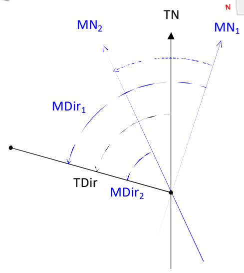
The line whose direction is measured does not move over time.

Only Magnetic North moves over time.

That means:

A line's true direction *does not* change.

A line's magnetic direction *does* change.



C. Magnetic Conversions

7. Computations

Example (1)

The magnetic bearing of line AB in 1885 was recorded as N58°45'E and the declination was 5°20' E.

What is the true bearing of the line?

Build the sketch in pieces.

C. Magnetic Conversions

7. Computations

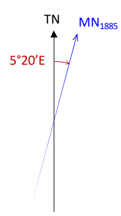
Example (1)

The magnetic bearing of line AB in 1885 was recorded as N58°45'E and the declination was 5°20' E.

What is the true bearing of the line?

Build the sketch in pieces.

Add the declination & magnetic meridian.



C. Magnetic Conversions

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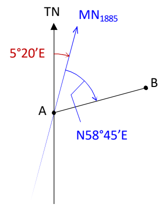
The magnetic bearing of line AB in 1885 was recorded as N58°45'E and the declination was 5°20' E.
What is the true bearing of the line?

Build the sketch in pieces.
Add the declination & magnetic meridian.
Then the line and magnetic bearing.



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What is the true bearing of the line?

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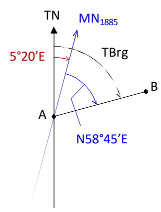
Then the line and magnetic bearing.
And finally label the true bearing.



C. Magnetic Conversions

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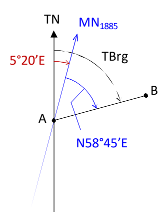


Angle = 5°20'+58°45' = 64°05'
→ **<u>TBrg = N 64°05' W</u>**

C. Magnetic Conversions

7. Computations

Example (2)

The magnetic bearing of line PQ in 1925 was recorded as S86°35’W. The present true bearing of the line is S79°50’W. What was the declination in 1925?

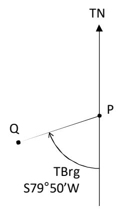
C. Magnetic Conversions

7. Computations

Example (2)

The magnetic bearing of line PQ in 1925 was recorded as S86°35’W. The present true bearing of the line is S79°50’W. What was the declination in 1925?

Add the line with its true bearing.



C. Magnetic Conversions

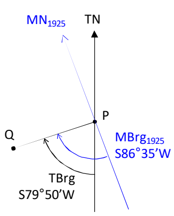
7. Computations

Example (2)

The magnetic bearing of line PQ in 1925 was recorded as S86°35’W. The present true bearing of the line is S79°50’W. What was the declination in 1925?

Add the line with its true bearing.

Using the 1925 magnetic bearing, add the magnetic meridian.



C. Magnetic Conversions

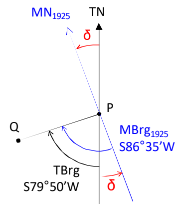
7. Computations

Example (2)

The magnetic bearing of line PQ in 1925 was recorded as S86°35’W. The present true bearing of the line is S79°50’W. What was the declination in 1925?

Add the line with its true bearing.
Using the 1925 magnetic bearing, add the magnetic meridian.

δ = 86°35’ - 79°50’ = 6°45’
δ = 6°45’W



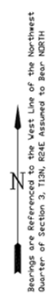
D. Traverse to Traverse Conversion

Often, when computing a traverse, the direction of one line is assumed

- If the relationship between assumed north and true north can be determined then the true directions of the traverse lines can be computed.

This can also be done when two surveyors use two different assumed directions for adjacent surveys.

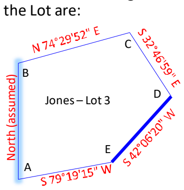
- If the surveys share a line, then one survey can be rotated into the other.



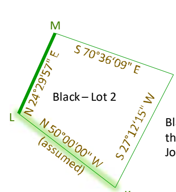
D. Traverse to Traverse Conversion

Example (3)

Surveyor Jones surveyed Lot 3. He assumed the direction of one line (AB) as due North. The resulting directions around the Lot are:



Surveyor Black surveyed Lot 2 next door. She assumed the direction of one line (KL) as N50°00’00”W. The resulting directions around the Lot are:

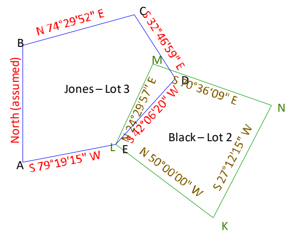


Black’s line ML is the same as Jones’ line DE.

D. Traverse to Traverse Conversion

Example (3)

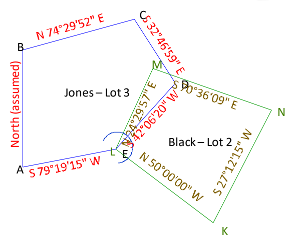
- Pick one end of the common line as a pivot point.
- Rotate one survey into the other.



D. Traverse to Traverse Conversion

Example (3)

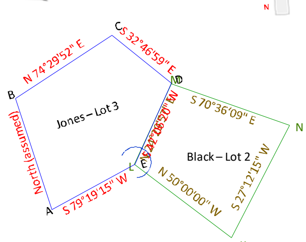
- Pick one end of the common line as a pivot point.
- Rotate one survey into the other.
- To rotate Jones' survey into Black's…



D. Traverse to Traverse Conversion

Example (3)

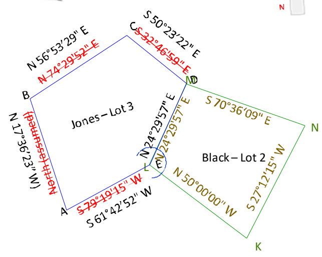
- Pick one end of the common line as a pivot point.
- Rotate one survey into the other.
- To rotate Jones' survey into Black's…
  - 42°06'20"-24°29'57"
  - = **<u>17°36'23" ccw</u>**



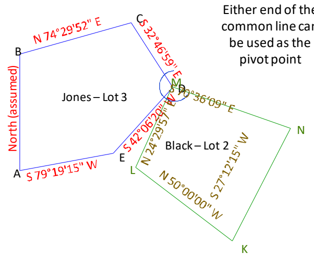
D. Traverse to Traverse Conversion

Example (3)

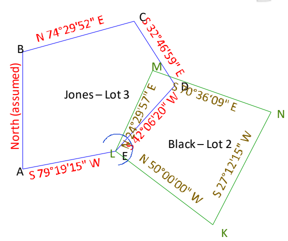
- Each of Jones' bearings changes by 17°36'23"
  - Depending on quadrant, the bearing angle may increase or decrease.
- Pivoting Jones' survey around the other point would result in the same bearings.



D. Traverse to Traverse Conversion



Either end of the common line can be used as the pivot point

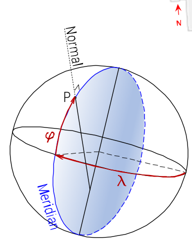


E. Grid and Geodetic Conversions

1. Geodetic North
   - Geodetic north is defined by the reference ellipsoid and its fit.
   - NAD 83 uses GRS 80 which is closely fit to Earth's mass center.

Normal	A line from the observer's position, P, perpendicular to the ellipsoid
Meridian	An elliptical section containing the normal and semi-minor axes.

Geodetic meridians converge.



E. Grid and Geodetic Conversions

2. Grid North

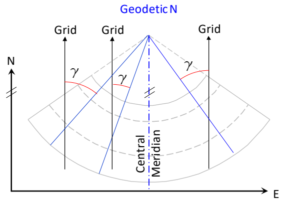
A function of the projection & its fit.
Grid north meridians are parallel

a. Cone: Lambert Conic

Convergence, γ, is angle between Grid and Geodetic North.

γ=0° at CM, magnitude increases moving E or W

Direction behavior



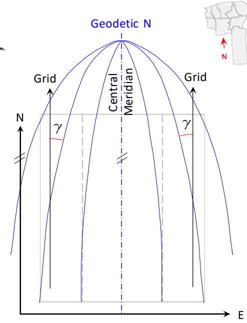
E. Grid and Geodetic Conversions

2. Grid North

b. Cylinder: Transverse Mercator

γ=0° at CM, magnitude increases moving E or W

Some change moving N or S but, except for UTM, the zones are generally small so the effect is negligible.



E. Grid and Geodetic Conversions

2. Grid North

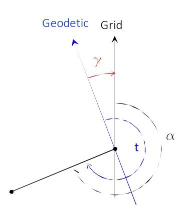
c. Converting

γ is :

- positive East of the CM
- negative West of the CM

$t = \alpha - \gamma$

- t Grid azimuth
- α Geodetic azimuth
- γ Convergence



E. Grid and Geodetic Conversions

3. Where do we get convergence?
   a. It depends on the coordinate system.
   Currently:
   (1) SPC & UTM
   - NGS (NCAT, Survey Mark Data Sheets)
   - Most mapping & GIS software
   - Other misc. software, spreadsheets, etc.

   (2) Regional LDPs
   - Custodian tools
   - May or may not be in mapping & GIS software

E. Grid and Geodetic Conversions

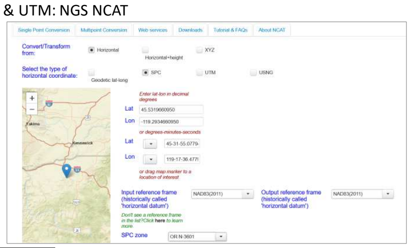
3. Where do we get convergence?
   b. SPC & UTM: NGS Survey Mark Datasheet

```
RB1433  DESIGNATION -  IRRIGON
RB1433  ___________________________________________________________________
RB1433* NAD 83(1991) POSITION- 45 53 19.65182(N) 119 29 34.66095(W)   ADJUSTED
RB1433* NAVD 88 ORTHO HEIGHT -   105.0   (meters)      344.    (feet) VERTCON3
RB1433  ___________________________________________________________________
RB1433  HORZ ORDER       -  SECOND

RB1433. The following values were computed from the NAD 83(1991) position.
RB1433;                    North         East     Units Scale Factor Converg.
RB1433;SPC OR N      -   247,421.247 2,578,160.582   MT  0.99997363  +0 42 51.0
RB1433;SPC OR N      -   811,749.50  8,458,532.09   iFT  0.99997363  +0 42 51.0
RB1433;SPC WA S      -    62,238.525   578,161.597   MT  0.99998789  +0 43 53.4
RB1433;SPC WA S      -   204,194.23  1,896,851.84   sFT  0.99998789  +0 43 53.4
RB1433;UTM  11       - 5,084,713.832   306,579.688   MT  1.00005994  -1 47 25.7
```

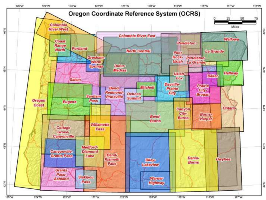
E. Grid and Geodetic Conversions

3. Where do we get convergence?
   c. SPC & UTM: NGS NCAT



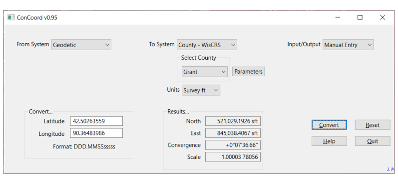
E. Grid and Geodetic Conversions

3. Where do we get convergence?
   d. Regional LDP



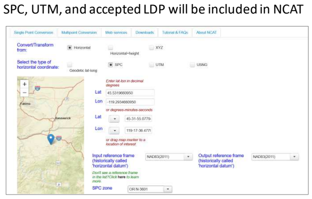
E. Grid and Geodetic Conversions

3. Where do we get convergence?
   d. Regional LDP
      Surveying/Mapping; GIS software
      Standalone software



E. Grid and Geodetic Conversions

3. Where do we get convergence?
   e. New Datums
      North America - NATRF2022
         SPC, UTM, and accepted LDP will be included in NCAT



E. Grid and Geodetic Conversions

4. Example (4)

Point *Veo* is *Irrigon's* azimuth point in SPC and UTM zones.

From the NGS Survey Mark Data Sheet

```
RB1433:              Pri Az Mark      Grid Az
RB1433:SPC OR N -   VEO             347 27 07.9
RB1433:SPC WA S -   VEO             347 26 05.5
RB1433:UTM  11  -   VEO             349 57 24.6
```

What is the geodetic azimuth from *Irrigon* to Veo?

E. Grid and Geodetic Conversions

4. Example (4)

```
RB1433;                     North          East     Units Scale Factor Converg.
RB1433;SPC OR N     -   247,421.247 2,578,160.582    MT   0.99997363   +0 42 51.0
RB1433;SPC OR N     -   811,749.50  8,458,532.09    iFT   0.99997363   +0 42 51.0
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RB1433;UTM  11      - 5,084,713.832   306,579.688    MT   1.00005994   -1 47 25.7
....
RB1433:                 Primary Azimuth Mark                      Grid Az
RB1433:SPC OR N     -   VEO                                       347 27 07.9
RB1433:SPC WA S     -   VEO                                       347 26 05.5
RB1433:UTM  11      -   VEO                                       349 57 24.6
```

$t = \alpha - \gamma$

$\rightarrow \alpha = t + \gamma$

$= 347°27'07.9" + (+0°42'51.0")$

$= 348°09'58.9"$

F. PLSS Corner Restoration Using Grid Coordinates

1. Cardinal Equivalents

Direction basis for PLSS is True Meridian.

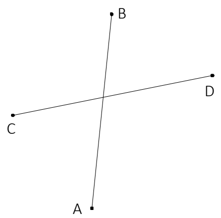
For lost corner re-establishment by proportionate measurement working in SPC, UTM, or LDP, must convert Grid to True directions.

2009 Manual treats Geodetic and True the same, which isn't *technically* true, but close enough.

Convergence can be compensated before or after Single- or Double Proportionate Measurement (SPM; DPM)

F. PLSS Corner Restoration Using Grid Coordinates

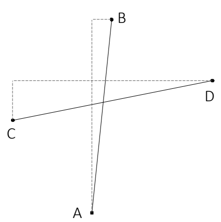
2. DPM Example



N-S	Grid $Brng_{AB}$	Grid $Dist_{AB}$
E-W	Grid $Brng_{CD}$	Grid $Dist_{CD}$

F. PLSS Corner Restoration Using Grid Coordinates

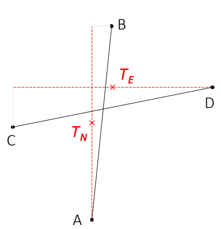
2. DPM Example



N-S	Grid $Brng_{AB}$	Grid $Dist_{AB}$
	Grid Lat_{AB}	Grid Dep_{AB}
E-W	Grid $Brng_{CD}$	Grid $Dist_{CD}$
	Grid Lat_{AB}	Grid Dep_{AB}

F. PLSS Corner Restoration Using Grid Coordinates

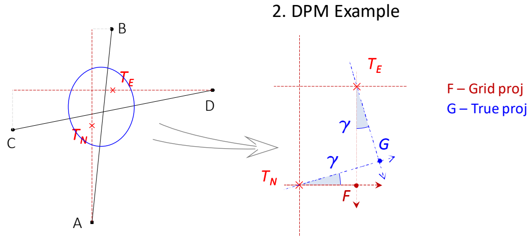
2. DPM Example



N-S	Grid $Brng_{AB}$	Grid $Dist_{AB}$
	Grid Lat_{AB}	Grid Dep_{AB}
	Set T_N by SPM	
E-W	Grid $Brng_{CD}$	Grid $Dist_{CD}$
	Grid Lat_{AB}	Grid Dep_{AB}
	Set T_E by SPM	

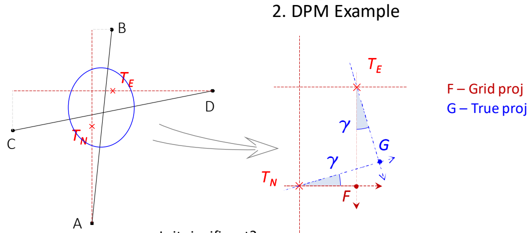
F. PLSS Corner Restoration Using Grid Coordinates

2. DPM Example



F. PLSS Corner Restoration Using Grid Coordinates

2. DPM Example



Is it significant?
At *Irrigon* γ = +0°43′13.2″ in *Columbia East* OCRS.
Can shift position a few feet.

G. Trivia: Astronomic

1. Background

In traditional control surveys, directions were determined using astronomic observations. Observing stars, typically Polaris.

Wild T-4 theodolite, used exclusively for star observations.
0.1″ circle resolution H, 0,05″ est,
Only 439 produced. **Weight: 220 lbs**

Wild T-3theodolite, used for star observations and triangulation.
0.2″ circle resolution; 0.1″ estimation

Kern DKM3 used for star observations and triangulation.
0.5″ circle resolution; 0.1″ estimation

G. Trivia: Astronomic

1. Background

FGCC 1984 Standards

3.2 Triangulation

Triangulation is a measurement system comprised of joined or overlapping triangles of angular observations supported by occasional distance and astronomic observations. Triangulation is used to extend horizontal control.

Network Geometry

Order Class	First	Second I	Second II	Third I	Third II
Station spacing not less than (km)	15	10	5	0.5	0.5
Average minimum distance angle† of figures not less than	40°	35°	30°	30°	25°
Minimum distance angle† of all figures not less than	30°	25°	25°	20°	20°
Base line spacing not more than (triangles)	5	10	12	15	15
Astronomic azimuth spacing not more than (triangles)	8	10	10	12	15

† Distance angle is angle opposite the side through which distance is propagated.

Instrumentation

Only properly maintained theodolites are adequate for observing directions and azimuths for triangulation. Only precisely marked targets, mounted stably on tripods or supported towers, should be employed. The target should have a clearly defined center, resolvable at the minimum control spacing. Optical plummets or collimators are required to ensure that the theodolites and targets are centered over the marks. Microwave-type electronic distance measurement (EDM) equipment is not sufficiently accurate for measuring higher-order base lines.

Order Class	First	Second I	Second II	Third I	Third II
Theodolite, least count	0.2"	0.2"	1.0"	1.0"	1.0"

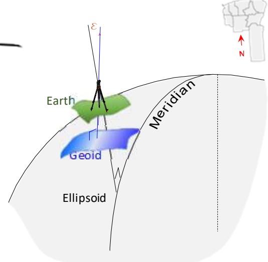
G. Trivia: Astronomic

2. Astronomic North

"...the positive direction of a line tangent to the (gravity) equipotential surface at the observer." ... ???

NGS Geodetic Glossary

Instrument is oriented to the geoid, which is irregular.



G. Trivia: Astronomic

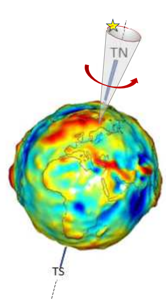
2. Astronomic North

A celestial body is observed to determine location of astronomic (aka, celestial) north.

Typically observe Sun or Polaris.

Polaris is not directly on the celestial polar axes.

Over 24 hours it travels a circular path around the north pole.



G. Trivia: Astronomic

2. Astronomic North

A star is observed at night.

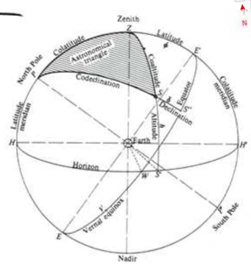
Horiz & vert angles measured.

Time of obs recorded.

Ephemeris used to determine star position at obs time.

Star and instrument positions are used to calculate where astronomic north is.

PZS triangle



Celestial Sphere

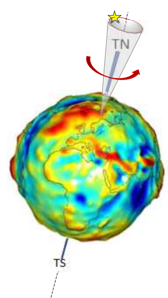
G. Trivia: Astronomic

2. Astronomic North

Astronomic meridians converge

but

Because geoid is irregular so are the meridians.



G. Trivia: Astronomic

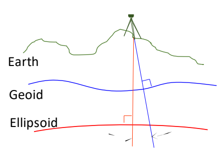
3. Deflection of the Vertical

The difference between

- direction of gravity
- ellipsoid normal

at instrument location.

Skewness of ellipsoid-geoid fit.



G. Trivia: Astronomic

4. LaPlace Correction

A component of the deflection of the vertical used to correct an astronomic direction to a geodetic one.

$$\alpha_A - \alpha_G = (\lambda_A - \lambda_G)\sin\varphi_G$$

- α_A - astronomic direction
- α_G - geodetic direction
- λ_A – astronomic longitude
- λ_G – geodetic longitude
- φ_G – geodetic latitude
- $(\lambda_A - \lambda_G)\sin\varphi_G$ – LaPLace correction

Astronomic values are referenced to geoid.

Geodetic values are referenced to ellipsoid.

G. Trivia: Astronomic

4. LaPlace Correction

Where do we get the LaPlace correction?

Survey Mark Data Sheet

```
RB1433 ***********************************************************************
RB1433  DESIGNATION -  IRRIGON
RB1433  PID         -  RB1433
RB1433  STATE/COUNTY-  OR/MORROW
RB1433  COUNTRY     -  US
RB1433  USGS QUAD   -  IRRIGON (2017)
RB1433
RB1433                       *CURRENT SURVEY CONTROL
RB1433  ______________________________________________________________________
RB1433* NAD 83(1991) POSITION- 45 53 19.65182(N) 119 29 34.66095(W)   ADJUSTED
RB1433* NAVD 88 ORTHO HEIGHT -   105.0   (meters)      344.    (feet) VERTCON3
RB1433  ______________________________________________________________________
RB1433  GEOID HEIGHT    -        -21.839 (meters)                     GEOID18
RB1433  LAPLACE CORR    -           0.90  (seconds)                   DEFLEC18
RB1433  HORZ ORDER      -   SECOND
```

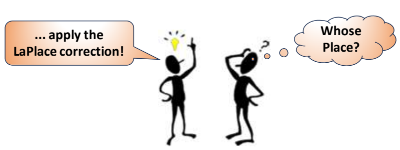
NGS software: DEFLCxx (xx latest year)

G. Trivia: Astronomic

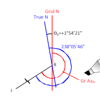
4. LaPlace Correction

Will you ever use the LaPlace correction?

Probably not, but it's interesting trivia you can use to impress your friends.



Contents



Any Questions?