Technician's Day

May 1, 2025

Organized by MSPS Young Surveyors

The Technician's Day Program has been created as an alternative program during MSPS events to offer support to technicians and paraprofessionals regardless of their stage in progressing towards licensure. The program can be meaningful if you have just started surveying, and it can be helpful if you are ready to become a PLS during the next year! The material will include helpful tips covering a wide range of topics from theoretical math (important for FS and PS exams), calculator use, surveying math, how to prepare for exams, real-life experiences from young surveyors who've just become enrolled as LSIs (or LSITs), as well as PLSs.

Missouri Society of Professional Surveyors
Est. 1957

Lodge of the Four Seasons
Lake Ozark, Missouri

RE-ESTABLISHING LOST CORNERS

IN THE MISSOURI PLSS

Francis Duncan PLS

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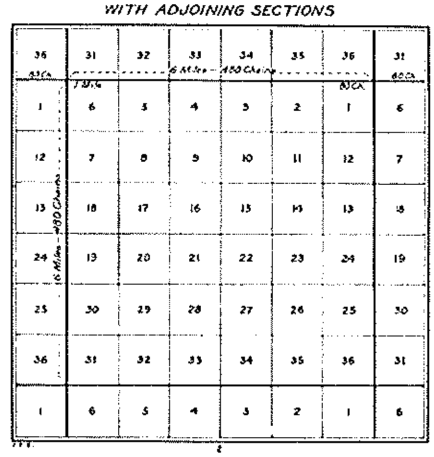
US PLSS Fundamentals

- **USPLSS**: US Public Land Survey System
  - Grid survey system used by US Federal Govt.
- Structure of the PLSS
  - Township: Largest area of land measurement
    - 6x6 mile area
  - Section: Each Township contains 36 sections
    - 1x1 mile area
    - Nearly every corner of every section has a physical monument set by the GLO or state surveyors

THEORETICAL
TOWNSHIP DIAGRAM
SHOWING
METHOD OF NUMBERING SECTIONS
WITH ADJOINING SECTIONS



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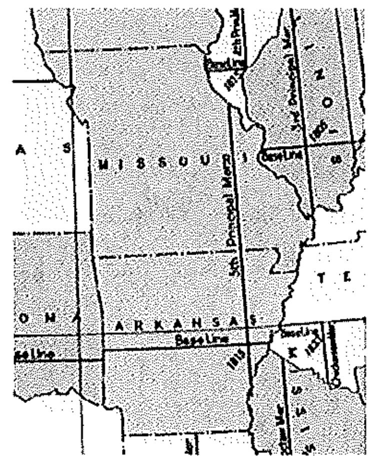
MO PLSS Fundamentals

- <u>**Missouri is Different**</u>
  - Followed Tiffin's 1815 Instructions
  - <u>5th Principal Meridian</u> originating from I.P. in Arkansas. Ran due North
  - **<u>Base line:</u>** Perpendicular to 5th Principal Meridian. Ran due West
  - Subdivide into 6x6 mile (townships with **<u>Twp</u>** and **<u>Range</u>** lines
  - Subdivide townships into 1x1 mile sections (80 chains)
  - Monuments set every half mile (40 chains) with **closing corners on north and west lines of Twp, called a "Double Corner"**
  - **No mention of regular locations of Guide Meridians or Standard Parallels (correction lines). Run irregularly and as needed and were called "Correction Lines" and "Auxiliary Meridians"**



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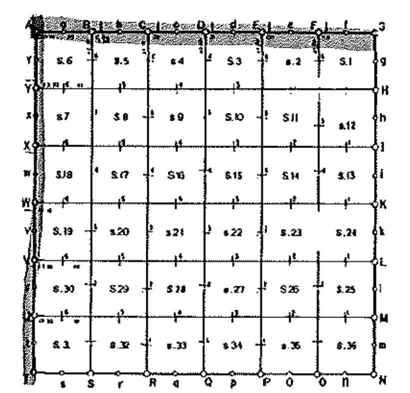
Why is My Corner "Doubled"?

- Tiffin's instructions result in what we call "Double Corners".
- When closed on Township or Range lines to N and W, the distance from the closest standard corner was recorded (called "lap"), and a **monument set** at the closing corner
- **Other states leave this corner un-monumented**
  - "Corner" and "monument" are not synonymous
  - **<u>Corner:</u>** a theoretical location and legal entity
  - **<u>Monument:</u>** a physical marker locating a corner



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Definition Review:

- **Standard Corner:** Corner on the exterior of the township
  - Set when the **exterior lines of the township were run; set every 40 ch**
- **Closing Corner:** Corner that closes on a township exterior
  - Monumented on the **previously surveyed township exterior** when the township was subdivided into sections
- **Quarter Corner:** Corner on the midpoint* between section corners
  - **not set at the midpoint on closing sections and thus called* ***"blank corners"***
- **Section Corner:** Corner on the interior of the township
  - Section corners **can be standard or closing** but not every section corner is

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Why Do I Care?

Missouri is special, even compared to other PLSS states

- The process of re-establishing lost corners governed by State Statues (Rsmo Ch. 60) **not the BLM manual***
  - **The BLM manual remains an important reference on subjects not specifically covered by the Missouri statutes*
- Missouri statutes hold **standard corners** and **closing corners** to be of the same weight
- Guide Meridians are treated as standard range lines in Missouri
  - Standard Parallels are taken into account You should understand the Missouri statutes as well as all other areas of your practice
  - It is **your duty** to follow these statutes as a Missouri practitioner

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So, what do the statutes say?

60.315. Lost corners reestablishment — rules. (paraphrased)

The following rules shall be applied only when it is determined that corner is lost:

(The rules utilize proportional measurement which harmonizes surveying practice with legal and equitable considerations. This plan of relocating a lost corner is always employed unless it can be shown that the corner so located is in substantial disagreement with the general scheme of the original government survey as monumented. In such cases the surveyor shall use procedures that produce results consistent with the original survey of that township.)

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Statutes continued

(1) Existent original corners shall not be disturbed. ...discrepancies between new and record measurements shall not in any manner affect the measurements beyond the existent corners; the differences shall be distributed proportionately within the several intervals along the line between the corners;

(2) Standard parallels shall be given precedence over other township exteriors, and, ordinarily, the latter shall be given precedence over subdivisional lines; section corners shall be located or reestablished before the position of lost quarter-section corners can be determined;

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Statutes continued

(3) Lost township corners common to four townships shall be reestablished by double proportionate measurement between the nearest existent corners on opposite sides of the lost township corner;

(4) Lost township corners located on standard parallels and common only to two townships shall be reestablished by single proportionate measurement between the nearest existent corners on opposite sides of the lost township corner on the standard parallel;

9

Statutes continued

(5) Lost corners on township exteriors, excluding corners referenced in subdivision (3) of this section, whether they are standard or closing corners, shall be reestablished by single proportionate measurement on the line connecting the next nearest existent standard or closing corner on opposite sides of the lost corner;

(6) A lost interior corner of four sections shall be reestablished by double proportionate measurement;

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Statutes continued

(7) All lost quarter-section corners on the section boundaries within the township shall be reestablished by single proportionate measurement between the adjoining section corners, after the section corners have been identified or reestablished; and

(8) Where a line has been terminated with a measurement in one direction only, a lost corner shall be reestablished by record bearing and distance, counting from the nearest regular corner, the latter having been duly identified or reestablished.

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Say that again, but, shorter

- There are 5 primary types of corners
- Adjacent corners can be **standard** or **closing**
- Single or Double proportion
- There is a 6th corner we will discuss later

Types of Corners	
Corner to four (4) townships	Double Proportion according to GLO Plat, to nearest adjacent corners on all 4 directions
Corner to two (2) townships **(Standard Parallels)**	Single Proportion according to Plat, to next nearest adjacent corners on standard line to each side of lost corner.
Corner on township exterior (Standard, Quarter or closing)	Single Proportion according to dimensions on Plat, between next nearest adjacent corners.
Section corners on the interior of a township	Double Proportion according to Plat dimensions, between next nearest adjacent section corners.
Quarter section corners	Single proportion between the adjoining section corners after the section corners have been identified or reestablished.

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Before We Continue

- Resurveying on the MO PLSS is a deep subject. We will scratch the surface
- There are always exceptions. Our scope today is for standard scenarios
- I will not cover how to determine that a corner is lost, only the process used to re-establish a lost corner
- Proportioning should be your last resort, but it is vital to perform correctly
- Further reading on the subject is covered in your hand out.
- Special thanks to **Dr. Elgin** who wrote "The U.S. Public Land Survey System for Missouri" (Third Edition)
  - My primary source for this topic in addition to Dr Elgin's book is the Department of Agriculture (Missouri) website

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Proportioning:

- What is proportioning?
- "A statement of equality between two ratios…"

Example:

$$\frac{1}{2} = \frac{x}{5000}$$

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Proportioning:

- What is proportioning?
- "...in which the first of the four terms divided by the second equals the third divided by the fourth"

Example:

$$\frac{1}{2} = \frac{x}{5000} \quad 5000=2x$$

$5000/2 = 2500 = x$

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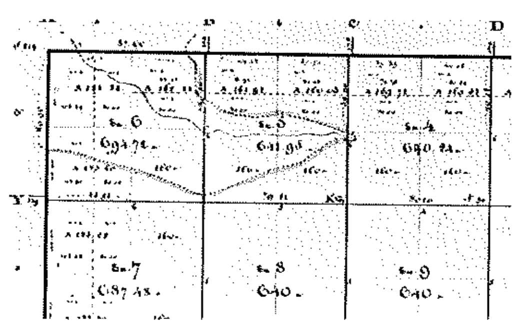
Proportioning:

How we apply this to surveying:

- We take the relationship from our **known record distances** and apply that to our **unknown position between our measured distances.**
- **Record:** Found in your **GLO Plat (Chains)**
- **Measured:** The result of the work you do in the field to recover existing monuments. (Coordinates usually)



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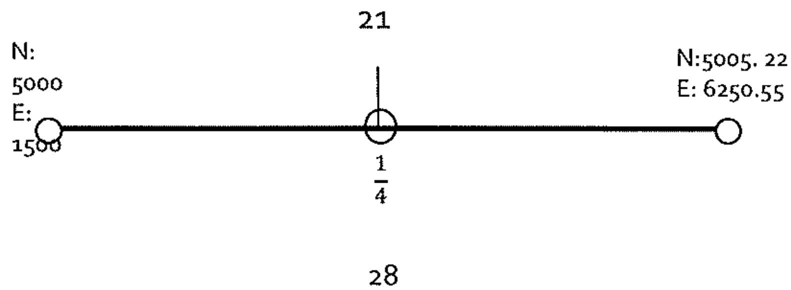
Lost Quarter Corner Interior of Township



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Lost Quarter Corner Interior of Township

Corner to four (4) townships	Double Proportion according to GLO Plat, to nearest adjacent corners on all 4 directions
Corner to two (2) townships **(Standard Parallels)**	Single Proportion according to Plat, to next nearest adjacent corners on standard line to each side of lost corner.
Corner on township exterior (Standard, Quarter or closing)	Single Proportion according to dimensions on Plat, between next nearest adjacent corners.
Section corners on the interior of a township	Double Proportion according to Plat dimensions, between next nearest adjacent section corners.
Quarter section corners	Single proportion between the adjoining section corners after the section corners have been identified or reestablished.

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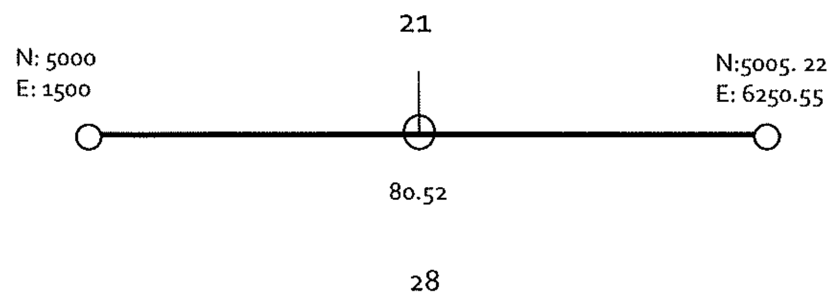
Lost Quarter Corner Interior of Township

Quarter section corners	Single proportion between the adjoining section corners after the section corners have been identified or reestablished.



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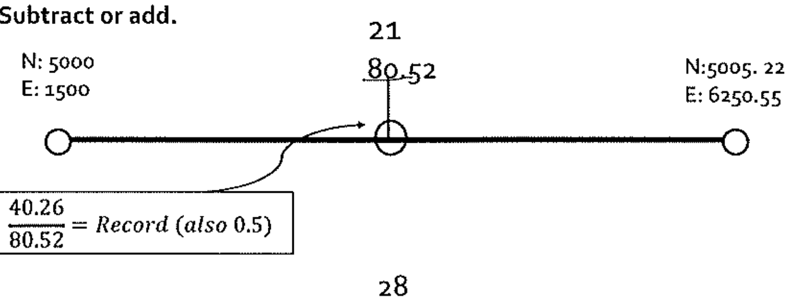
Lost Quarter Corner Interior of Township

Solution:
Step 1: Set up your known (Record) relationship
Step 2: Find your Measured relationships (Delta of your Northings and eastings)
Step 3: Apply proportion to each delta
Step 4: Subtract or add.

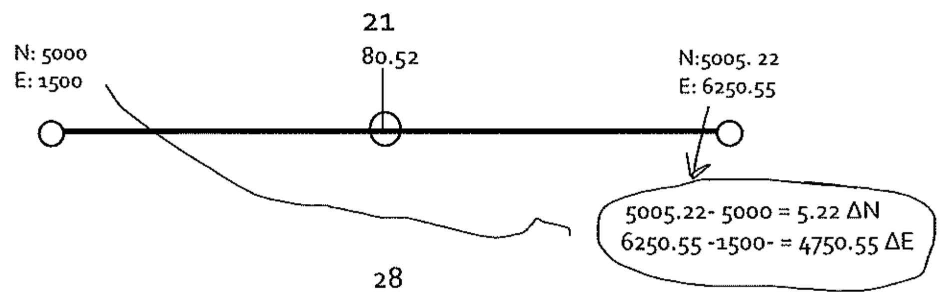


$$\frac{40.26}{80.52} = Record\ (also\ 0.5)$$

20

Lost Quarter Corner Interior of Township

Solution:
Step 1: Set up your known (Record) relationship
Step 2: Find your Measured relationships (Delta of your Northings and eastings)
Step 3: Apply proportion to each delta
Step 4: Subtract or add.



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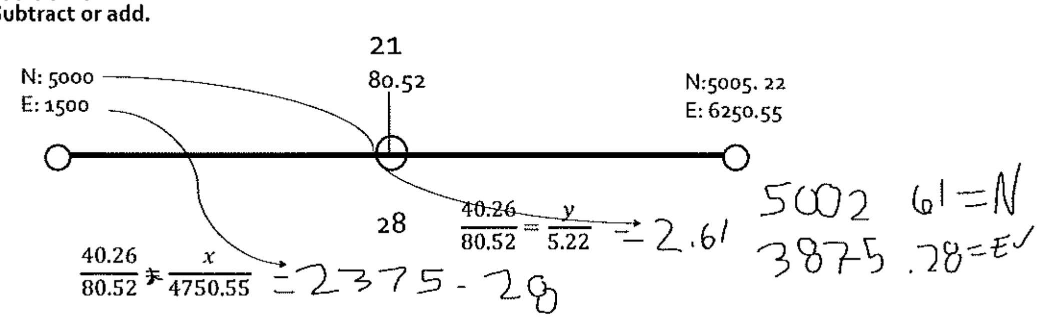
Lost Quarter Corner Interior of Township

Quarter section corners	Single proportion between the adjoining section corners after the section corners have been identified or reestablished.

Solution:
Step 1: Set up your known (Record) relationship
Step 2: Find your Measured relationships (Delta of your Northings and eastings)
Step 3: Apply proportion to each delta
Step 4: Subtract or add.



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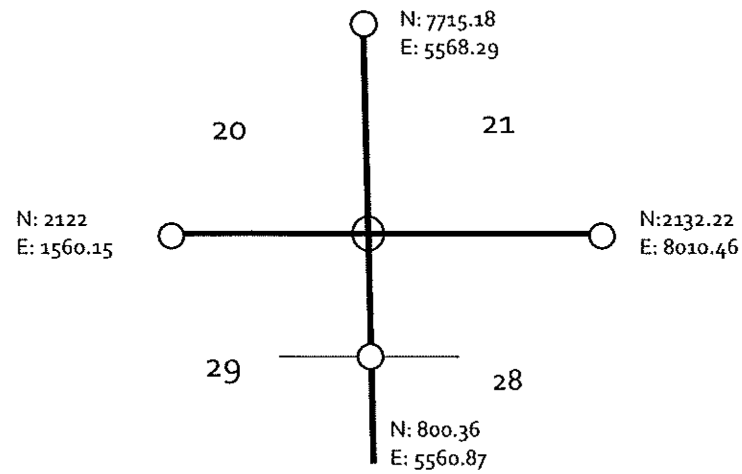
Lost Section Corner Interior of Township



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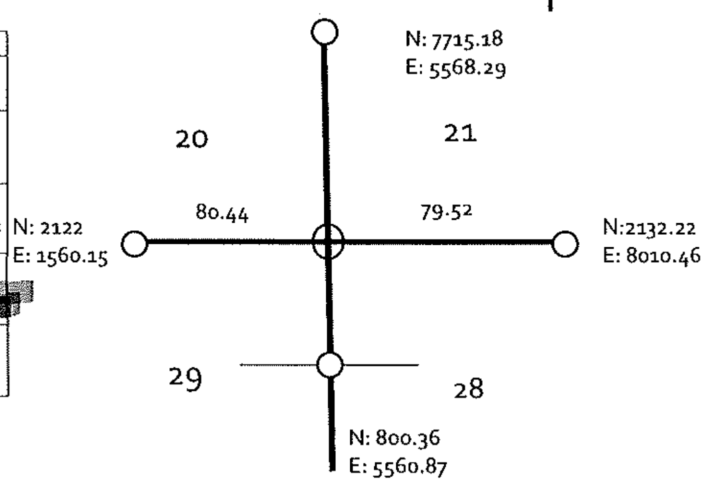
Lost Section Corner Interior of Township

Types of Corners	
Corner to four (4) townships	Double Proportion according to GLO Plat, to the nearest adjacent corners on each side.
Corner to two (2) townships (Standard Parallels)	Single Proportion according to GLO Plat, to the next nearest adjacent corners on the standard line to each side of the lost corner.
Corner on township exterior (Standard, Quarter or closing)	Single Proportion according to the dimensions on the GLO plat, between the next nearest adjacent corners.
Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, [redacted] section corners.
Quarter section corners	Single proportion between the adjoining section corners after the section corners have been identified or reestablished.



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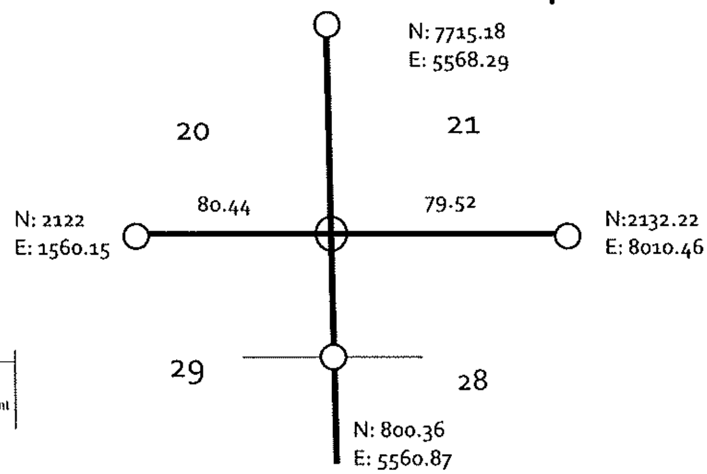
Lost Section Corner Interior of Township

Solution:
Step 1: Set up your known (Record) relationships
Step 2: Find your Measured relationships (Delta of your Northings and eastings)
Step 3: Apply proportion to each delta
Step 4: Subtract or add to get final coordinates.

	corners.
Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners.



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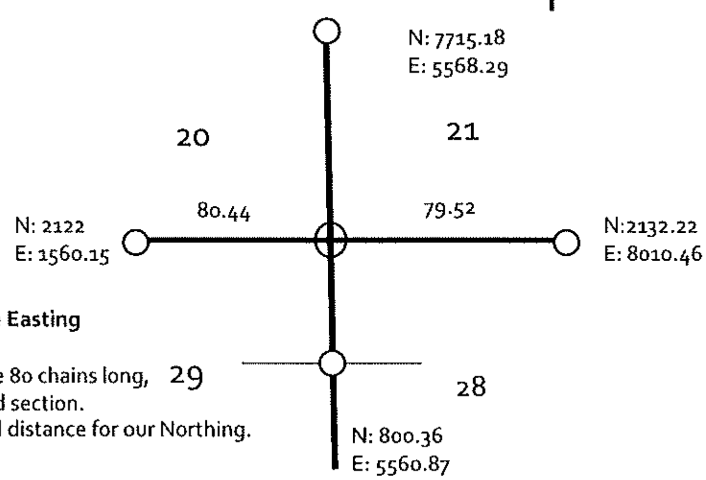
Lost Section Corner Interior of Township

Solution:
Step 1: Set up your known (Record) relationships

	corners.
Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners.



80.44 +79.52=159.96
This will serve as the record distance for the **Easting**

North/South lines are always assumed to be 80 chains long,
And will not be labeled as such in a standard section.
So 40+80 = 120 will serve as the total record distance for our Northing.

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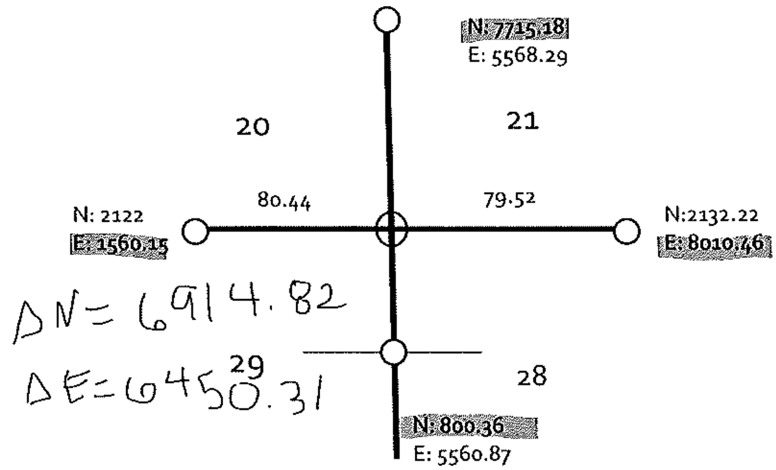
Lost Section Corner Interior of Township

Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners

Step 2: Find your Measured relationships (Delta of your Northings and eastings)

Note: You only need to find the delta easting for your east/west coordinates, and your delta northing for your north/south coordinates.



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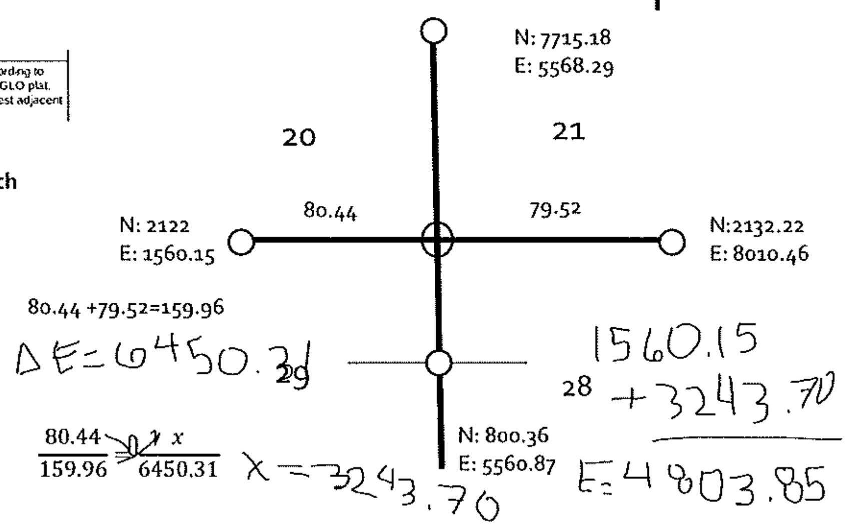
Lost Section Corner Interior of Township

Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners.

Step 3: Apply proportion to each delta
Step 4: Subtract or add to get final coordinates.

NOTE: MIND YOUR SIGNS! Think carefully about your set up.

We'll solve the easting first:



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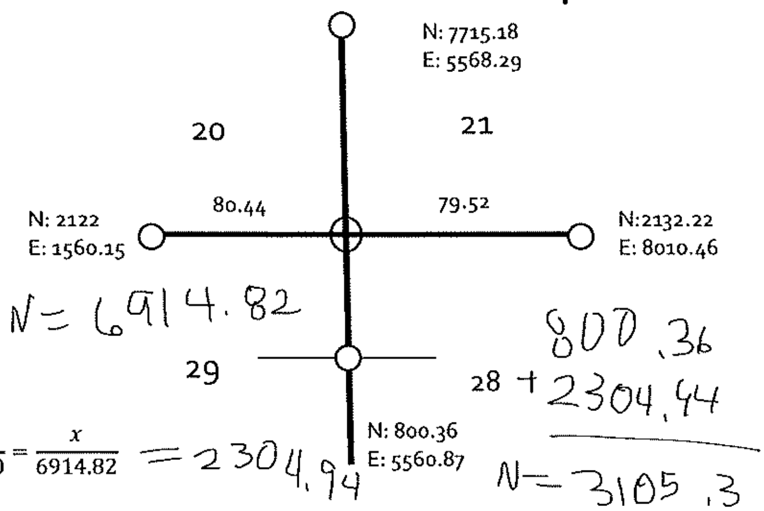
Lost Section Corner Interior of Township

Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners.

Step 3: Apply proportion to each delta
Step 4: Subtract or add to get final coordinates.

NOTE: MIND YOUR SIGNS! Think carefully about your set up.

Repeat with your northing:



$$\frac{40}{120} = \frac{x}{6914.82} = 2304.94$$

29

Lost Section Corner Interior of Township

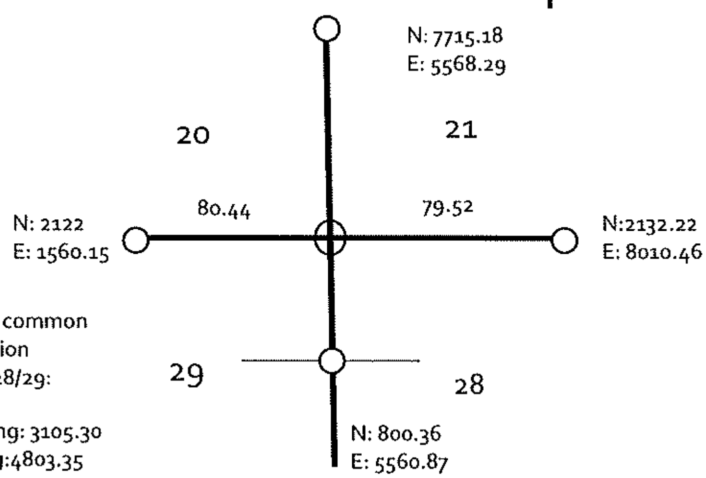
Section corners on the interior of a township	Double Proportion according to the dimensions on the GLO plat, between the next nearest adjacent section corners.

Step 3: Apply proportion to each delta
Step 4: Subtract or add to get final coordinates.

NOTE: MIND YOUR SIGNS! Think carefully about your set up.

Corner common to Section 20/21/28/29:

Northing: 3105.30
Easting: 4803.35



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Corners on the Township/Range Lines

- MO statutes: **standard and closing corners have the same weight**
  - NOT permissible to ignore closing corner simply for being a closing corner
- That said, remember that **standard corners** were set by the first GLO surveyors, and **closing corners set at a later time** by GLO filling in twps
- It is up to your professional judgment to decide whether or not to accept a closing corner
  - You should have sufficient evidence to back your decision
  - If accepting a closing corner will significantly alter the original position of the lost corner you are re-establishing when compared against other existing evidence, it is a good idea to keep looking
- For this presentation, the following problems will have "accepted" closing corners

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Lost Corners On Township Exterior Closing Corner Accepted

Types of Corners	
Corner to four (4) townships	**Double Proportion** according to GLO Plat, to the nearest adjacent corners on each side.
Corner to two (2) townships (Standard Parallels)	**Single Proportion** according to GLO Plat, to the next nearest [illegible] on the standard [illegible] on each side of the lost corner.
Corner on township exterior (Standard, Quarter or closing)	**Single Proportion** according to the dimensions on the GLO plat, between the next nearest adjacent corners.
Section corners on the interior of a township	**Double Proportion** according to the dimensions on the GLO plat, between the next nearest adjacent section corners
Quarter section corners	**Single proportion** between the adjoining section corners after the section corners have been identified or reestablished.

These will all be solved the same way, by single proportion as demonstrated in our first example.
Step 1: Set up your known (Record) relationship
Step 2: Find your Measured relationships (Delta of your Northings and eastings)
Step 3: Apply proportion to each delta
Step 4: Subtract or add.

Where it gets tricky is understanding what the record relationship is when you have multiple records in play.

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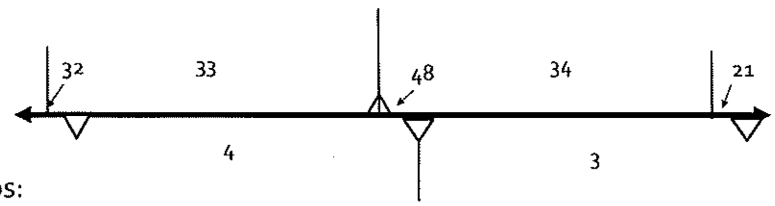
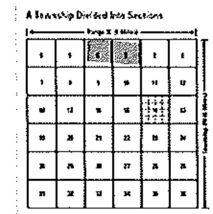
Lost Corners On Township Exterior
Closing Corner Accepted





Steps:

1.) we know that that standard corners were set 80 chains apart.

2.) we know that the "laps" of the closing corners were also recorded on the plat.

3.) We have all we need here to figure out everything we need to know about the record.

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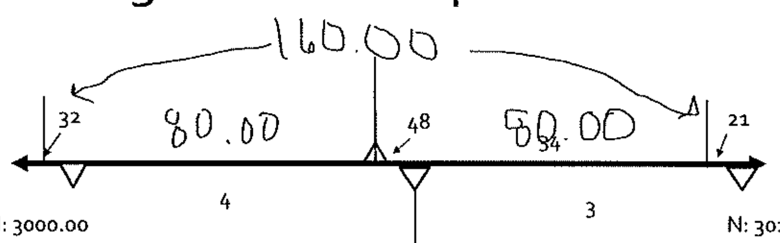
Lost Corners On Township Exterior
Closing Corner Accepted



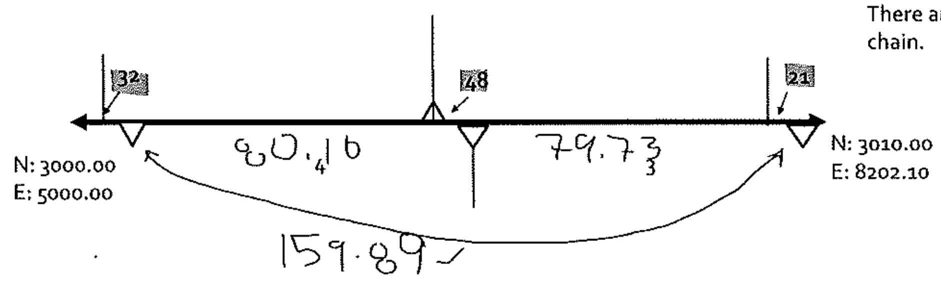
N: 3000.00
E: 5000.00

N: 3010.00
E: 8202.10

34

Lost Corners On Township Exterior Closing Corner Accepted

Note: laps are expressed as "links" There are 100 links to a chain.



80.00-.48-.21 = 79.73
80.00-.32-.48 = 80.16

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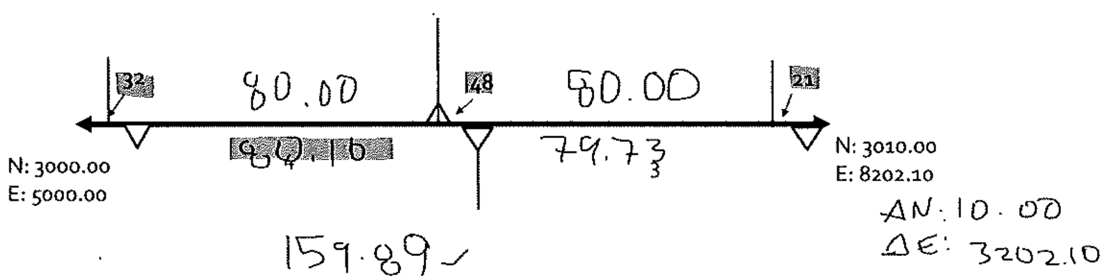
Lost Corners On Township Exterior Closing Corner Accepted

80.16 - .48 = 79.68



The Standard corner to section 33 and 34: $\frac{79.68}{159.89}$

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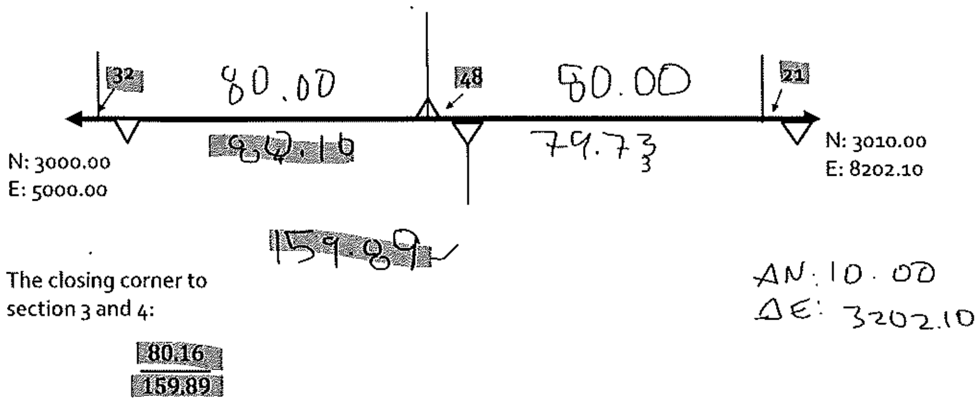
Lost Corners On Township Exterior Closing Corner Accepted



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The Blank Quarter Corner

- **60.345 Corners of ¼ *sections south of township line, east of range line,* how established.**
- ¼ section corners of sections south of twp line and east of range line, and not established by GLO survey will be established according to conditions represented upon the official government plat using single proportionate measurement between the section corners belonging to the same section as the ¼ section corner being established, the section corners having first been identified or reestablished.
- The proportional position shall be offset, if necessary, in a cardinal direction to the true line defined by the nearest adjacent corners on opposite sides of the ¼ section corner to be established.

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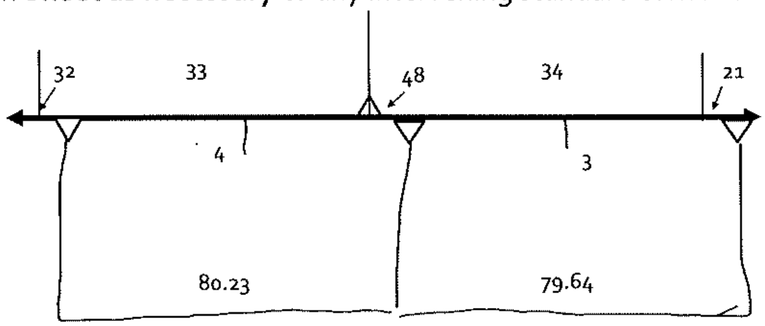
The Blank Quarter Corner

- Put simply: You will single proportion between the two adjacent section corners belonging to the same section as the blank quarter corner
- Then **offset as necessary** to any intervening standard corners.



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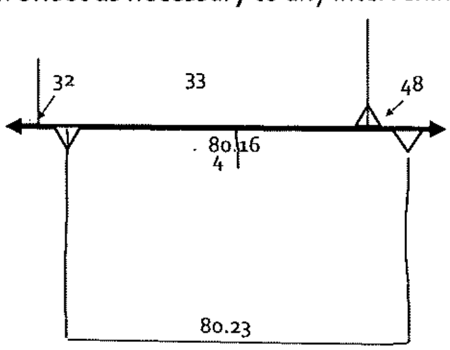
The Blank Quarter Corner

- Put simply: You will single proportion between the two adjacent section corners belonging to the same section as the blank quarter corner
- Then **offset as necessary** to any intervening standard corners.



Steps:
1.) Determine if an offset is needed: (yes, there is an intervening corner)
2.) Single proportion your easting between your closing corners. And then single proportion your northing between your closing corner, and standard corner.

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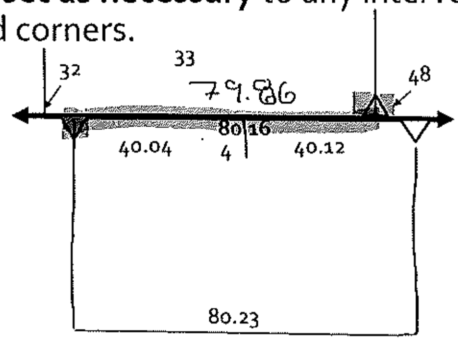
The Blank Quarter Corner

- Put simply: You will single proportion between the two adjacent section corners belonging to the same section as the blank quarter corner
- Then **offset as necessary** to any intervening standard corners.



Note: Remember protraction rules, that the excess is pushed towards the North and West.

Singe proportion:
40.04/80.16 for the Easting
And 40.04/79.86 for your northing, since the township line is defined by the closing and standard corner.

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Center of section (or center ¼)

- Given that you have the coordinates of the ¼ corners on the four sides of the section
- If not given, you may have to single (or even double proportion) from other corners beginning with the regular corners of the section

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WARNING

- To solve for the coordinates of the center of the section, DO NOT DOUBLE PROPORTION!
- Understand the problem…

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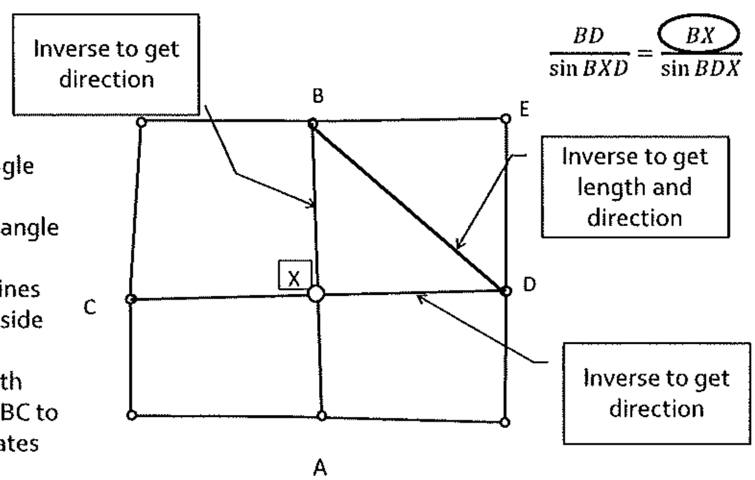
Law of sines: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin B}$

$$\frac{BD}{\sin BXD} = \frac{BX}{\sin BDX}$$

1. Calculate angle BDX
2. 2. Calculate angle BXD
3. Use law of sines to calculate side BX
4. Apply BX with direction of BC to get coordinates of X



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THEORETICAL
TOWNSHIP DIAGRAM
SHOWING
METHOD OF NUMBERING SECTIONS
WITH ADJOINING SECTIONS

36	31	32	33	34	35	36	31
1	6	5	4	3	2	1	6
12	7	8	9	10	11	12	7
13	18	17	16	15	14	13	18
24	19	20	21	22	23	24	19
25	30	29	28	27	26	25	30
36	31	32	33	34	35	36	31
1	6	5	4	3	2	1	6

80 Ch.

6 Miles — 480 Chains

80 Ch.

1 Mile

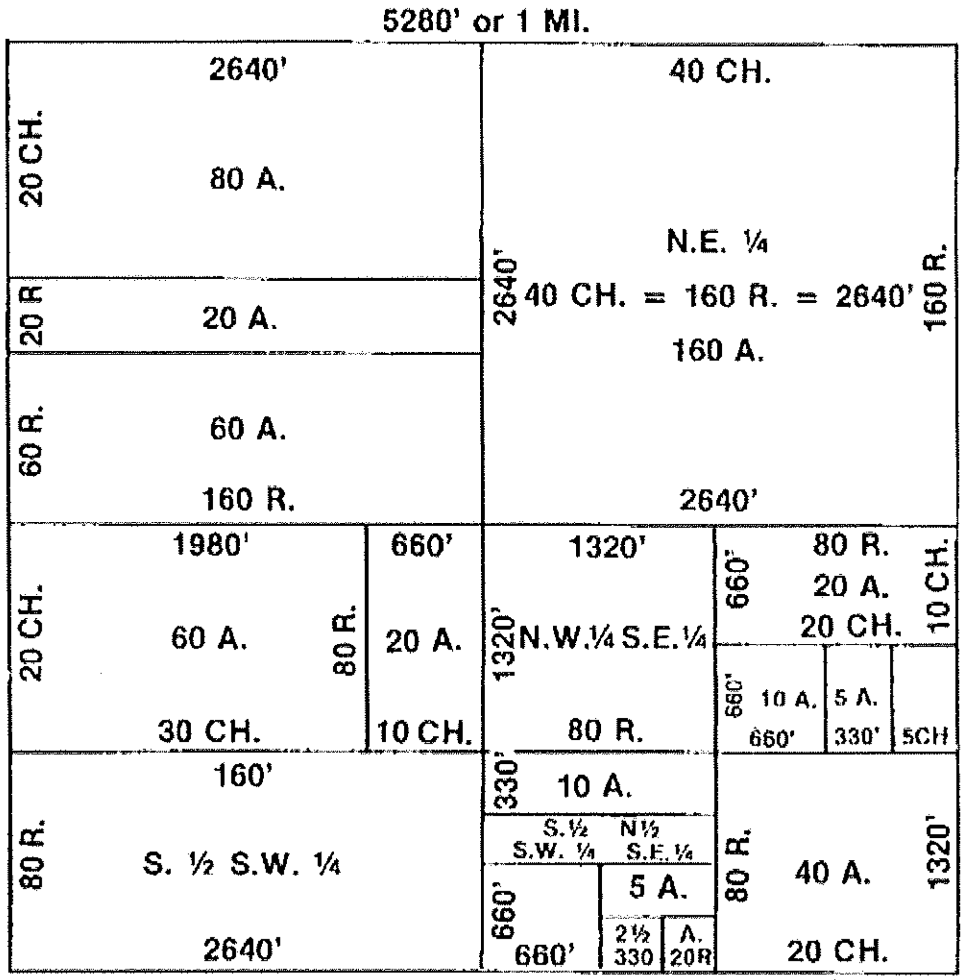
80 Ch.

6 Miles — 480 Chains

I.V.S.

Land Measure

SECTION OF LAND 640 ACRES



1 LINK..................7.92 INCHES

100 LINKS...............1 CHAIN OR 66 FT.

25 LINKS................1 ROD OR 16.5 FT.

1 ROD, PERCH, OR POLE.........16.5 FT.

10 SQ. CHAINS..........1 ACRE

1 MILE..................320 RDS. OR 5280 FT.

1 MILE..................80 CHAINS OR 1760 YDS.

43,560 SQ. FT............1 ACRE

8 RDS. WIDE X 20 RDS. LONG........1 ACRE

640 ACRES..............1 SECTION

4 RDS...................1 CHAIN

160 SQ. RDS.............1 ACRE

1 SQ. MILE..............1 SECTION

36 SQ. MILE.............1 TOWNSHIP

Do you know what you are talking about?

Preparation for the FS (but maybe for the other two also)

- Precision in language means knowing grammar, spelling and punctuation. Yes, you are graded on this in the exams, especially on the description you will have to write.

- But knowing precisely what a term used in surveying is..., and knowing what it isn't is something a professional surveyor should ALWAYS know, not just during the exam.

Good texts for reference (very incomplete):

1. NSPS *Definitions of Surveying and Related Terms*
2. *Black's Law Dictionary* (abridged or unabridged)
3. A standard surveying text like *Elementary Surveying by Ghilani.* The surveying book by McCormac may be too elementary.
4. Either *Brown's Boundary Control and Legal Principles* or *Evidence and Procedures for Boundary Location*

Abut

Adjoin

Adjacent

Alidade

Contiguous

Declination

Vertical

Horizontal (line, plane, etc.)

Level (surface, line, etc.)

Zenith

Nadir

Backsight

Foresight

Latitude

Departure

Error of Closure

Precision

Accuracy

Error

Error Sources

Error Types

Mistake

Blunder

Collimation

Spherical trigonometry

Geoid

Model

Atmospheric refraction

Earth curvature

GLO

Double corner

Blank quarter corner

COGO

Tension

Datum

Longitude, λ (lambda)

Latitude, ϕ (phi)

BLM

Conveyance

Grant

Deed

Office of Land Records (county)

Sextant

Greenwich

Easement

Lien

Two-peg adjustment

Gun

Shot

Shoot

Legs

Rod

Pole

Books Every Land Surveyor Should Have in Their Library

suggestions from: Francis Duncan

Humbly, as the title says, I think that a good library is the foundation of a good surveyor. Since our profession is largely based on cumulative experience, solid mathematical principles, case law, and statutes; there is simply no point at which you can have "too many" references.

Many of these are also out of print, but I've had luck with used bookstores/eBay or finding PDFs of books that have entered the public domain. This is a work in progress list, but I think it's a good starting point.

Missouri Specific:

-The U.S. Public Land Survey System for Missouri: A Manual on the GLO System, Resurveys, Example Problems and GLO Plats: Dr. Richard L. Elgin

-Trees of Missouri: Donald R. Kurz

-Riparian Boundaries for Missouri: A Guide to Surveying Inland Non-Tidal Riparian and Littoral Boundaries: Dr. Richard L. Elgin (Check with MSPS for availability)

-A Collection of Original Instructions to Surveyors of the Public lands (there is a version by

Roy Minnick, but you can find PDFs everywhere. I think it's important to at least glance over Tiffin's actual instructions)

-Most current copy of the Missouri State Statues/regulations pertaining to Land Surveying in Missouri

Boundary Matters:

-The Legal Elements of Boundaries and Adjacent Properties: Ray H. Skelton

-Brown's Boundary and Legal Principles: Walter G. Robillard, Donald A. Wilson

-Evidence and Procedures for Boundary Location: Brown and Eldridge

-Water Boundaries : George M. Cole

-Easements Relating to Land Surveying and Title Examination: Donald A. Wilson

-2009 Manual of Surveying Instructions for the Survey of Public Lands: BLM

-Restoration of Lost or Obliterated Corners Guide for Surveyors 1974 Booklet: BLM

-Writing Legal Descriptions: Gurdon H. Wattles

-Boundaries and Landmarks: A C Mulford

-Interpreting Land Records: Donald A. Wilson

Theory of Practice and Ethics:

-The Pincushion Effect: Jeffery Lucas

-Ethics For the Professional Surveyor: Dennis Mouland PLS

Technical:

-GPS and GNSS for Land Surveyors.: Jan Van Sickle

-GNSS- Global Navigation Satellite Systems: GPS GLONASS, Galileo, and More: Hofmann

-Elemental Surveying An introduction to Geomatics: Charles Ghilani, Paul Wolf (Co-Authors vary depending on recent editions)

-Errors in Practical Measurements in Science, Engineering and Technology: Bary B. Austin

-Construction Surveying and Layout: A Step-by-Step Field Engineering Methods Manual: Wesley G. Crawford

-Survey Drafting: Gurdon H. Wattles

-Surveying Measurements and Their Analysis: R.B Buckner

References:

-Definitions of Surveying and Associated Terms: NSPS

-Black's Law Dictionary: Bryan A. Garner

-1956 US DEPT INTERIOR Standard Field Tables & Trigonometric Formulas

Exam Study:

-1001 Solved Surveying Fundamentals Problems: Jan Van Sickle

-Land Survey Reference Manual: Andre Harbin

Sixth post April 2025
Version 2.5

Contents

Gravity acceleration (g) = 9.807 m/s^2 = 32.174 ft/sec^2

Speed of light in a vacuum (c) = 299,792,458 m/s = 186,282 miles/sec

°C = (°F – 32)/1.8

1 min of latitude (ϕ) ≅ 1 nautical mile

1 nautical mile = 6,076 ft

Mean radius of the earth ≅ 20,906,000 ft ≅ 6,372,000 m

Metric Prefixes		
Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	**micro**	**μ**
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d

Metric Prefixes		
Multiple	Prefix	Symbol
10^{1}	deka	da
10^{2}	**hecto**	**h**
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	**peta**	**P**
10^{18}	exa	E

Land Description Diagram

The diagram that follows is from the U.S. Department of the Interior, Bureau of Land Management.

3 MATHEMATICAL AND SURVEYING-RELATED FORMULAS

Straight Line

The general form of the equation is

$$Ax + By + C = 0$$

The standard form of the equation is

$$y = mx + b,$$

which is also known as the *slope-intercept* form.

The *point-slope* form is

$$y - y_1 = m(x - x_1)$$

Given two points: slope,

$$m = (y_2 - y_1)/(x_2 - x_1)$$

The angle between lines with slopes m_1 and m_2 is

$$\alpha = \arctan\left[(m_2 - m_1)/(1 + m_2 \cdot m_1)\right]$$

Two lines are perpendicular if $m_1 = -1/m_2$

The distance between two points is

$$d = \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}$$

Quadratic Equation

$$ax^2 + bx + c = 0$$

$$x = \text{Roots} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

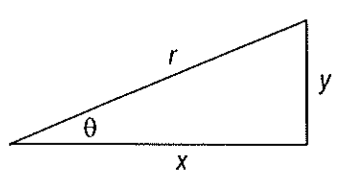
Trigonometry

Trigonometric functions are defined using a right triangle.

$\sin\theta = y/r$, $\cos\theta = x/r$

$\tan\theta = y/x$, $\cot\theta = x/y$

$\csc\theta = r/y$, $\sec\theta = r/x$



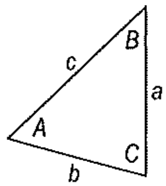
Law of Sines $\dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}$

Law of Cosines

$a^2 = b^2 + c^2 - 2bc \cos A$

$b^2 = a^2 + c^2 - 2ac \cos B$

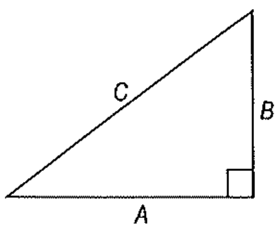
$c^2 = a^2 + b^2 - 2ab \cos C$



Brink, R.W., *A First Year of College Mathematics*, D. Appleton-Century Co., Inc., Englewood Cliffs, NJ, 1937.

Right Triangles

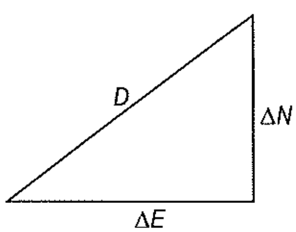
Pythagorean Theorem



$A^2 + B^2 = C^2$

$C = \sqrt{A^2 + B^2}$

Inverse Distance



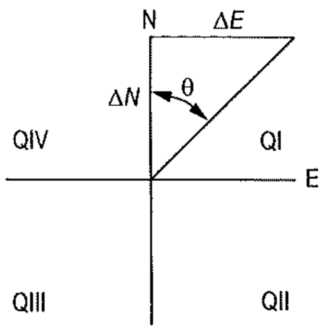
D = distance

ΔN = change in northing (latitude)

ΔE = change in easting (departure)

$D = \sqrt{\Delta N^2 + \Delta E^2}$

Inverse Direction



QI–QIV are quadrant numbers

$$\theta = \arctan\frac{\Delta E}{\Delta N} + C$$

where

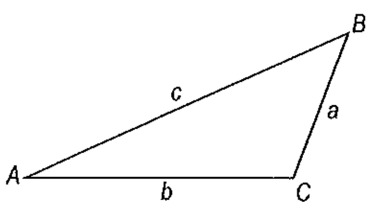
C = 0° in QI

C = 180° in QII

C = 180° in QIII

C = 360°in QIV

Oblique Triangles



Law of sines

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Law of cosines

$$a^2 = b^2 + c^2 - 2bc\cos A$$

or

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

Area of a Triangle

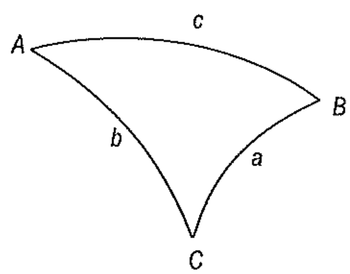
$$\text{Area} = \frac{ab\sin C}{2}$$

$$\text{Area} = \frac{a^2 \sin B \sin C}{2\sin A}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

where $s = (a + b + c)/2$

Spherical Triangles



Law of sines

$$\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B} = \frac{\sin c}{\sin C}$$

Law of cosines

$\cos a = \cos b \cos c + \sin b \sin c \cos A$

Area of sphere = $4\pi R^2$

Volume of sphere = $\frac{4}{3}\pi R^3$

Spherical excess in sec $= \dfrac{bc\sin A}{9.7 \times 10^{-6} R^2}$

where R = mean radius of the earth

Horizontal Circular Curves

D = degree of curve, arc definition

D_c = degree of curve, chord definition

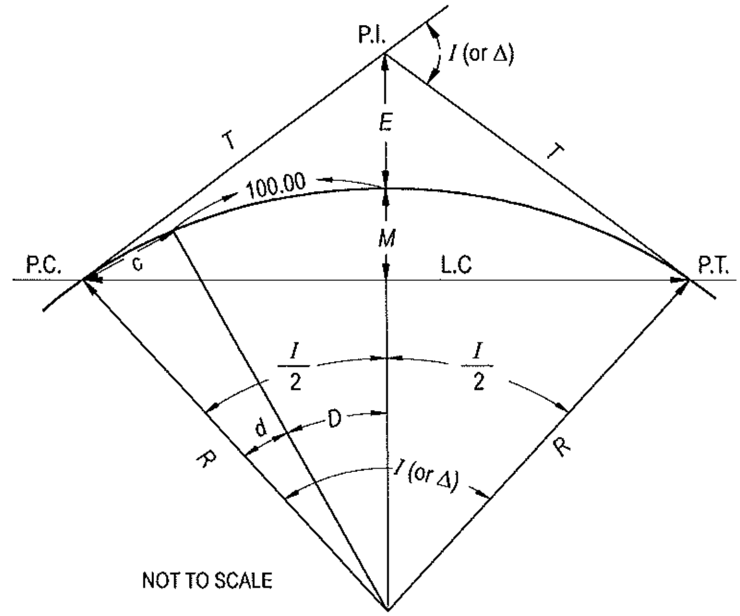
L = length of curve from P.C. to P.T.

c = length of sub-chord

ℓ = length of arc for sub-chord

d = central angle for sub-chord

I or Δ = angle of interior or delta



$D = \frac{5{,}729.58}{R}$

Radius by chord definition, $R = \frac{50}{\sin\left(\frac{D}{2}\right)}$

$T = R \tan\left(\frac{I}{2}\right)$

$L = RI\frac{\pi}{180} = \frac{I}{D}(100)$

$LC = 2R\sin\left(\frac{I}{2}\right)$

$c = 2R\sin\left(\frac{d}{2}\right)$

$d = \ell D/100$

$M = R\left[1 - \cos\left(\frac{I}{2}\right)\right]$

$E = R\left[\frac{1}{\cos\left(\frac{I}{2}\right)} - 1\right]$

Area of sector $= \frac{RL}{2} = \frac{\pi R^2 I}{360}$

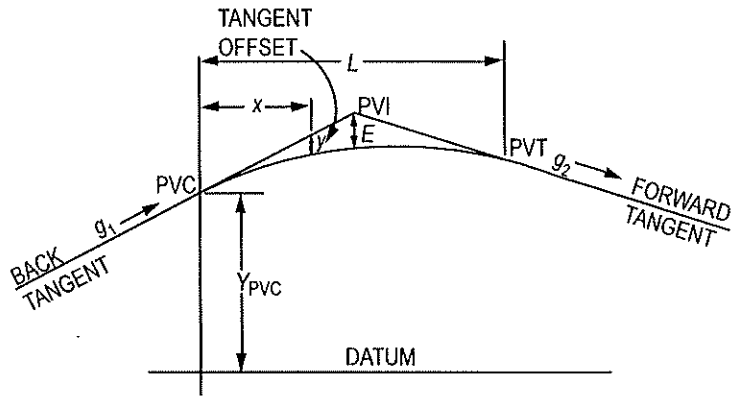
Area of segment $= \frac{\pi R^2 I}{360} - \frac{R^2 \sin I}{2}$

Area between curve and tangents $= R(T - L/2)$

$R = \frac{AC}{2\sin(a+b)}$

Equation of a circle, $X^2 + Y^2 = R^2$

Vertical Curve Formulas



VERTICAL CURVE FORMULAS
NOT TO SCALE

L = length of curve (horizontal)

PVC = point of vertical curvature

PVI = point of vertical intersection

PVT = point of vertical tangency

g_1 = grade of back tangent

g_2 = grade of forward tangent

x = horizontal distance from PVC (or point of tangency) to point on curve

a = parabola constant

y = tangent offset

E = tangent offset at PVI

r = rate of change of grade

Tangent elevation $= Y_{PVC} + g_1 x$

and $= Y_{PVI} + g_2 (x - L/2)$

Curve elevation $= Y_{PVC} + g_1 x + ax^2$

$= Y_{PVC} + g_1 x + [(g_2 - g_1)/(2L)]\, x^2$

$y = ax^2$; $\quad a = \dfrac{g_2 - g_1}{2L}$ = parabola constant

$E = a\left(\dfrac{L}{2}\right)^2$; $\quad r = \dfrac{g_2 - g_1}{L}$ = rate of change of grade

Horizontal distance to min/max elevation on curve, $x_m = -\dfrac{g_1}{2a} = \dfrac{g_1 L}{g_1 - g_2}$

Photogrammetry

Vertical images:

$$\text{Scale} = \frac{\text{distance } ab}{\text{distance } AB} = \frac{f}{H - h}$$

$$\text{Relief displacement} = \frac{rh}{H}$$

H = C-factor × contour interval

Parallax equations:

$$p = x - x'$$

$$X = \frac{xB}{p}$$

$$Y = \frac{yB}{p}$$

$$h = H - \frac{fB}{p}$$

$$h_2 = h_1 + \frac{(p_2 - p_1)}{p_2}(H - h_1)$$

where:

f = focal length

h = height above datum

H = flying height above datum

r = radial distance from principal point

p = parallax measured on stereo pair

B = air base of stereo pair

x, y = coordinates measured on left photo of stereo pair

x' = coordinate measured on right photo of stereo pair

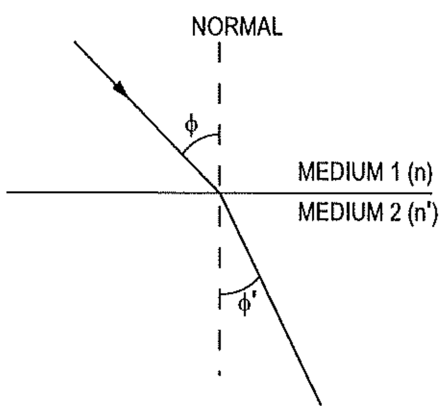
X, Y = ground coordinates

C-factor = empirical value based on precision of photogrammetric instrumentation

Physics

Lens equation:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$



where:

o = object distance

I = image distance

f = focal length

Snell's laws:

$n \sin \phi = n' \sin \phi'$

where:

n = refractive index

ϕ = angle of incidence

$s = \frac{1}{2} at^2$

where:

s = distance traveled starting from zero velocity

a = constant acceleration

t = time of travel

Curvature and Refraction

Curvature (c) and atmospheric refraction (r) corrections for vertical angles:

$c \approx 4.905$ sec/1,000 ft $c \approx 16.192$ sec/1 km

$(c \,\&\, r) \approx 4.244$ sec/1,000 ft $(c \,\&\, r) \approx 13.925$ sec/1 km

and for level rod readings:

$c \approx 0.0240\, D^2$ ft $c \approx 0.0785\, K^2\, m$

$(c \,\&\, r) \approx 0.0206\, D^2$ ft $(c \,\&\, r) \approx 0.0675\, K^2\, m$

where:

D = thousands of ft

K = kilometers

$c \approx 0.667\, M^2$

$(c \,\&\, r) \approx 0.574\, M^2$

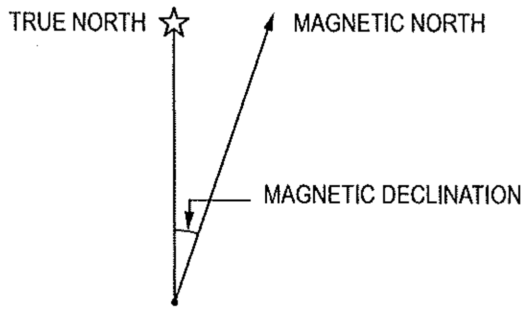
where:

M = distance in miles

Allowable angular error for an individual angle:

$$\tan \sphericalangle = \frac{1}{10{,}000}$$

Magnetic Declination



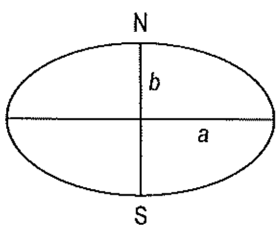
Geodesy

Ellipsoid

a = semimajor axis

b = semiminor axis

ϕ = latitude



Flattening, $f = \dfrac{a-b}{a}$ (usually published as $1/f$)

Eccentricity, $e^2 = \dfrac{a^2 - b^2}{a^2}$

Radius in meridian, $M = \dfrac{a\left(1-e^2\right)}{\left(1-e^2\sin^2\phi\right)^{3/2}}$

Radius in prime vertical, $N = \dfrac{a}{\left(1-e^2\sin^2\phi\right)^{1/2}}$

Angular convergence of meridians

$$\theta_{\text{rad}} = \frac{d\tan\phi\left(1-e^2\sin^2\phi\right)^{1/2}}{a}$$

Linear convergence of meridians

$$= \frac{\ell d \tan\left(1 - e^2 \sin^2 \phi\right)^{1/2}}{a}$$

where:

ϕ = latitude

d = distance along parallel at latitude ϕ

ℓ = length along meridians separated by d

Ellipsoid definitions:

GRS80: a = 6,378,137.0 m

$1/f$ = 298.25722101

Clarke 1866: a = 6,378,206.4 m

$1/f$ = 294.97869821

Orthometric correction:

Correction = $-0.005288 \sin 2\phi \, h \, \Delta\phi$ arc1'

where:

ϕ = latitude at starting point

h = datum elevation in meters or feet at starting point

$\Delta\phi$ = change in latitude in minutes between the two points (+ in the direction of increasing latitude or towards the pole)

$h \approx H + N$

where:

h = ellipsoidal height

N = geoid undulation

H = orthometric height

Mensuration of Areas and Volumes

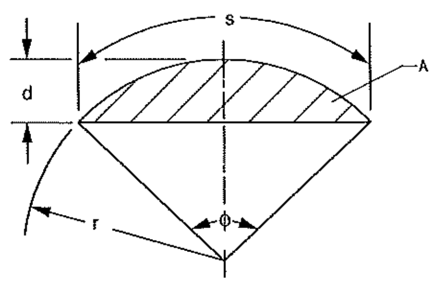
Nomenclature

A = total surface area

P = perimeter

V = volume

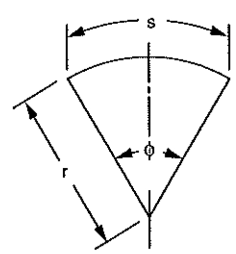
Circular Segment



$$A = \left[r^2(\phi - \sin\phi)\right]/2$$
$$\phi = s/r = 2\left\{\arccos\left[(r-d)/r\right]\right\}$$

Source: Gieck, K., and R. Gieck, *Engineering Formulas*, 1st American ed., New York: McGraw-Hill, 1971.

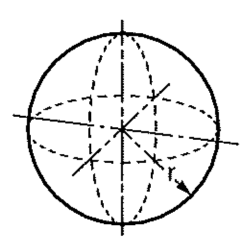
Circular Sector



$$A = \phi r^2/2 = sr/2$$
$$\phi = s/r$$

Source: Gieck, K., and R. Gieck, *Engineering Formulas*, 1st American ed., New York: McGraw-Hill, 1971.

Sphere



$$V = 4\pi r^3/3 = \pi d^3/6$$
$$A = 4\pi r^2 = \pi d^2$$

Source: Gieck, K., and R. Gieck, *Engineering Formulas*, 1st American ed., New York: McGraw-Hill, 1971.

State Plane Coordinates

Reduce horizontal ground distance (DH) to geodetic (ellipsoidal) distance (DE)

$$DE = DH \times EF$$

where:

$$EF = \text{elevation factor} = \frac{R}{R + H + N}$$

and:

R = ellipsoidal radius

H = orthometric height

N = geoid height

Reduce geodetic (ellipsoidal) distance (DE) to grid distance (DG)

$$DG = DE \times SF$$

where:

SF = projection scale factor

For precisions less than 1/200,000, may use approximate ellipsoid radius $R \approx 20{,}906{,}000$ ft and neglect geoid height.

Arc distance (AR) to chord distance (CH) correction

$$AR - CH = \frac{CH^3}{24R^2}$$

where R is radius of the arc distance

Electronic Distance Measurement

$$V = c/n$$

$$\lambda = V/f$$

$$D = \left(\frac{m\lambda + d}{2}\right)$$

where:

V = velocity of light through the atmosphere (m/s)

c = velocity of light in a vacuum

n = index of refraction

λ = wave length (m)

f = modulated frequency in hertz (cycles/sec)

D = distance measured

m = integer number of full wavelengths

d = fractional part of the wavelength

Atmospheric Correction

A 10°C temperature change or a pressure difference of 1 in. of mercury produces a distance correction of approximately 10 parts per million (ppm).

Area Formulas

Area by coordinates where i is point order in a closed polygon.

$$\text{Area} = \frac{1}{2}\left[\sum_{i=1}^{n} X_i Y_{i+1} - \sum_{i=1}^{n} X_i Y_{i-1}\right]$$

Trapezoidal Rule

$$\text{Area} = w\left(\frac{h_1 + h_n}{2} + h_2 + h_3 + h_4 + \ldots + h_{n-1}\right)$$

Simpson's 1/3 Rule

$$\text{Area} = w\left[h_1 + 2\left(\sum h_{\text{odds}}\right) + 4\left(\sum h_{\text{evens}}\right) + h_n\right]/3$$

where w = length of a common interval between offsets

Earthwork Formulas

Average end area formula

$$\text{Volume} = L(A_1 + A_2)/2$$

Prismoidal formula

$$\text{Volume} = L(A_1 + 4A_m + A_2)/6$$

where:

A_m = area of mid-section

L = distance between A_1 and A_2

Pyramid or cone

$$\text{Volume} = h(\text{area of base})/3$$

Probability and Statistics

Standard Deviation

$$\sigma = \sqrt{\frac{\sum(x_i - \overline{x})^2}{n-1}} = \sqrt{\frac{\sum v^2}{n-1}}$$

where:

σ = standard deviation (sometimes referred to as standard error)

Σv^2 = sum of the squares of the residuals (deviation from the mean)

n = number of observations

$\bar{x}$ = mean of the observations (individual measurements x_i)

Error Propagation

$$\sigma_{\text{sum}} = \sqrt{\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_n^2}$$

$$\sigma_{\text{series}} = \sigma\sqrt{n}$$

$$\sigma_{\text{mean}} = \frac{\sigma}{\sqrt{n}}$$

$$\sigma_{\text{product}} = \sqrt{A^2\sigma_b^2 + B^2\sigma_a^2}$$

$$\Sigma = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix}$$

$$\tan 2\theta = \frac{2\sigma_{xy}}{\sigma_x^2 - \sigma_y^2}$$ where θ = the counterclockwise angle from the x axis

Relative Weights

Relative weights are inversely proportional to variances, or:

$$W_a \propto \frac{1}{\sigma_a^2}$$

Weighted mean:

$$\overline{M}_w = \frac{\sum WM}{\sum W}$$

where:

$\overline{M}_w$ = weighted mean

ΣWM = sum of individual weights times their measurements

ΣW = sum of the weights

Confidence Intervals

Confidence Interval for the Mean μ of a Normal Distribution

(A) Standard deviation σ is known

$$\overline{X} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \le \mu \le \overline{X} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$$

(B) Standard deviation σ is known

$$\overline{X} - t_{\alpha/2}\frac{s}{\sqrt{n}} \le \mu \le \overline{X} + t_{\alpha/2}\frac{s}{\sqrt{n}}$$

where $t_{\alpha/2}$ corresponds to $n-1$ degrees of freedom.

Confidence Interval for the Variance σ^2 of a Normal Distribution

$$\frac{(n-1)s^2}{x^2_{\alpha/2,\,n-1}} \le \sigma^2 \le \frac{(n-1)s^2}{x^2_{1-\alpha/2,\,n-1}}$$

Confidence Interval for the Ratio of Two Normal Distribution Variances

$$\frac{S_1^2}{S_2^2 F_{\alpha/2,\,n_1-1,\,n_2-1}} \le \frac{\sigma_1^2}{\sigma_2^2} \le \frac{S_1^2}{S_2^2 F_{\alpha/2,\,n_2-1,\,n_1-1}}$$

Values of $Z_{\alpha/2}$

Confidence Interval	$Z_{\alpha/2}$
80%	1.2816
90%	1.6449
95%	1.9600
96%	2.0537
98%	2.3263
99%	2.5758

Three-Wire Leveling

Three-wire (3-wire) leveling is the process of leveling then reading and recording the upper middle and lower line in the level reticule and taking the mean of the readings. The mean is used as the reading.

Matrices

A matrix is an ordered rectangular array of numbers with m rows and n columns. The element a_{ij} refers to row i and column j.

The rank of a matrix is equal to the number of rows that are linearly independent.

Multiplication of Two Matrices

$$A = \begin{bmatrix} A & B \\ C & D \\ E & F \end{bmatrix}$$ $A_{3,2}$ is a 3-row, 2-column matrix

$$B = \begin{bmatrix} H & I \\ J & K \end{bmatrix}$$ $B_{2,2}$ is a 2-row, 2-column matrix

In order for multiplication to be possible, the number of columns in A must equal the number of rows in B.

Multiplying matrix B by matrix A occurs as follows:

$$C = \begin{bmatrix} A & B \\ C & D \\ E & F \end{bmatrix} \cdot \begin{bmatrix} H & I \\ J & K \end{bmatrix}$$

$$C = \begin{bmatrix} (A \cdot H + B \cdot J) & (A \cdot I + B \cdot K) \\ (C \cdot H + D \cdot J) & (C \cdot I + D \cdot K) \\ (E \cdot H + F \cdot J) & (E \cdot I + F \cdot K) \end{bmatrix}$$

Matrix multiplication is not commutative.

Addition of Two Matrices

$$\begin{bmatrix} A & B & C \\ D & E & F \end{bmatrix} + \begin{bmatrix} G & H & I \\ J & K & L \end{bmatrix} = \begin{bmatrix} A+G & B+H & C+I \\ D+J & E+K & F+L \end{bmatrix}$$

Identity Matrix

The matrix $\mathbf{I} = (a_{ij})$ is a square $n \times n$ matrix with 1's on the diagonal and 0's everywhere else.

Matrix Transpose

Rows become columns. Columns become rows.

$$A = \begin{bmatrix} A & B & C \\ D & E & F \end{bmatrix} \quad A^T = \begin{bmatrix} A & D \\ B & E \\ C & F \end{bmatrix}$$

Inverse $[\ ]^{-1}$

The inverse B of a square $n \times n$ matrix A is

$$B = A^{-1} = \frac{\text{adj}(A)}{|A|}$$

where

adj(A) = adjoint of A (obtained by replacing A^T elements with their cofactors)

$|A|$= determinant of A

$[\mathbf{A}][\mathbf{A}]^{-1} = [\mathbf{A}]^{-1}[\mathbf{A}] = [\mathbf{I}]$

where **I** is the identity matrix.

Matrix Properties

Suppose A is N × N over real numbers. Then if one of the following is true, all are true. If one of the following is false, all are false.

1. A is nonsingular.
2. A has an inverse.
3. A*X = 0 has a unique solution.
4. Determinant of A is not equal to zero.
5. Columns of A are linearly independent.
6. Rows of A are linearly independent.
7. Rank of A is N.
8. A is row equivalent to I (identity matrix).
9. Null Space of A = {0}.

Source: Cullen, C., *Matrices and Linear Transformations*. Reading, Massachusetts: Addison-Wesley, 1967.

Determinants

A *determinant of order n* consists of n^2 numbers, called the *elements* of the determinant, arranged in n rows and n columns and enclosed by two vertical lines.

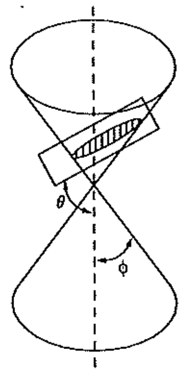
For a second-order determinant:

$$\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix} = a_1b_2 - a_2b_1$$

For a third-order determinant:

$$\begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} = a_1b_2c_3 + a_2b_3c_1 + a_3b_1c_2 - a_3b_2c_1 - a_2b_1c_3 - a_1b_3c_2$$

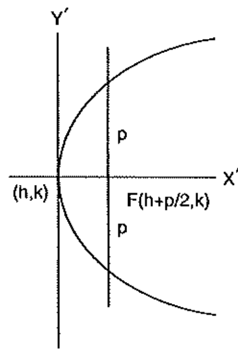
Conic Sections



e = eccentricity = $\cos\theta/(\cos\phi)$
[Note: X' and Y', in the following cases, are translated axes.]

Source: Gieck, K., and R. Gieck, *Engineering Formulas*, 1st American ed., New York: McGraw-Hill, 1971.

Case 1. Parabola $e = 1$:

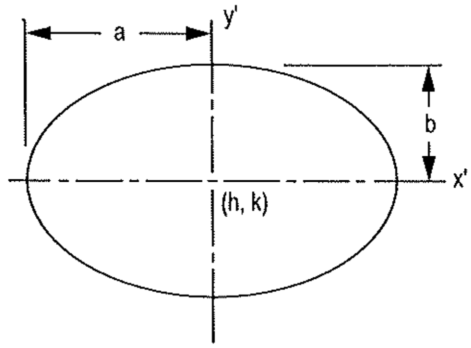


$(y - k)^2 = 2p(x - h)$; Center at (h, k) is the standard form of the equation. When $h = k = 0$,

Focus: $(p/2, 0)$; Directrix: $x = -p/2$

Source: Brink, R.W., *A First Year of College Mathematics*, Englewood Cliffs, NJ: D. Appleton-Century Company, Inc., 1937.

Case 2. Ellipse $e < 1$:



$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$; Center at (h, k) is the standard form of the equation. When $h = k = 0$,

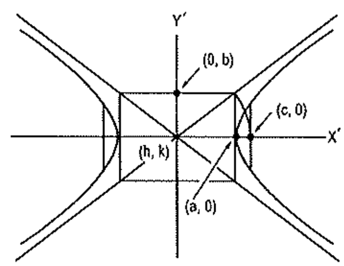
Eccentricity: $e = \sqrt{1 - (b^2/a^2)} = c/a$

$b = a\sqrt{1 - e^2}$;

Focus: $(\pm\, ae, 0)$; Directrix: $x = \pm\, a/e$

Source: Brink, R.W., *A First Year of College Mathematics*, Englewood Cliffs, NJ: D. Appleton-Century Company, Inc., 1937.

Case 3. Hyperbola $e > 1$:



$\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$;

Center at (h, k) is the standard form of the equation. When $h = k = 0$,

Eccentricity: $e = \sqrt{1 + (b^2/a^2)} = c/a$

$b = a\sqrt{e^2 - 1}$;

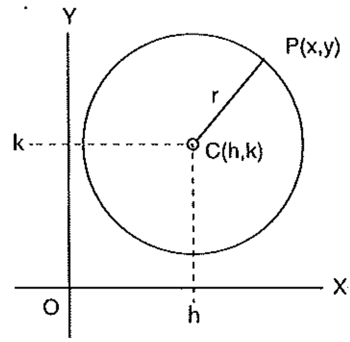
Focus: $(\pm\, ae, 0)$; Directrix: $x = \pm\, a/e$

Source: Brink, R.W., *A First Year of College Mathematics*, Englewood Cliffs, NJ: D. Appleton-Century Company, Inc., 1937.

Case 4. Circle $e = 0$:

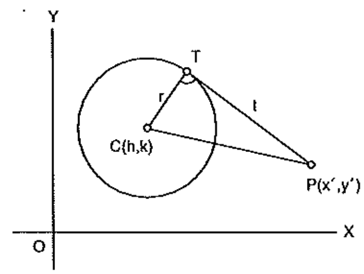
$(x-h)^2 + (y-k)^2 = r^2$; Center at (h, k) is the standard form of the equation with radius

$$r = \sqrt{(x-h)^2 + (y-k)^2}$$



Length of the tangent line from a point on a circle to a point (x',y'):

$$t^2 = (x'-h)^2 + (y'-k)^2 - r^2$$



Source: Brink, R.W., *A First Year of College Mathematics*, Englewood Cliffs, NJ: D. Appleton-Century Company, Inc., 1937.

Conic Section Equation

The general form of the conic section equation is

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$$

where not both A and C are zero.

If $B^2 - 4AC < 0$, an ellipse is defined.

If $B^2 - 4AC > 0$, a hyperbola is defined.

If $B^2 - 4AC = 0$, the conic is a parabola.

If $A = C$ and $B = 0$, a circle is defined.

If $A = B = C = 0$, a straight line is defined.

$$x^2 + y^2 + 2ax + 2by + c = 0$$

is the normal form of the conic section equation, if that conic section has a principal axis parallel to a coordinate axis.

$h = -a;\ k = -b$

$r = \sqrt{a^2 + b^2 - c}$

If $a^2 + b^2 - c$ is positive, a circle, center $(-a, -b)$.

If $a^2 + b^2 - c$ equals zero, a point at $(-a, -b)$.

If $a^2 + b^2 - c$ is negative, locus is imaginary.

Differential Calculus

The Derivative

For any function $y = f(x)$, the derivative $= D_x y = dy/dx = y'$

$$y' = \underset{\Delta x \to 0}{\text{limit}} \left[(\Delta y)/(\Delta x)\right]$$

$$= \underset{\Delta x \to 0}{\text{limit}} \left\{\left[f(x + \Delta x) - f(x)\right]/(\Delta x)\right\}$$

y' = the slope of the curve $f(x)$.

<u>Test for a Maximum</u>

$y = f(x)$ is a maximum for

$x = a$, if $f'(a) = 0$ and $f''(a) < 0$.

<u>Test for a Minimum</u>

$y = f(x)$ is a minimum for

$x = a$, if $f'(a) = 0$ and $f''(a) > 0$.

<u>Test for a Point of Inflection</u>

$y = f(x)$ has a point of inflection at $x = a$,

if $f''(a) = 0$, and

if $f''(x)$ changes sign as x increases through

$x = a$.

The Partial Derivative

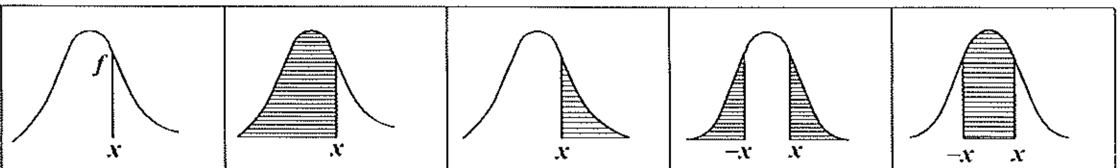
In a function of two independent variables x and y, a derivative with respect to one of the variables may be found if the other variable is *assumed* to remain constant. If *y is kept fixed*, the function

$z = f(x, y)$

becomes a function of the *single variable x*, and its derivative (if it exists) can be found. This derivative is called the *partial derivative of z with respect to x*. The partial derivative with respect to x is denoted as follows:

$$\frac{\partial z}{\partial x} = \frac{\partial f(x,y)}{\partial x}$$

Unit Normal Distribution Table



x	$f(x)$	$F(x)$	$R(x)$	$2R(x)$	$W(x)$
0.0	0.3989	0.5000	0.5000	1.0000	0.0000
0.1	0.3970	0.5398	0.4602	0.9203	0.0797
0.2	0.3910	0.5793	0.4207	0.8415	0.1585
0.3	0.3814	0.6179	0.3821	0.7642	0.2358
0.4	0.3683	0.6554	0.3446	0.6892	0.3108
0.5	0.3521	0.6915	0.3085	0.6171	0.3829
0.6	0.3332	0.7257	0.2743	0.5485	0.4515
0.7	0.3123	0.7580	0.2420	0.4839	0.5161
0.8	0.2897	0.7881	0.2119	0.4237	0.5763
0.9	0.2661	0.8159	0.1841	0.3681	0.6319
1.0	0.2420	0.8413	0.1587	0.3173	0.6827
1.1	0.2179	0.8643	0.1357	0.2713	0.7287
1.2	0.1942	0.8849	0.1151	0.2301	0.7699
1.3	0.1714	0.9032	0.0968	0.1936	0.8064
1.4	0.1497	0.9192	0.0808	0.1615	0.8385
1.5	0.1295	0.9332	0.0668	0.1336	0.8664
1.6	0.1109	0.9452	0.0548	0.1096	0.8904
1.7	0.0940	0.9554	0.0446	0.0891	0.9109
1.8	0.0790	0.9641	0.0359	0.0719	0.9281
1.9	0.0656	0.9713	0.0287	0.0574	0.9426
2.0	0.0540	0.9772	0.0228	0.0455	0.9545
2.1	0.0440	0.9821	0.0179	0.0357	0.9643
2.2	0.0355	0.9861	0.0139	0.0278	0.9722
2.3	0.0283	0.9893	0.0107	0.0214	0.9786
2.4	0.0224	0.9918	0.0082	0.0164	0.9836
2.5	0.0175	0.9938	0.0062	0.0124	0.9876
2.6	0.0136	0.9953	0.0047	0.0093	0.9907
2.7	0.0104	0.9965	0.0035	0.0069	0.9931
2.8	0.0079	0.9974	0.0026	0.0051	0.9949
2.9	0.0060	0.9981	0.0019	0.0037	0.9963
3.0	0.0044	0.9987	0.0013	0.0027	0.9973
Fractiles					
1.2816	0.1755	0.9000	0.1000	0.2000	0.8000
1.6449	0.1031	0.9500	0.0500	0.1000	0.9000
1.9600	0.0584	0.9750	0.0250	0.0500	0.9500
2.0537	0.0484	0.9800	0.0200	0.0400	0.9600
2.3263	0.0267	0.9900	0.0100	0.0200	0.9800
2.5758	0.0145	0.9950	0.0050	0.0100	0.9900

4 ECONOMICS

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	to F given P	$(F/P, i\%, n)$	$(1+i)^n$
Single Payment Present Worth	to P given F	$(P/F, i\%, n)$	$(1+i)^{-n}$
Uniform Series Sinking Fund	to A given F	$(A/F, i\%, n)$	$\frac{i}{(1+i)^n - 1}$
Capital Recovery	to A given P	$(A/P, i\%, n)$	$\frac{i(1+i)^n}{(1+i)^n - 1}$
Uniform Series Compound Amount	to F given A	$(F/A, i\%, n)$	$\frac{(1+i)^n - 1}{i}$
Uniform Series Present Worth	to P given A	$(P/A, i\%, n)$	$\frac{(1+i)^n - 1}{i(1+i)^n}$
Uniform Gradient Present Worth	to P given G	$(P/G, i\%, n)$	$\frac{(1+i)^n - 1}{i^2(1+i)^n} - \frac{n}{i(1+i)^n}$
Uniform Gradient † Future Worth	to F given G	$(F/G, i\%, n)$	$\frac{(1+i)^n - 1}{i^2} - \frac{n}{i}$
Uniform Gradient Uniform Series	to A given G	$(A/G, i\%, n)$	$\frac{1}{i} - \frac{n}{(1+i)^n - 1}$

Nomenclature and Definitions

A...........Uniform amount per interest period
B...........Benefit
BV.........Book value
C...........Cost
d............Inflation adjusted interest rate per interest period
D_j..........Depreciation in year j
EV.........Expected value
F...........Future worth, value, or amount
f............General inflation rate per interest period
G...........Uniform gradient amount per interest period
i ....Interest rate per interest period
i_e ....Annual effective interest rate
MARR..Minimum acceptable/attractive rate of return
m...........Number of compounding periods per year
n............Number of compounding periods; or the expected life of an asset
P...........Present worth, value, or amount
r............Nominal annual interest rate
S_n ....Expected salvage value in year n

Book Value

$BV = \text{initial cost} - \Sigma D_j$

Capitalized Costs

Capitalized costs are present worth values using an assumed perpetual period of time.

Capitalized Costs $= P = \frac{A}{i}$

Benefit-Cost Analysis

In a benefit-cost analysis, the benefits B of a project should exceed the estimated costs C.

$B - C \geq 0$, or $B/C \geq 1$

5 ETHICS

Surveyor's Canons

Canon 1. A Professional Surveyor should refrain from conduct that is detrimental to the public.

Canon 2. A Professional Surveyor should abide by the rules and regulations pertaining to the practice of surveying within the licensing jurisdiction.

Canon 3. A Professional Surveyor should accept assignments only in one's area of professional competence and expertise.

Canon 4. A Professional Surveyor should develop and communicate a professional analysis and opinion without bias or personal interest.

Canon 5. A Professional Surveyor should maintain the confidential nature of the surveyor-client relationship.

Canon 6. A Professional Surveyor should use care to avoid advertising or solicitation that is misleading or otherwise contrary to the public interest.

Canon 7. A Professional Surveyor should maintain professional integrity when dealing with members of other professions.

Source: Excerpt from the National Society of Professional Surveyors (NSPS) Surveyor's Creed and Canons, https://www.nsps.us.com/page/CreedandCanons, as posted on April 18, 2019.

Job Safety Analysis

Job safety analysis (JSA) is known by many names, including activity hazard analysis (AHA), or job hazard analysis (JHA). Hazard analysis helps integrate accepted safety and health principles and practices into a specific task. In a JSA, each basic step of the job is reviewed, potential hazards identified, and recommendations documented as to the safest way to do the job. JSA techniques work well when used on a task that the analysts understand well. JSA analysts look for specific types of potential accidents and ask basic questions about each step, such as these:

Can the employee strike against or otherwise make injurious contact with the object?

Can the employee be caught in, on, or between objects?

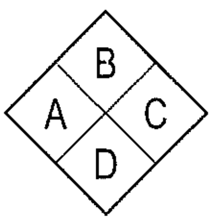
Can the employee strain muscles by pushing, pulling, or lifting?

Is exposure to toxic gases, vapors, dust, heat, electrical currents, or radiation possible?

Hazard Assessments—Hazardous Materials Classification

Hazard Assessment

The fire/hazard diamond below summarizes common hazard data available on the Safety Data Sheet (SDS) and is frequently shown on chemical labels.



Position A – Health Rating (Blue)
4 = Can be lethal
3 = Serious or permanent injury
2 = Temporary incapacitation or residual injury
1 = Significant irritation
0 = No hazard beyond ordinary combustibles

Position B – Flammability Rating (Red)
4 = Rapidly or completely vaporized and burn readily
3 = Ignite readily in ambient conditions
2 = Ignite when moderately heated
1 = Require preheating for ignition
0 = Will not burn under normal fire conditions

Position C – Instability Rating (Yellow)
4 = May detonate or have explosive reaction
3 = Shock and heat may detonate or cause explosive reaction
2 = Violent chemical change at elevated temperatures
1 = Unstable if heated
0 = Normally stable

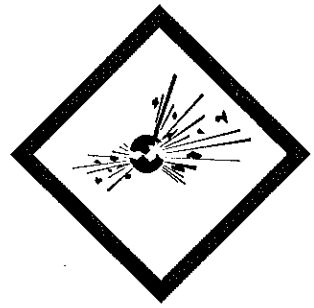
Position D – Special Hazards (White)
OX = Oxidizers
~~W~~ = Water Reactives
SA = Simple Asphyxiants

No other hazards should be listed in this quadrant. In cases where a unique hazard symbol exists, it must be placed outside of the white special hazard quadrant.

GHS PICTOGRAMS AND HAZARD CLASSES

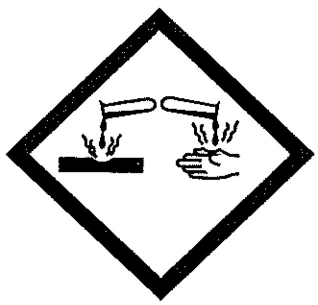
• OXIDIZERS

• FLAMMABLES
• SELF-REACTIVES
• PYROPHORICS
• SELF-HEATING
• EMITS FLAMMABLE GAS
• ORGANIC PEROXIDES

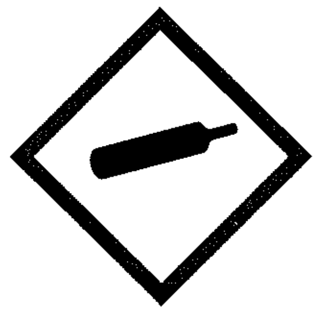


• EXPLOSIVES
• SELF-REACTIVES
• ORGANIC PEROXIDES

• ACUTE TOXICITY (SEVERE)



• CORROSIVES



• GASES UNDER PRESSURE

• CARCINOGEN
• RESPIRATORY SENSITIZER
• REPRODUCTIVE TOXICITY
• TARGET ORGAN TOXICITY
• MUTAGENICITY
• ASPIRATION TOXICITY

• ENVIRONMENTAL TOXICITY

• IRRITANT
• DERMAL SENSITIZER
• ACUTE TOXICITY (HARMFUL)
• NARCOTIC EFFECTS
• RESPIRATORY TRACT IRRITATION

Occupational Safety and Health Administration, *A Guide to The Globally Harmonized System of Classification and Labelling of Chemicals (GHS)*. United States Department of Labor, https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf

NCEES
advancing licensure for engineers and surveyors

NCEES Fundamentals of Surveying (FS)
CBT Exam Specifications

Effective Beginning with the July 2020 Examinations

- The FS exam is a computer-based test (CBT). It is closed book with an electronic reference.
- Examinees have 6 hours to complete the exam, which contains 110 questions. The 6-hour time also includes a tutorial and an optional scheduled break.
- The FS exam uses both the International System of Units (SI) and the U.S. Customary System (USCS).

	Number of Questions
1. Surveying Processes and Methods	**16–24**

A. Instrumentation (e.g., GNSS/GPS, levels, total stations, robotic total stations, scanners, UAS)
B. GNSS/GPS surveys (e.g., static, kinematic, OPUS, real-time networks)
C. Control surveys (e.g., horizontal, vertical, network design, accuracy standards)
D. Cadastral (e.g., Public Land Survey System [PLSS], boundary, metes and bounds, land title)
E. Topographic surveys
F. Construction surveys (e.g., layout, as-built, quantity)
G. Land development (e.g., subdivision design/platting, land use, environmental, flood plains, wetlands)
H. Field record keeping and documentation (e.g., procedures, field books, raw data files)

2. Mapping Processes and Methods	**14–21**

A. Basic mapping concepts (e.g., scaling, symbols, features, legend, contours, cartography)
B. Types of maps (e.g., plan and profile, cross section, plat, record of survey, ALTA, topographic, planimetric)
C. CAD (e.g., 2-D, 3-D, building information modeling [BIM])
D. GIS (e.g., feature collection, map projections, coordinate systems, metadata, database design and management, spatial data analysis, GIS applications)
E Digital terrain model (e.g., machine control, triangulated irregular network [TIN], digital surface model, digital elevation model)
F. Photogrammetry and remote sensing (e.g., close range, conventional, softcopy, ground control, quality control, flight planning, project planning, UAS, drone, LiDAR, satellite, digital image analysis and processing)

3. Boundary Law and Real Property Principles **19–29**

A. Public records and descriptions (e.g., land descriptions, mineral rights, ownership rights, weighting evidence)
B. Common law principles (e.g., controlling elements, unwritten rights, adverse possession)
C. Easements (e.g., granted, implied/prescriptive)
D. Simultaneous and sequential conveyances
E. Metes and bounds
F. PLSS
G. Water law (e.g., riparian, littoral rights, water marks/levels)
H. Sources of law (e.g., federal/state/local, administrative, common, citations, legal research)
I. Encumbrances (e.g., restrictive covenants, mortgages, liens)
J. Real property law (e.g., deeds, chains of title)

4. Surveying Principles **13–20**

A. Basic surveying (e.g., horizontal surveys, vertical surveys, understanding of historical methods and instruments, route surveying, magnetic declination)
B. Geodesy (e.g., spherical trigonometry, geometric, physical, geodetic coordinates, orthometric corrections, convergence, geodetic reductions, gravity modeling, geoid modeling)
C. Applied geodesy (e.g., datums and datum conversions, latitude/longitude, coordinate transformations, state plane coordinate system [SPCS], map projections, control networks, reduction of observations, deflection of vertical, satellite coordinate systems)

5. Survey Computations and Computer Applications **17–26**

A. Coordinate geometry
B. Traverse closure and adjustments
C. Leveling (e.g., differential, trigonometric, reciprocal, precise)
D. Least squares adjustments
E. Area
F. Horizontal curves
G. Vertical curves
H. Volume (e.g., mass diagrams, earthwork)
I. Spreadsheets
J. Slopes and grades

6. Business Concepts **11–17**

A. Project planning (e.g., resource management, scheduling, cost estimation, tracking)
B. Safety (e.g., signage, basic first aid, safety equipment)
C. Liabilities (e.g., negligence, employee behavior, errors and omissions)
D. Contracts (e.g., basic elements, scope of work, specifications)
E. Supervision (e.g., survey team leadership, personnel management)
F. Project documentation and record management

G. Ethics

H. Communication (e.g., written communication, oral communication, alternate forms of communication, conflict resolution)

7. Applied Mathematics and Statistics **10–15**

A. College mathematics (e.g., trigonometry, analytical geometry and calculus, linear algebra and matrix theory)

B. Probability and statistics (e.g., mean, median, mode, hypothesis testing, normal distribution, linear regression)

C. Measurement science (e.g., error analysis, error propagation, positional tolerance, positional accuracy, random/systematic/blunder errors, unit conversions)

D. Quantitative reasoning (e.g., critical thinking, data analysis and validation, blunder detection, data quality, redundancy)

Fundamentals of Surveying (FS) Standards

Effective Beginning with the July 2020 Examinations

Revisions are shown in red.

In addition to the NCEES *FS Reference Handbook*, the following standards will be supplied in the exam as searchable, electronic pdf files with links for easy navigation. This NCEES YouTube video shows how standards will be presented on the exam. Standards will be provided as individual documents on the exam, and only one document at a time can be opened and searched. This ensures the exam software runs large files effectively. The handbook and standards will be available the entire exam.

Solutions to exam questions that reference a standard of practice are scored based on this list and the revision year shown. Solutions based on other standards will not receive credit.

NCEES does not sell standards or printed copies of the NCEES handbook. The NCEES handbook is accessible from your MyNCEES account.

ABBREVIATION	STANDARD TITLE
ALTA	*Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys,* 2021, American Land Title Association®, Washington, DC, and National Society of Professional Surveyors, Frederick, MD, www.nsps.us.com.
FEMA*	*FEMA Elevation Certificate and Instructions*, 2023, Federal Emergency Management Agency, Hyattsville, MD, www.fema.gov.
FGCS	Section 3.5 Geodetic Leveling in *FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*, 2004, Federal Geographic Data Committee, Reston, VA, www.fgdc.gov.
GPAS	*Geospatial Positioning Accuracy Standards*, Federal Geographic Data Committee, Reston, VA, www.fgdc.gov. • Parts 1–3, 1998 • Part 4, 2002 • Part 5, 2005
NPSP Model	*NSPS Model Standards,* Sections A–H, 2002, National Society of Professional Surveyors, Frederick, MD, www.nsps.us.com.
USNMAS	*United States National Map Accuracy Standards*, 1947, U.S. Bureau of the Budget, Washington, DC, www.usgs.gov.

*This FEMA document is not searchable within the exam platform.

NCEES
advancing licensure for engineers and surveyors

Principles and Practice of Surveying (PS)
CBT Exam Specifications

Effective beginning January 1, 2019

- The PS exam is computer based. It is closed book with an electronic reference.
- Examinees have 7 hours to complete the exam, which contains 100 questions. The 7-hour time also includes a tutorial and an optional scheduled break.
- The exam uses the U.S. Customary System (USCS) of units.
- The exam is developed with questions that will require a variety of approaches and methodologies, including design, analysis, and application.

Number of Questions

1. Legal Principles — 18–27

A. Principles of Evidence
   1. How to search for data and for physical evidence to evaluate data
   2. How to evaluate data
   3. Parol evidence
   4. Prescriptive rights
   5. Adverse possession
   6. Acquiescence
   7. Controlling elements
   8. Easement rights

B. Common Law Boundary Principles
   1. Historical and current common law principles
   2. Riparian and littoral rights
   3. Sovereign rights, including both navigable waters and eminent domain
   4. Sovereign land grants

C. Sequential and Simultaneous Conveyance Concepts
   1. Types of conveyances
   2. Junior/senior rights
   3. Record and physical evidence

D. Legal Descriptions for Real Property Transactions
   1. Preparation and interpretation of legal descriptions
   2. Controlling elements and how they impact the description
   3. Unwritten rights and how they impact the description
   4. Encumbrances and how they impact the description
   5. Easements and how they impact the description

E. Evidence for the Perpetuation of the U.S. PLSS

2. Professional Survey Practices **22–33**

A. Public/Private Record Sources
   1. Resources for private and public records
   2. Local public records indexing and filing system
   3. Local survey office records

B. Documentation, Supervision, and Clear Communication of Field Procedures
   1. Field surveying techniques
   2. Field surveying practices
   3. Data collection protocols

C. GPS/GNSS including satellite constellations, static GPS, RTK, PPP, and virtual networks

D. Surveying Principles and Computations
   1. Technical computations
   2. Applicable software

E. Monumentation Standards
   1. Applicable monumentation criteria
   2. Monument types

F. Land Development Solutions
   1. Regulatory land development criteria
   2. Construction criteria
   3. Land development implementation procedures

G. Survey Maps/Plats/Reports
   1. Technical communications by schematic, platting, and mapping processes and procedures
   2. Communication options

H. GIS
   1. GIS spatial databases and metadata
   2. Datums and projections related to GIS

3. Standards and Specifications **8–12**

A. BLM Manual of Surveying Instructions

B. ALTA/NSPS Land Title Survey Standards
   1. Current ALTA/NSPS Land Title Survey Standards
   2. State statutes regarding boundary surveys in conjunction with ALTA/NSPS Land Title Surveys

C. FEMA Requirements
   1. FEMA specifications and instructions
   2. Horizontal and vertical datums related to FEMA flood zones
   3. Current FEMA elevation certificate
   4. FEMA Flood Insurance Study

4. Business Practices — 13–19

A. General Business Practices and Procedures
   1. Project planning and project management
   2. Deliverables
   3. Costs, budgets, and contracts
   4. Types of surveys
   5. Site features and conditions
   6. Scope of services
   7. Appropriate equipment and instruments

B. Risk Management Procedures
   1. Safety procedures
   2. QA/QC methods
   3. Risk management in contracts
   4. Insurance needs and requirements
   5. Potential liabilities

C. Professional Conduct

D. Communication with Clients, Staff, Related Professions, and the Public
   1. Different forms of communications
   2. Appropriate type of communication to convey concepts
   3. Related professions and their impact on client needs and deliverables

5. Areas of Practice — 24–36

A. ALTA/NSPS Land Title Surveys
   1. Legal documents, such as deeds, easements, and agreements
   2. Zoning information as applied to ALTA/NSPS Land Title Surveys
   3. Title insurance commitment letters and policies
   4. Underground features as applied to ALTA/NSPS Land Title Surveys

B. Control Networks and Geodetic Network Surveys
   1. Datums and reference frames relative to control networks
   2. Differences between local datums and geodetic datums
   3. Equipment appropriate for control surveys
   4. The Federal Geographic Data Committee Geospatial Positioning Accuracy Standards
   5. The National Geospatial Programs (NGP) Standards and Specifications—Digital Data Standards

C. Construction Surveys
   1. Construction plan reading
   2. Construction calculations including slopes, grades, and plan details
   3. Construction techniques and activities
   4. Horizontal and vertical positioning relative to a plan or datum

D. Boundary Surveys
   1. Physical boundary evidence
   2. Boundary reconciliations
   3. Historical measurement accuracy, equipment, and techniques
   4. Legal principles related to boundary surveys

E. Route Surveys for Alignments and Utilities
   1. Route alignment stationing practices
   2. Reading and interpreting roadway and utility plans

F. Topographic
   1. Topographic/planimetric mapping and control standards
   2. Interpretation, reconciliation, and adjustment of topographic survey data
   3. QA/QC procedures as applied to topographic surveys
   4. Ground, hydrographic, and remote sensing equipment
   5. The U.S. National Map Accuracy Standards as applied to topographic surveys
   6. Tools and techniques required to perform hydrographic, bathymetric, and remote sensing surveys
   7. Nomenclature related to utilities

G. Surveys to Establish New Parcels, Lots, or Units
   1. Types of subdivisions
   2. Platting
   3. Condominiums and associations
   4. Deed restrictions and restrictive covenants
   5. Zoning and subdivision ordinances

H. As-Built/Record Drawing Surveys
   1. As-built/record drawing calculations including slopes, grades, and plan details
   2. As-built/record drawing techniques and activities
   3. Horizontal and vertical as-built/record drawing positions relative to a plan or datum

I. Consultation Services
   1. Site topography and slope for development purposes
   2. Site access for development purposes
   3. Zoning standards related to new projects
   4. Floodplains as related to land development

Principles and Practice of Surveying (PS) Standards

Effective beginning January 1, 2019

Revisions are shown in red.

In addition to the NCEES *PS Reference Handbook*, the following standards will be supplied on the exam as searchable, electronic pdf files with links for easy navigation. This NCEES YouTube video shows how standards will be presented on the exam. Standards will be provided as individual documents on the exam, and only one document at a time can be opened and searched. This ensures the exam software runs large files effectively. The handbook and standards will be available the entire exam.

Solutions to exam questions that reference a standard of practice are scored based on this list and the revision year shown. Solutions based on other standards will not receive credit.

NCEES does not sell standards or printed copies of the NCEES handbook. The NCEES handbook is accessible from your MyNCEES account.

ABBREVIATION	STANDARD TITLE
ALTA	*Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys*, 2021, American Land Title Association®, Washington, DC, and National Society of Professional Surveyors, Frederick, MD, www.nsps.us.com.
FEMA*	*FEMA Elevation Certificate and Instructions*, 2023, Federal Emergency Management Agency, Hyattsville, MD, www.fema.gov.
FGCS	Section 3.5 Geodetic Leveling in *FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*, 2004, Federal Geographic Data Committee, Reston, VA, www.fgdc.gov.
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NCEES

EXAMINEE GUIDE

November 2024

CONTENTS

LAND SURVEYOR MISSOURI SPECIFIC EXAMINATION

The Missouri Specific Land Surveyor Exam is a two part examination. Passing both parts of the Missouri state-specific examination (as well as passing the required NCEES Fundamentals of Surveying examination and the Principles of Surveying examination) will be required to become licensed as a Professional Land Surveyor in Missouri.

Part I and Part II of the Missouri State-Specific exam is each one-hour and fifteen minutes in length each. Both parts of the exam are open-book.

Missouri State-Specific Land Surveying Examination Content			
PART I – GENERAL All multiple choice & write a boundary description – 1.25 hours in length		**PART II – US PUBLIC LAND SURVEY SYSTEM (USPLSS)** Multiple choice & mathematical problems – 1.25 hours in length	
Missouri Standards for Property Boundary Surveys from a plat, write a boundary description - Includes the boundary description writing exercise, which is about one-fourth of the "Standards" points. The description exercise translates to about 9% of the total exam.	40.5%	Original GLO procedures, the GLO System as applied to Missouri, GLO Section protraction	32.7%
Statutes and Rules of the Missouri Board for Architects, Professional Engineers, Professional Land Surveyors and Professional Landscape Architects and Missouri Statutes applicable to surveying	33.5%	Numerical calculator problems applied to USPLSS for MO. The application of Chapter 60 RSMo	35.6%
Missouri State Plane Coordinate System	13.7%	Resurveys on the US Public Land Survey System as applied in Missouri	31.7%
Missouri Riparian Boundaries	12.3%		

You must pass both parts of the Missouri state-specific examination. You may register for one or both parts of an exam administration. Any applicant who fails either Part I or Part II, or both parts of the examination, on the first attempt must apply to the Board to re-take Part(s) I and/or II by completing the "Reexamination/ Rescheduling Application" which can be obtained by accessing the Board's web site at: APEPLSPLA (mo.gov).

Note: **Exam candidates who fail to achieve a passing score on any part of the examination, will have unlimited opportunities for reexamination. However, these candidates will be required to wait 6 months before repeating the failed exam.**

Revised February 6, 2023

PREPARING FOR AND TAKING THE EXAM

NCEES exam sections:

Fundamentals of Surveying (PS) and Principles and Practice of Surveying (PS) Exams are now CBT (computer-based testing).

Format

- Look in licensing board (https://pr.mo.gov/apelsla.asp) and NCEES (https://ncees.org)websites.
- For FS and PS exams read the NCEES site on all aspects of the surveying exam. Go to their YouTube channel and watch all the videos
- MO exam actually two 75-minute exams
- Same calculator and other policies for rest of NCEES exams (be familiar with everything pertaining to preparing for, applying for and taking the exam on the Board and NCEES websites).
- Open book for MO exam; closed book for NCEES.
- You are provided with an on-screen calculator to use if you wish, but you may also bring your approved calculator to the NCEES exam.
- There is a reference handbook provided by NCEES. Download this and review in detail before the exam. There is also a downloadable specification or syllabus for the NCEES exams.
- Missouri posts a sample exam; strongly suggested that you take it before the exam.

Preparation

- Begin collecting information on what to study early!
- Talk to mentors, people who have taken the exam, check list published by the board.
- Read one or more standard general surveying text (i.e. Moffit and Bossler, etc., as well as a book concentrating on legal aspects, i.e. *Boundary Control and Legal Principles* by Brown, et al).
- Plan as part of your review, developing some familiarity with *Missouri Digest*. Visit a law library, learn to use it and visit and do some useful reading/studying weekly. Get help from law librarians on how to look up cases quoted in the annotated statutes (Vernon's). Don't forget that Google Scholar is a resource to read up on cases.
- Definitions text such as NSPS *Definitions of Surveying and Related Terms*, plus for amplification, *Black's Law Dictionary*, [if you have the abridged version, find out where you can access the unabridged version to compare definitions].
- Get an approved calculator (see NCEES website and learn how to use it as you study...it is worth the investment, regardless of when you think you might be taking the exam to buy a calculator that is approved today, so that you get used to using it as you study.
- Read and / or attend one or more review books or courses—courses are great because of discussion with your fellow students.
- Make notes in your books; tab them. But remember all this tabbing and highlighting is not so that you can frequently access your books during

the exam. You only have 75 minutes per section of the Missouri specific exam! Tabbing has to be secure...no loose sheets, slips of paper, tabs with worn out glue! If you have these, you may be expelled from examination room.

- Prepare review sheets, preferably typed or on cards for the things you think you might forget or get confused. You <u>don't take these in to the exam</u>...these are to help you review and study during every available moment such as while driving to the jobsite (assuming you're not the driver), TV commercials, time outs at games, etc.
- Bring headache medicine, other meds for conditioms you are prone to, calculator batteries and/or charger and other supplies if permitted. Find out where you can keep these for access, with proctor permission, if needed.
- Wear your most comfortable clothing for exam taking. They'll roll their eyes, but bedroom slippers, if they help, should be taken.
- Get to exam location early. Plan for disasters such as running out of gas, traffic jams, not being able to find parking, etc.
- If you live any appreciable distance away, seriously consider a nearby hotel, friend's house, etc. so that you can walk, take public transportation, OR, if you can arrange it, be dropped off.
- If you plan to drive in to the exam, come in a week early on the same day of the week to see what traffic is like and to scope out traffic patterns, parking, places to eat. (You may change your mind about driving! You may also decide to pack lunch.)

- Bring picture ID...without it no exam. Also other materials such as authorization to take exam.
- You will be provided pencil.
- No scratch paper except what they give you (usually margins and other blank areas of the exam booklet).
- You will not take anything away that they give you for the exam.

Taking the exam

- Relax as much as possible. Use physical exercise or stretching if that helps (within reason—you don't want to act like you might be cheating). Find out about gum, water, etc. this can vary year-to-year and even, sometimes with locations and the individuals you talk to.
- Review your review sheets or cards just before the exam starts, even if the exam is open book. Well before the exam starts, make sure these loose sheets, even if open book are put away!!!
- Once you get the exam booklet, read any instructions on the outside and **listen** carefully to any additional instructions that are given orally.
- Open the book only when you are given the signal to do so.
- Put you name or id number on the answer sheet, and put it aside.
- Now look through the exam by reading all the questions, not necessarily trying to understand every one.
- As you read through the first time, if you see questions that you know you know, first reread the question to make sure you understood it correctly, then answer and move on. Answering correctly means that

you also have read carefully *all* the answers you will be selecting from. Sometimes there is no one absolutely correct answer; rather the "best one." As you do this, spending seconds only on a question here and there, this will boost your confidence as every question you can confidently and correctly answer in less than 144 seconds means that you more for the more difficult ones.

- Once you have gotten through the exam the first time, now go back to the ones that you have to think about, do some calculations, etc. Answer these. DO NOT, yet, start looking through the books for answers.
- On your third pass, answer all the questions you know you can answer by going quickly to the correct book and the place in it.
- Fourth pass, answer every question you have not answered so far with your best guess. Remember there is no penalty for guessing. If you can narrow it down to three or two answers, this improves the odds of your guess being correct.
- On your fifth pass, if you still have time, if you discover that your guesses from the fourth pass are wrong, change them. But do it properly with a complete erasure and a completely blackened "bubble" for the correct choice.
- You need to write clearly, and with organization on the long-hand responses to questions such as writing a description, etc.
- On math problems you can get partial credit if you have your work neatly organized so that the grader can follow you.

- If you need to stretch, work out a cramp, use the toilet, take your exam and answer sheet to the proctor and ask for permission first. Be prepared for an answer of "no" or "wait" (until someone else who's also requested returns).

Evaluation

Technician's Day Program May 1, 2025

Please rate using 1 to 5, with 1 being Poor and 5 being Excellent

Please rate in terms of helpfulness to you in your career and/or ability to pass an exam

1. **Math Concepts Part I (Chris Sparks)** **1 2 3 4 5**

What was great?

What could improve?

2. **Real Applications in Surveying (Duncan and Paiva)** **1 2 3 4 5**

What was great?

What could improve?

3. **Math Concepts II (Chris Sparks)** **1 2 3 4 5**

What was great?

What could improve?

4. **Studying for the Exams (Devaney)** **1 2 3 4 5**

What was great?

What could improve?

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5. Would you like to see more programs like this? Yes No Maybe
6. If yes, as a day within a planned MSPS program in the spring or fall?
   Concurrent like this one extra day at back or front
7. Offer as separate standalone not with other program? Yes No Maybe
8. Do you know MSPS has a 3-day exam review course in August? Yes No I've attended
9. Would you like to see a 12-15 week course offered as prep for any of the exams?
10. If yes to the above, which? FS PS State-Specific (circle one or more)

Anything else? Please use reverse for your comments