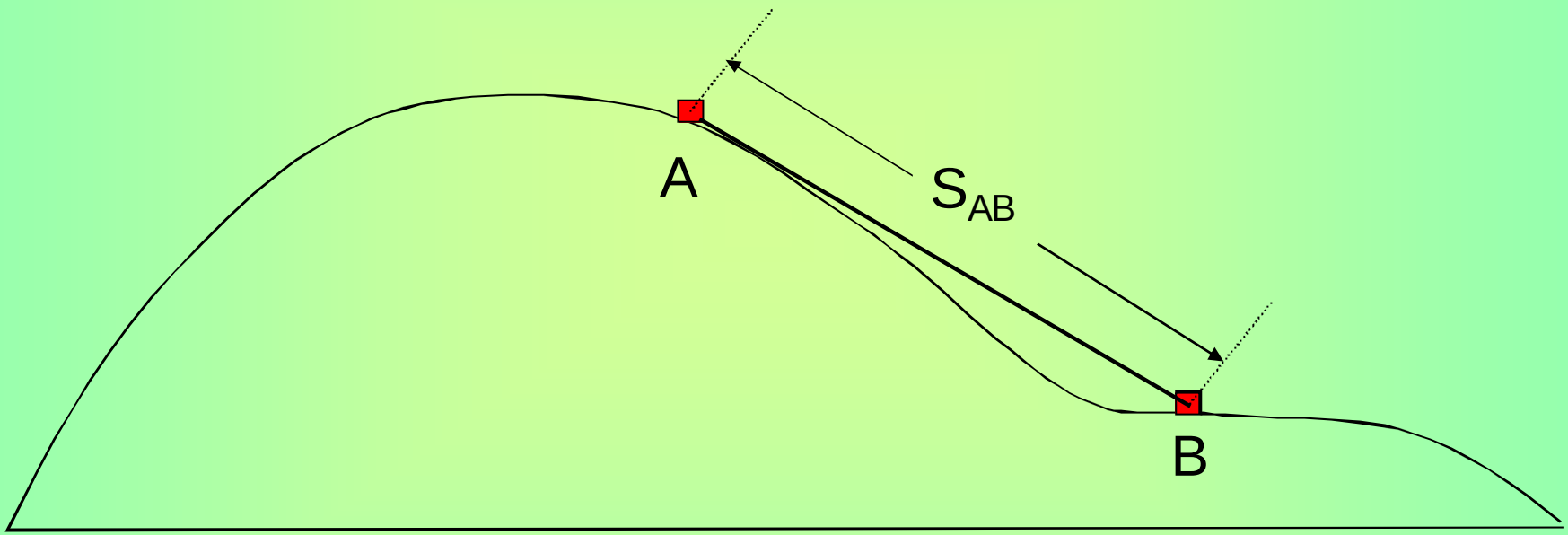
SURVEYING-I

Vertical Distance Measurement

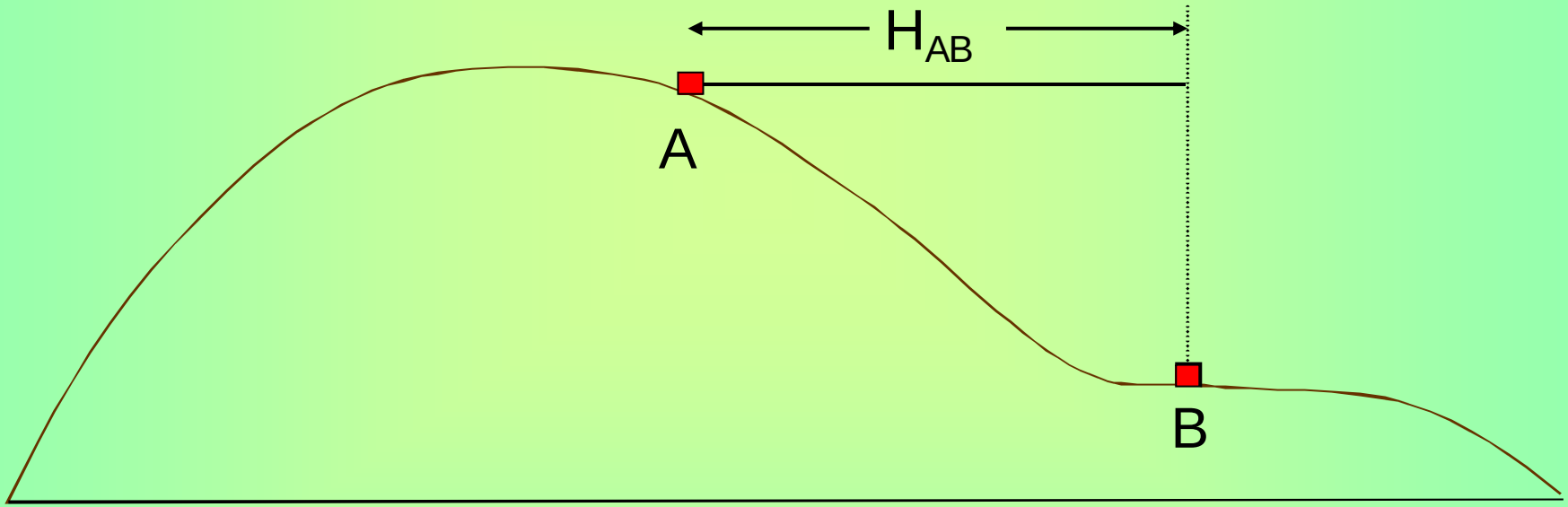
Introduction

- Surveying based on measuring two quantities
- Measurement of linear distances

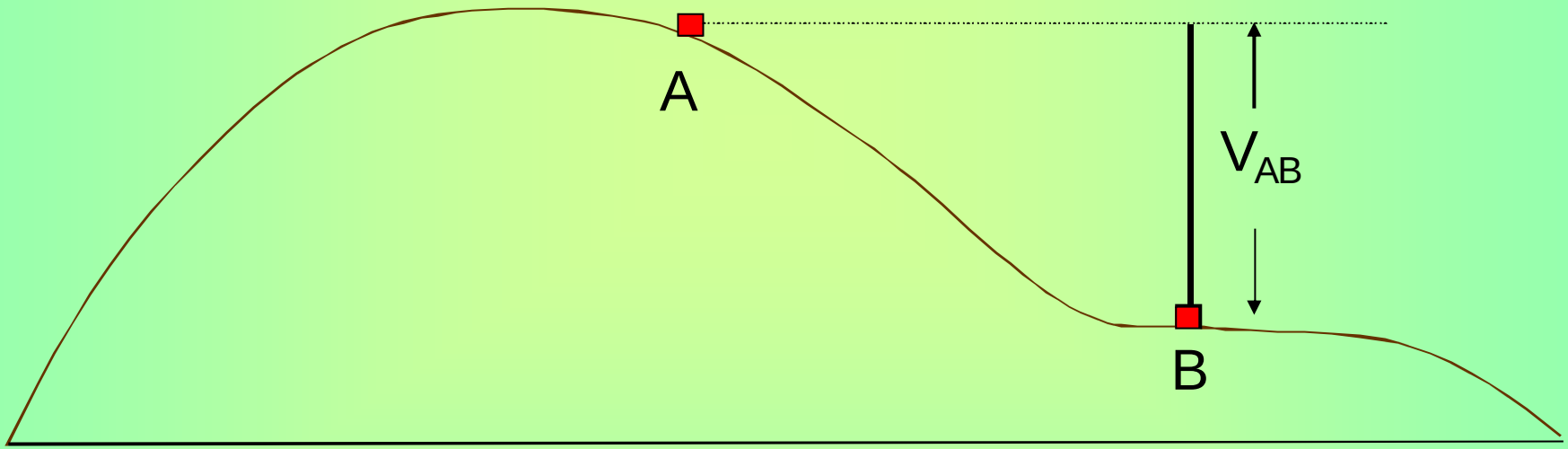
Slope Distance



Horizontal Distance

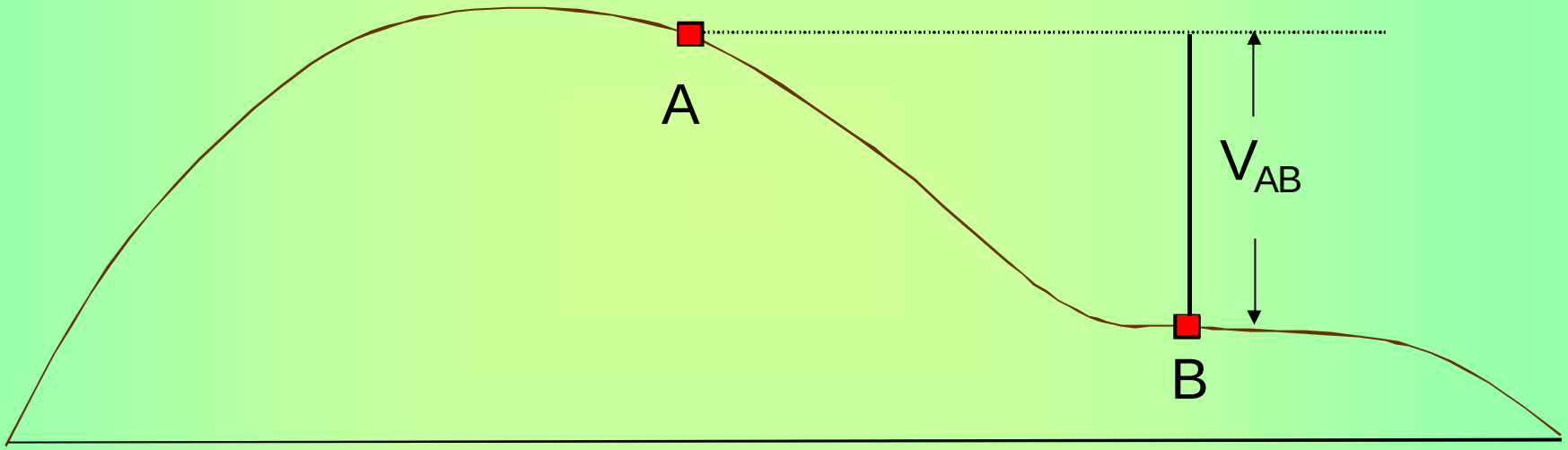


Vertical Distance



Introduction

- Vertical distance measurement = “leveling”



- Includes procedures that determine

Review Ideas and Definitions

- Vertical line
- Level surface (line)
- Horizontal plane (line)
- Vertical datum
- Elevation

Methods

- Traditional methods to determine elevation changes
- Recent approaches

Taping

- Process
- Applications
- Modern variations

Barometric Leveling

- Atmospheric pressure varies inversely with elevation
- Challenges
- Application

Trigonometric Leveling

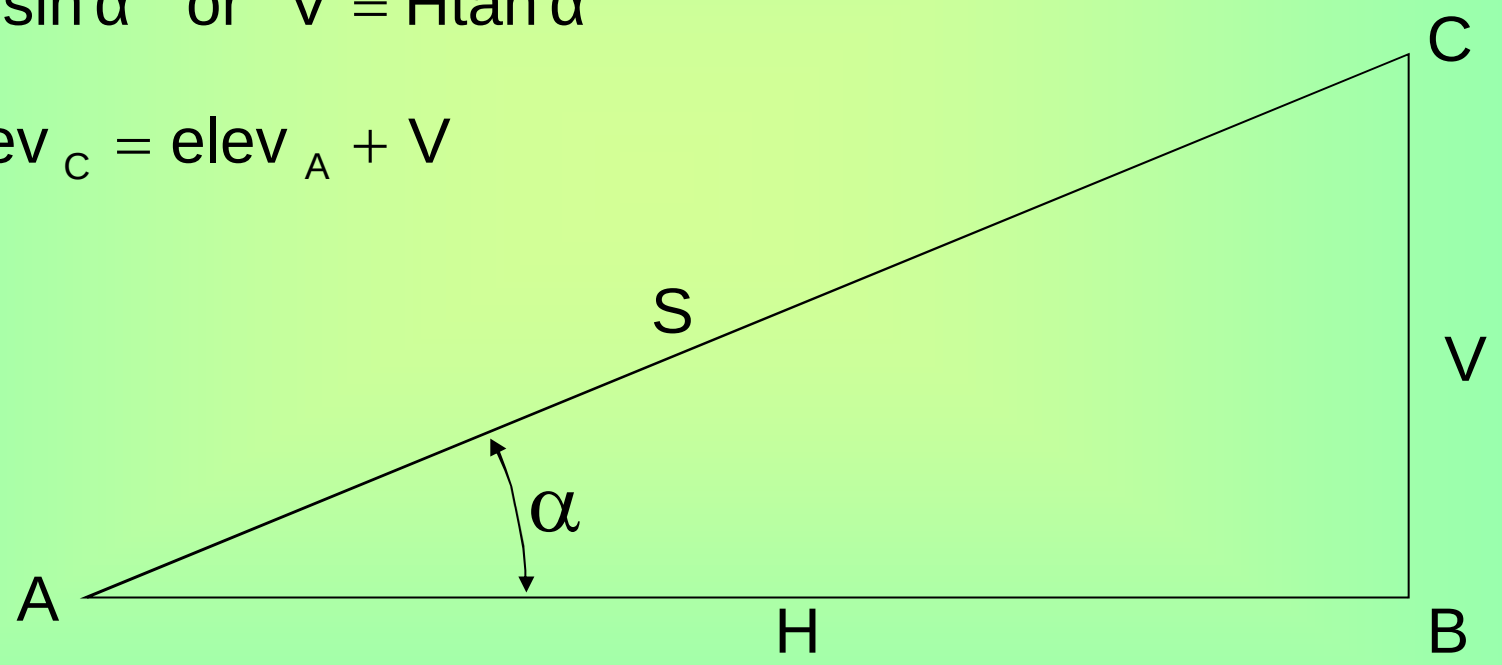
- Compute difference in elevation by measuring
- Measurements required
- Application

Concept of Trigonometric Leveling

- Based on solution of right triangle

$V = S\sin\alpha$ or $V = H\tan\alpha$

$\therefore \text{elev}_C = \text{elev}_A + V$



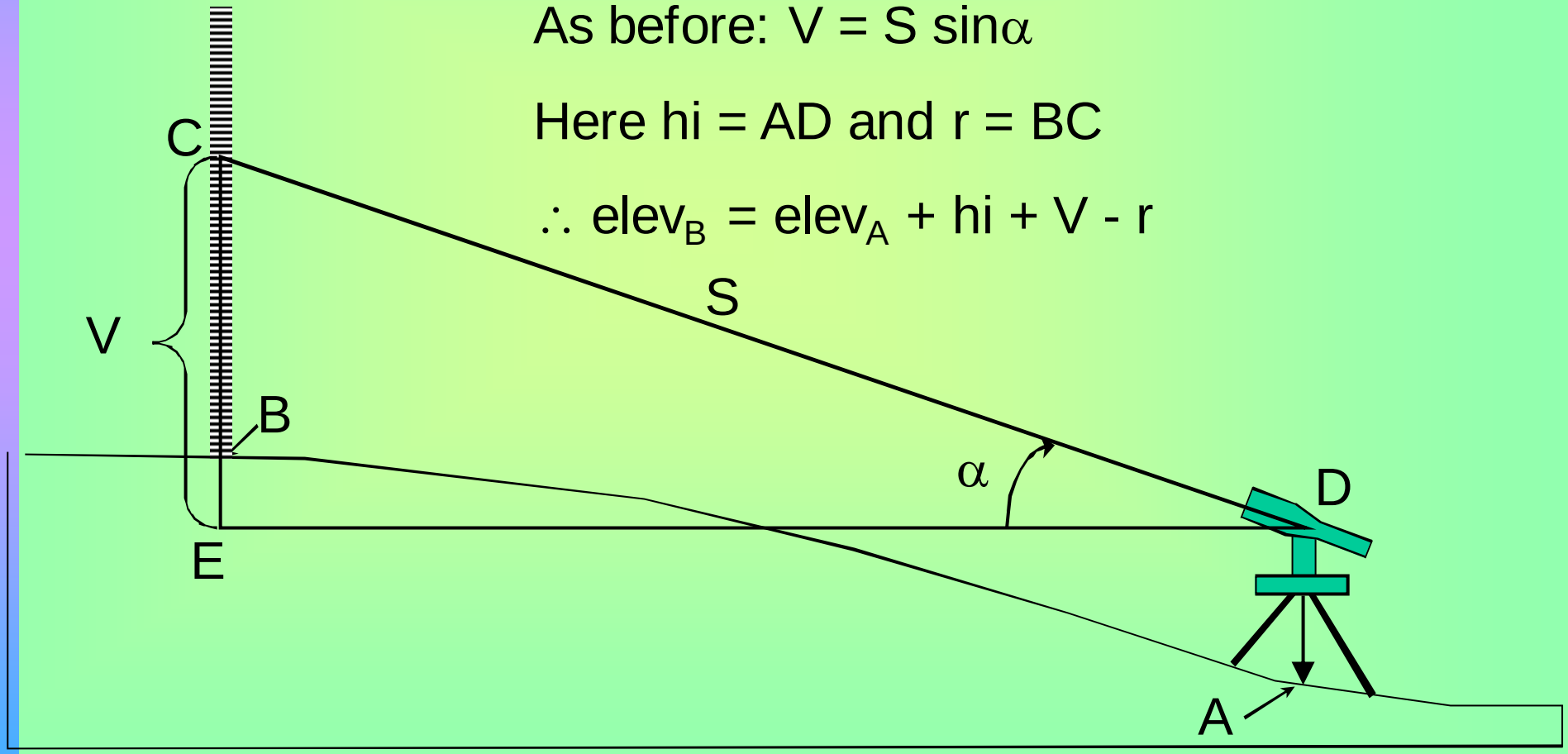
Real Trigonometric Leveling

Know elevation of A: want to find elevation of B

As before: $V = S \sin\alpha$

Here hi = AD and r = BC

$\therefore elev_B = elev_A + hi + V - r$



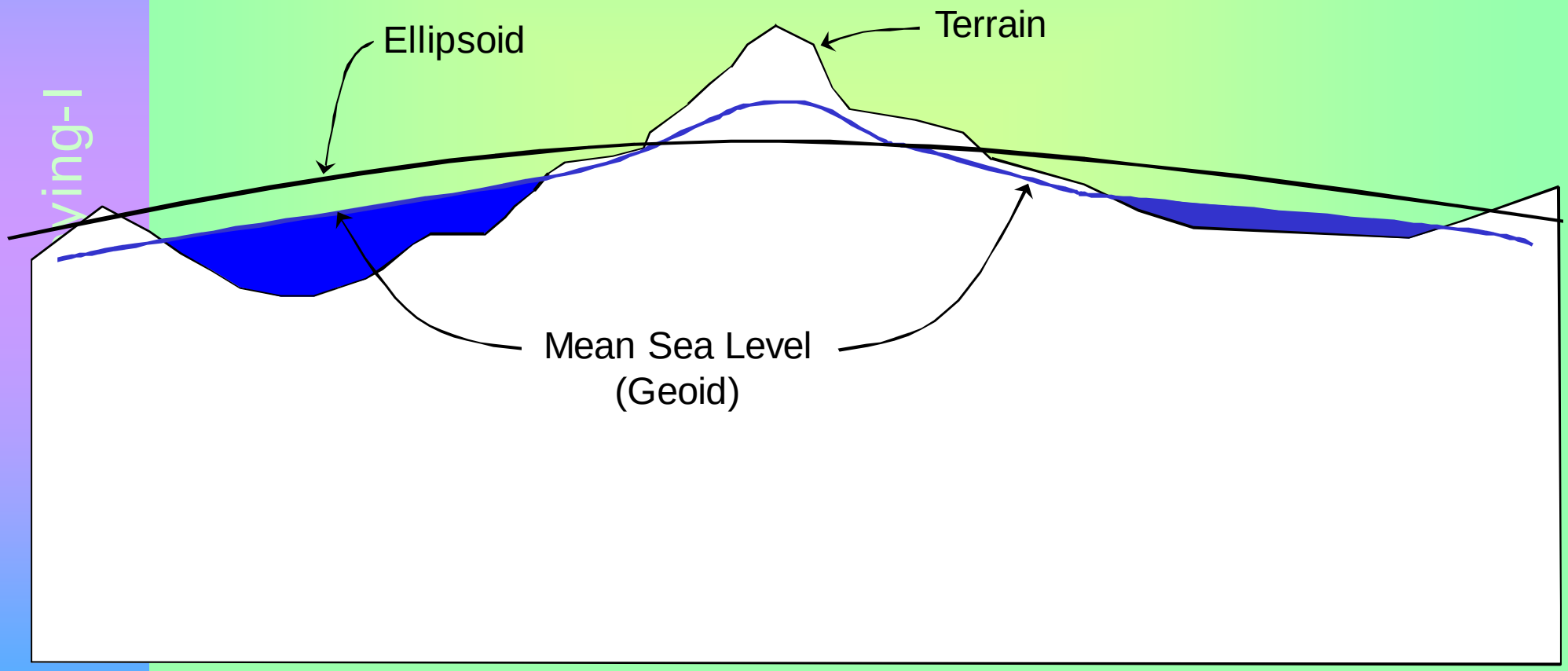
Applying Trigonometric Leveling

- Consider line length
  - Short lines (< ~1000 ft)
  - Longer lines
- Improving accuracy: reciprocal measurements

GPS Leveling

- Modern GPS provides 3D location
- Traditional differential leveling considers gravity
- Concern

Geoid-Ellipsoid Relationship



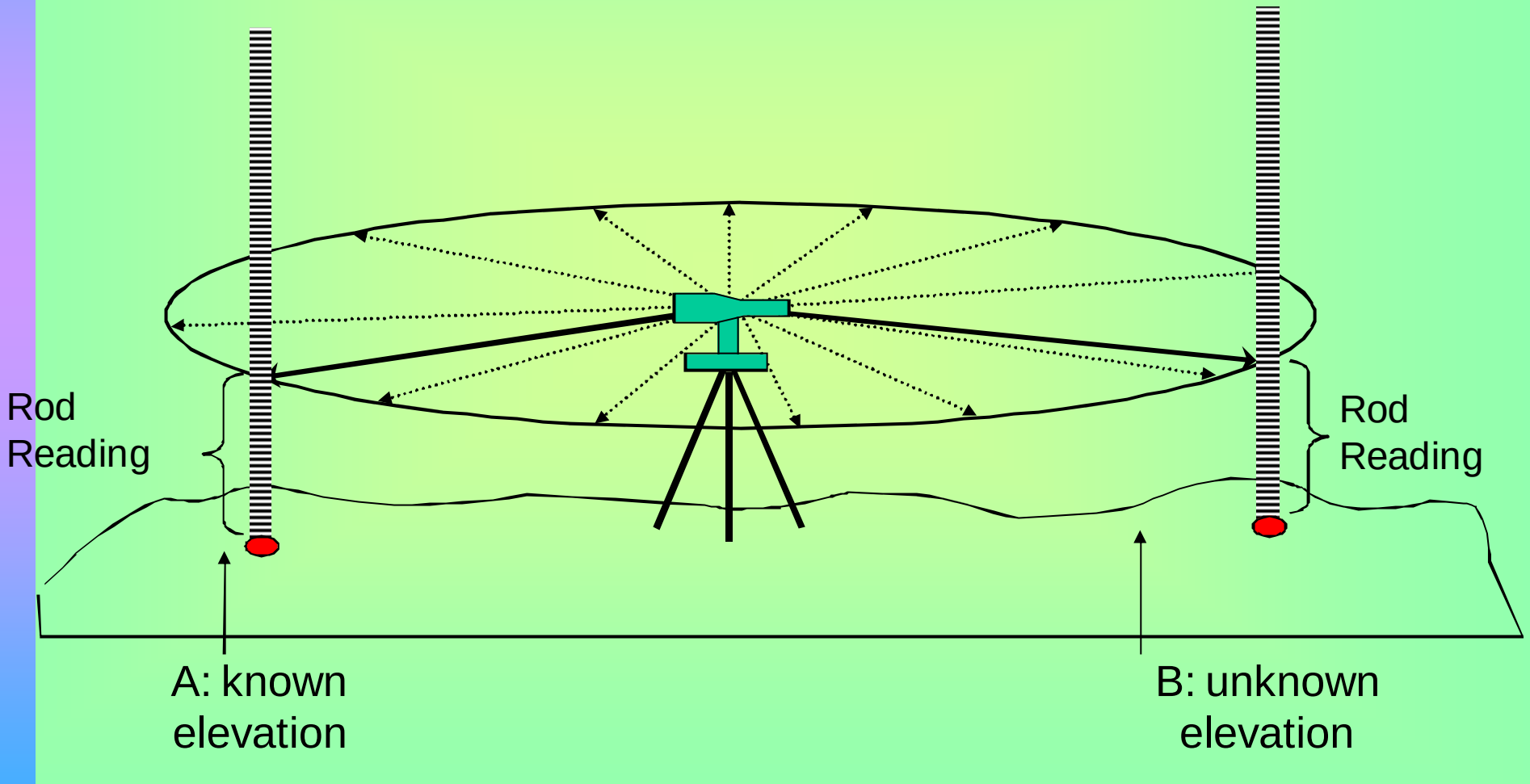
Converting Heights

- Conversions between ellipsoid heights and elevations
- Determining geoid height (N)

Differential Leveling

- Usage
- General concept

Theory of Leveling



Additional Ideas and Definitions

- Benchmark (BM)
- Considerations
- Mean Sea Level (MSL)
- Leveling

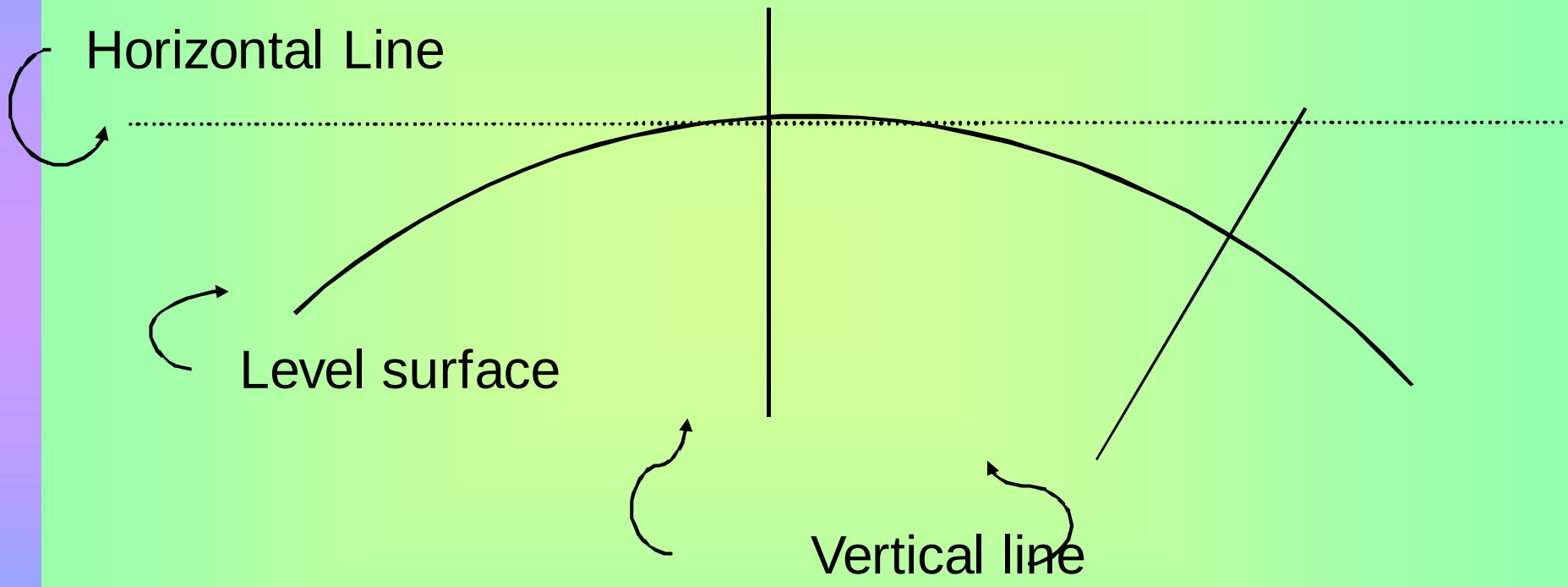
Additional Ideas and Definitions

- National Geodetic Vertical Datum of 1929 (NGVD29)
  - First national datum established
  - Adjustment of 100,000 km of leveling
  - Included long term tidal data → defined MSL
- North American Vertical Datum of 1988 (NAVD88)
  - Updated measurements
  - Adjustment of 625,000 km of leveling (US, Canada, Mexico)
  - Reference surface based on single tide gauge position
  - ∴ No longer referenced to MSL

Earth Curvature

- Earth curvature → horizontal lines ≠ level lines
- Impact

Earth Curvature

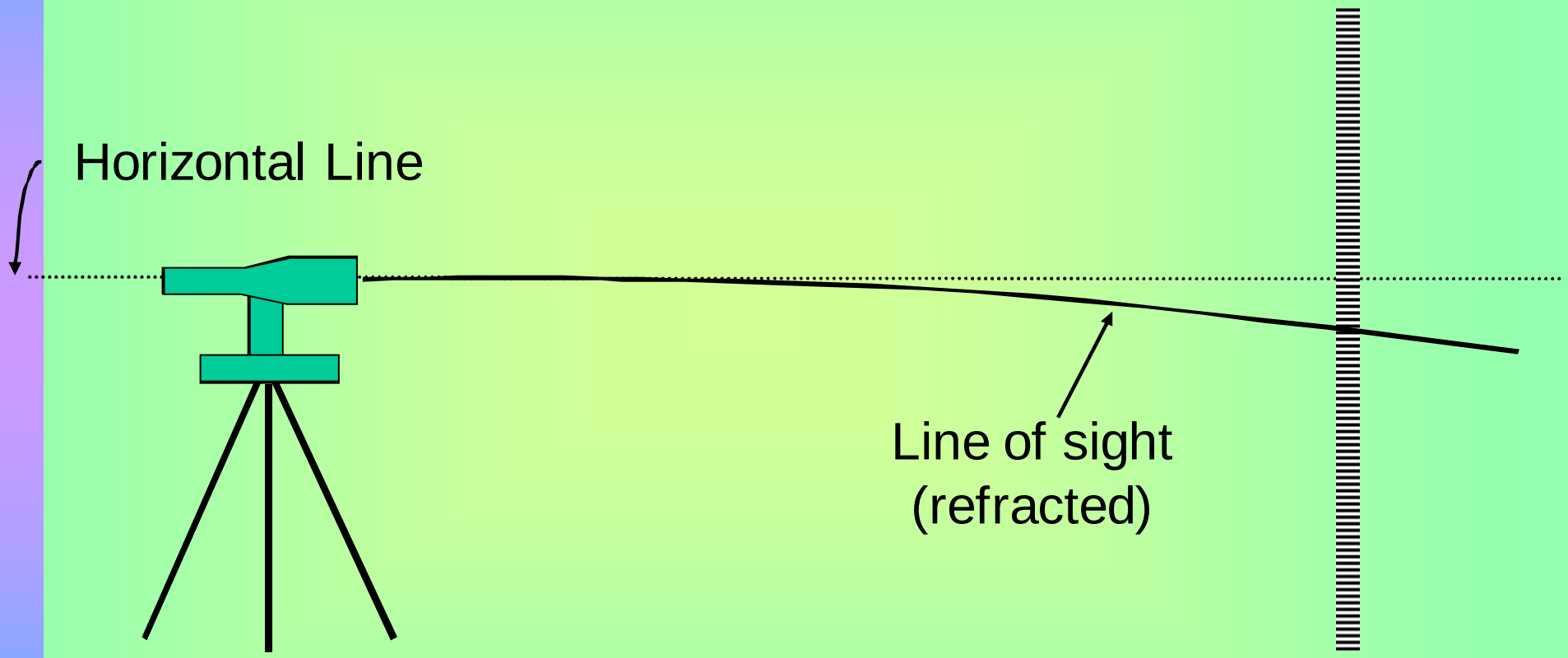


Atmospheric Refraction

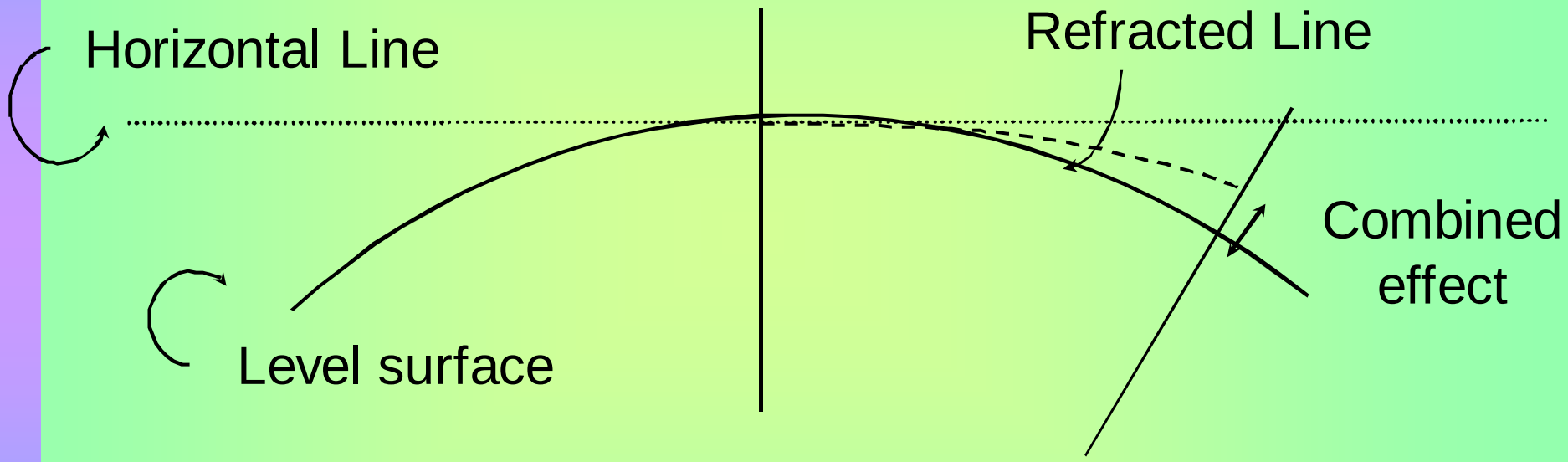
- Atmospheric refraction → horizontal lines ≠ level lines

- Impact

Atmospheric Refraction



Combining Effects



Differential Leveling Equipment

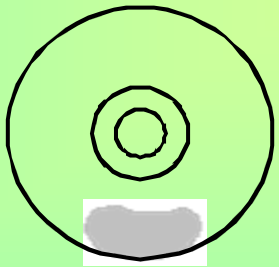
- Fundamentally two types of equipment
  - Level
  - Graduated rod
- Equipment variation

Differential Leveling Equipment

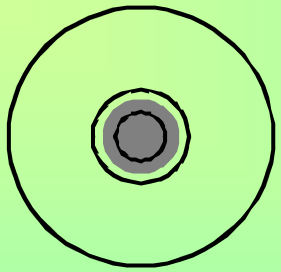
- Types of levels
  - Hand levels
  - Dumpy & Wye levels
  - Tilting levels
  - Automatic levels
  - Digital levels
  - Electronic laser levels

Leveling Instruments

- Dumpy levels
- Automatic levels



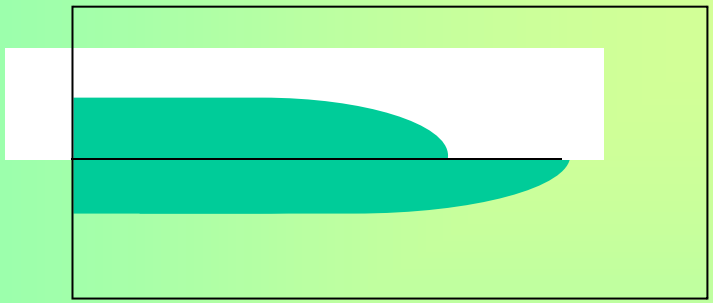
Not Level



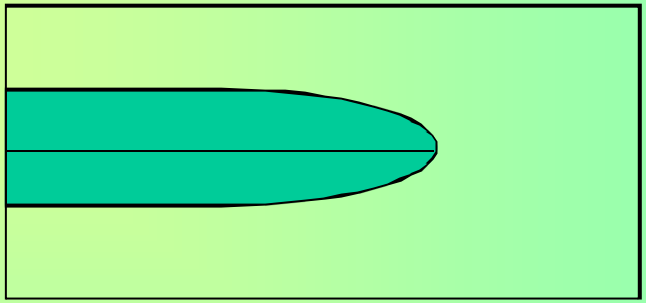
Level

Leveling Instruments

- Tilting levels



Before Coincidence



After Coincidence

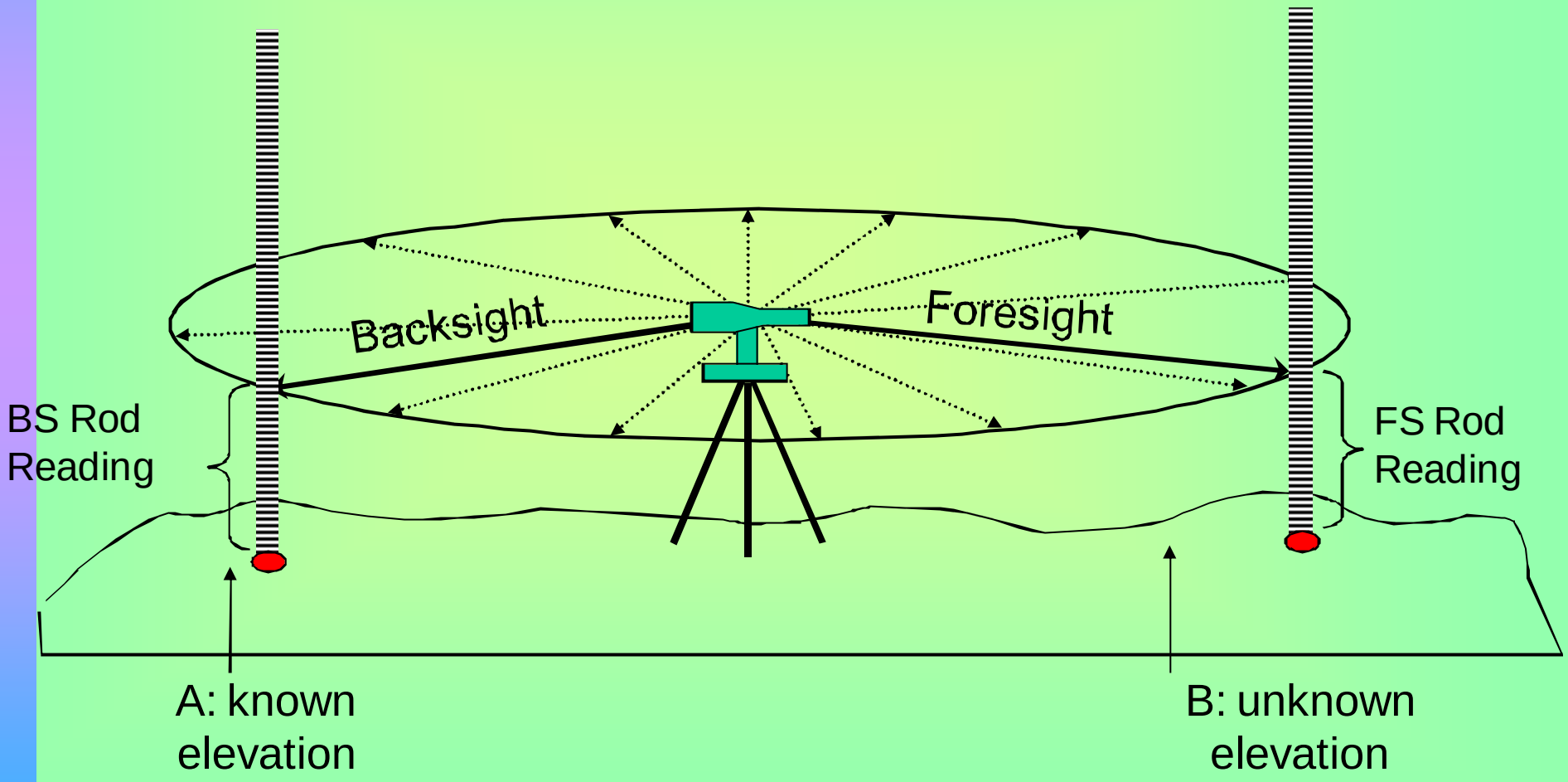
Differential Leveling Equipment

- Rods
  - Made of wood, fiberglass or metal
  - Graduated in decimal feet or decimal meters
- Types of rods
  - Philadelphia rod
  - Metric rod
  - Digital rod
  - Precision rod

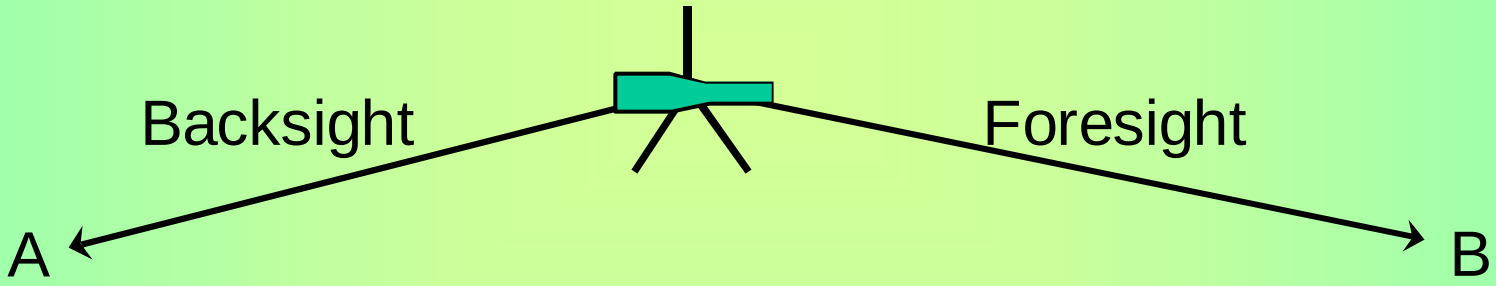
Differential Leveling Measurements

- Establishing horizontal plane
- Measuring vertical distances

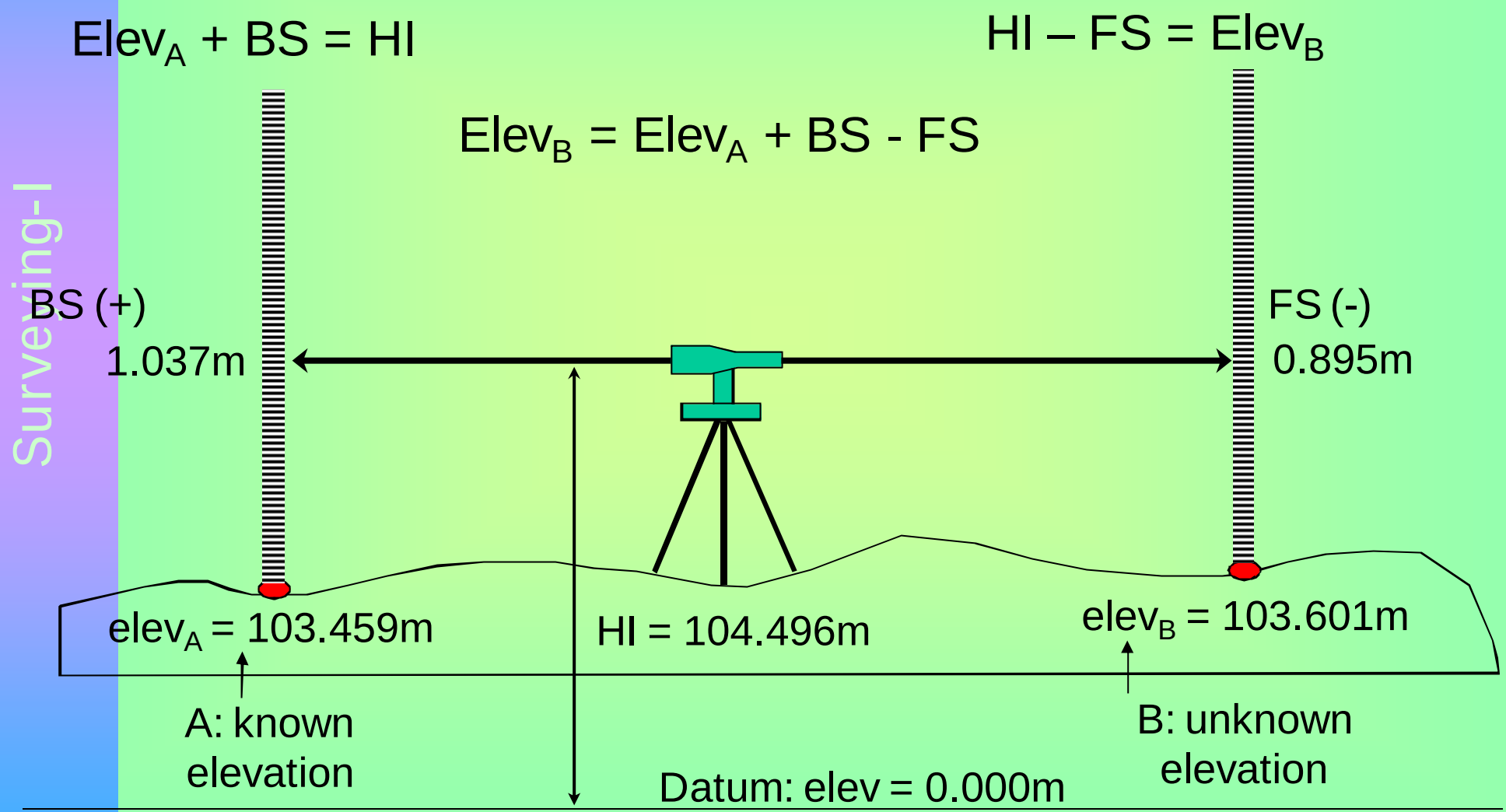
Theory of Leveling



Top View



Side View

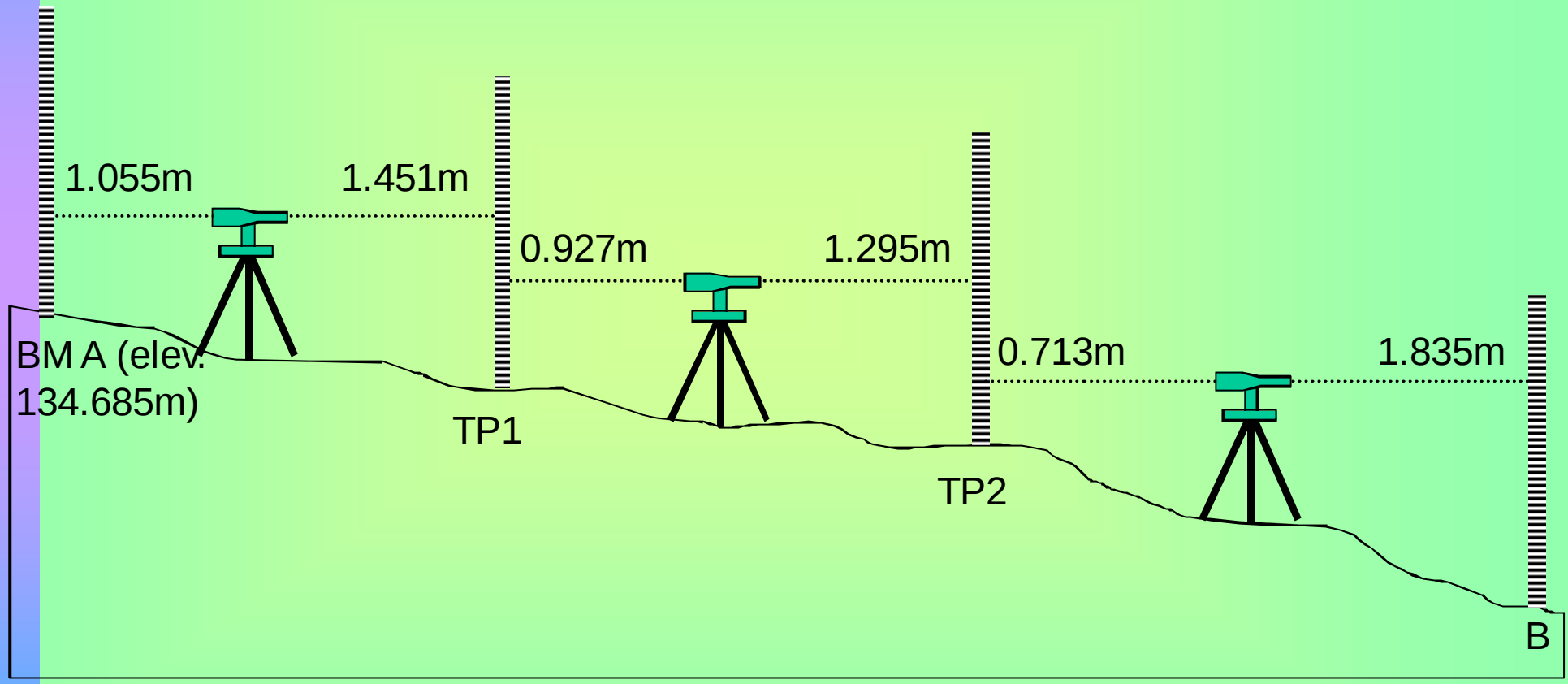


Operations in Differential Leveling

- Cannot usually determine elevation with one setup
- Establish turning points (TPs) and repeat basic process
  - TP characteristics
  - Create line of levels

Differential Leveling Example

Surveying-I



Differential Leveling Field Book

Point	BS(+)	HI	FS(-)	Elev.
BM A	1.055m			134.685m
		135.740m		
TP 1	0.927m		1.451m	134.289m
		135.216m		
TP 2	0.713m		1.295m	133.921m
		134.634m		
B			1.835m	132.799m

Differential Leveling Field Book

Point	BS(+)	HI	FS(-)	Elev.
BM A	1.055m			134.685m
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TP 1	0.927m		1.451m	134.289m
		135.216m		
TP 2	0.713m		1.295m	133.921m
		134.634m		
B	1.756m		1.835m	132.799m
		134.555m		
TP 3	1.533m		0.917m	133.638m
		135.171m		
TP 4	1.384m		0.841m	134.330m
		135.714m		
BM A			1.027m	134.687m

Closure

- General concept
- Level loop closure
- Methods: end on

Level Loop Closure

- Compute closure based on endpoint
- Define allowable closure
- Compare field closure to allowable closure

Differential Leveling Field Book

Point	BS(+)	HI	FS(-)	Elev.
BM A	1.055m			134.685m
		135.740m		
TP 1	0.927m		1.451m	134.289m
		135.216m		
TP 2	0.713m		1.295m	133.921m
		134.634m		
B	1.756m		1.835m	132.799m
		134.555m		
TP 3	1.533m		0.917m	133.638m
		135.171m		
TP 4	1.384m		0.841m	134.330m
		135.714m		
BM A			1.022m	134.692m

- Loop Closure = 134.692m – 134.685 m = 0.007m
- Allowable closure = 6 mm $\sqrt{6}$ = 14.6 mm $\therefore$ acceptable

Page Checks

- Leveling notes → lots of arithmetic
- For each page of notes
- Page checks only show arithmetic mistakes

Page Check

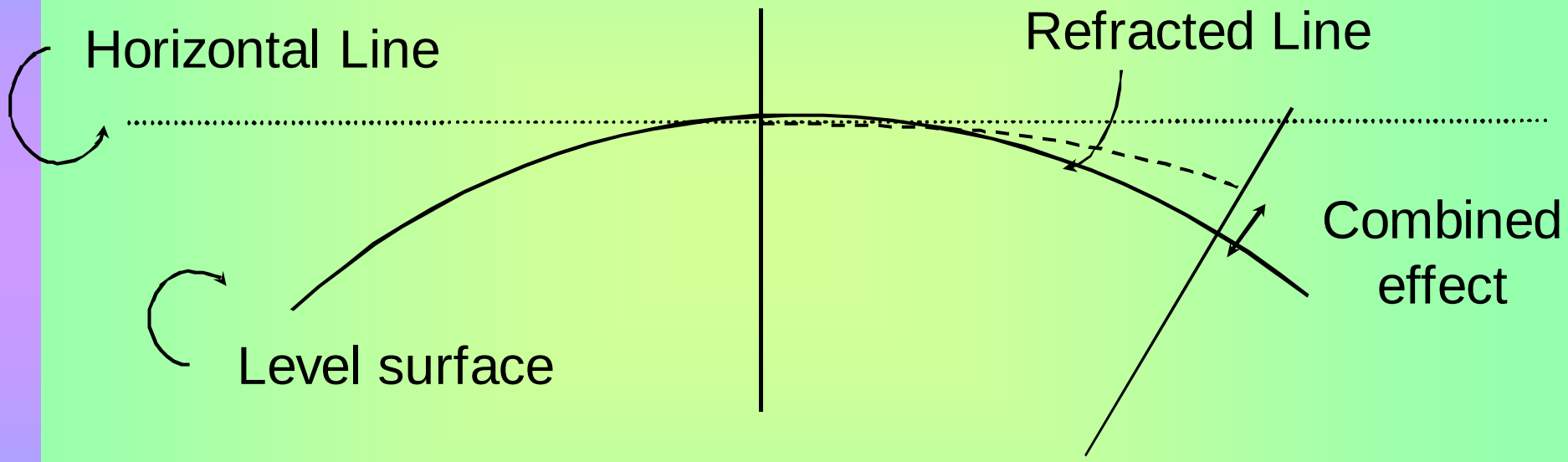
Point	BS(+)	HI	FS(-)	Elev.
BM A	1.055m			134.685m
		135.740m		
TP 1	0.927m		1.451m	134.289m
		135.216m		
TP 2	0.713m		1.295m	133.921m
		134.634m		
B	1.756m		1.835m	132.799m
		134.555m		
TP 3	1.533m		0.917m	133.638m
		135.171m		
TP 4	1.384m		0.841m	134.330m
		135.714m		
BM A			1.022m	134.692m
Sum	7.368m		7.361m	

- $\Sigma BS - \Sigma FS = 7.368m - 7.361m = 0.007m$
- $Elev_{Bottom} - Elev_{Top} = 134.692m - 134.685m = 0.007m$ ✓

Differential Leveling Errors & Mistakes

- Instrumental errors
- Personal errors
- Natural errors
- Mistakes

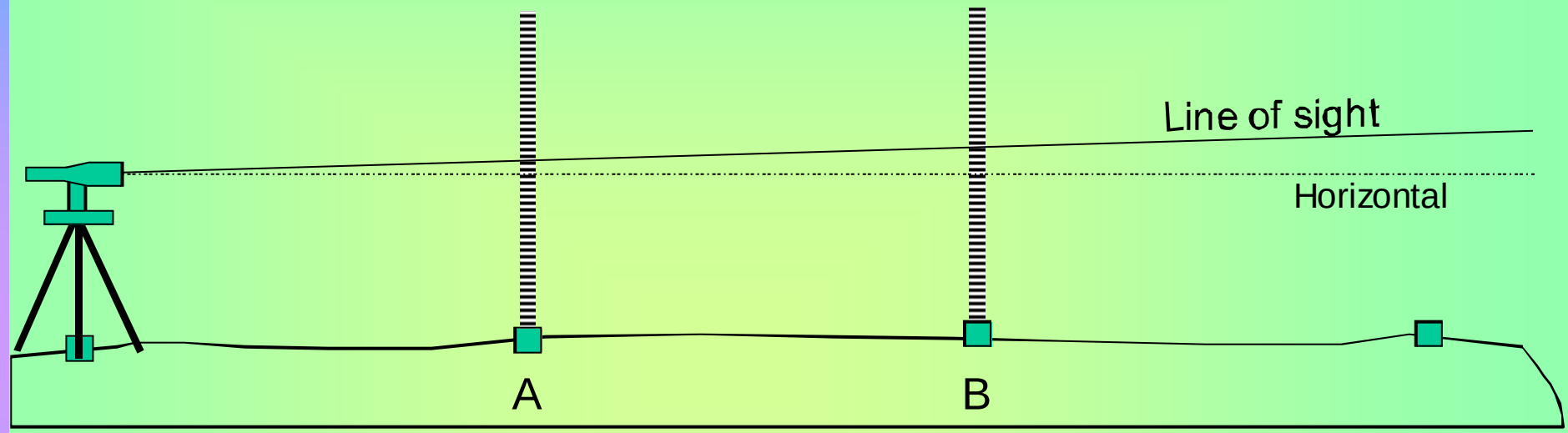
Earth Curvature and Refraction

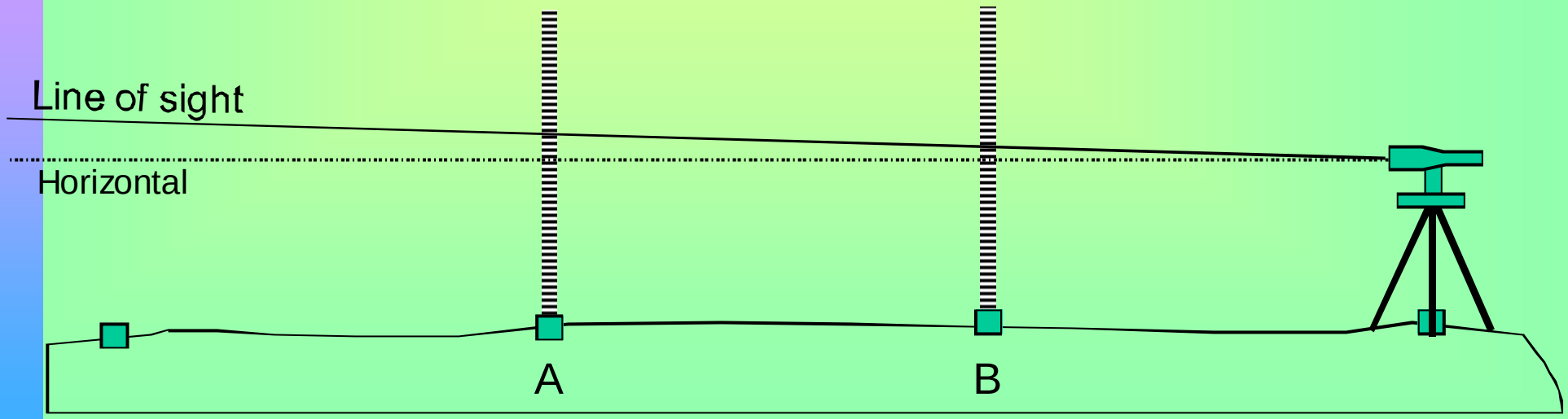


Line of Sight Error

- Issue
- Impact
- Solution

Collimation Error – Two Peg Test

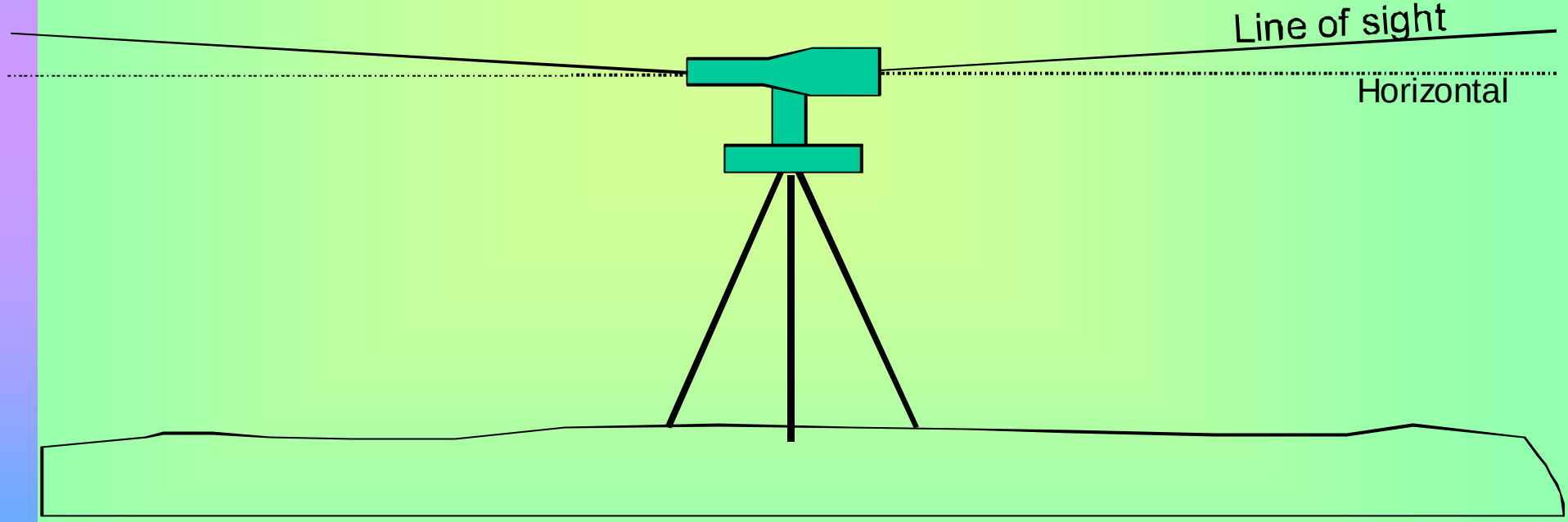




Balancing Foresights & Backsights

- Issue
- Solution
- In practice

Balancing FSs and BSs



Differential Leveling Errors

- Procedures to mitigate errors and mistakes

Level Loop Adjustment

- Purpose of adjustment

- Methods for adjusting based on:

Level Loop Adjustment

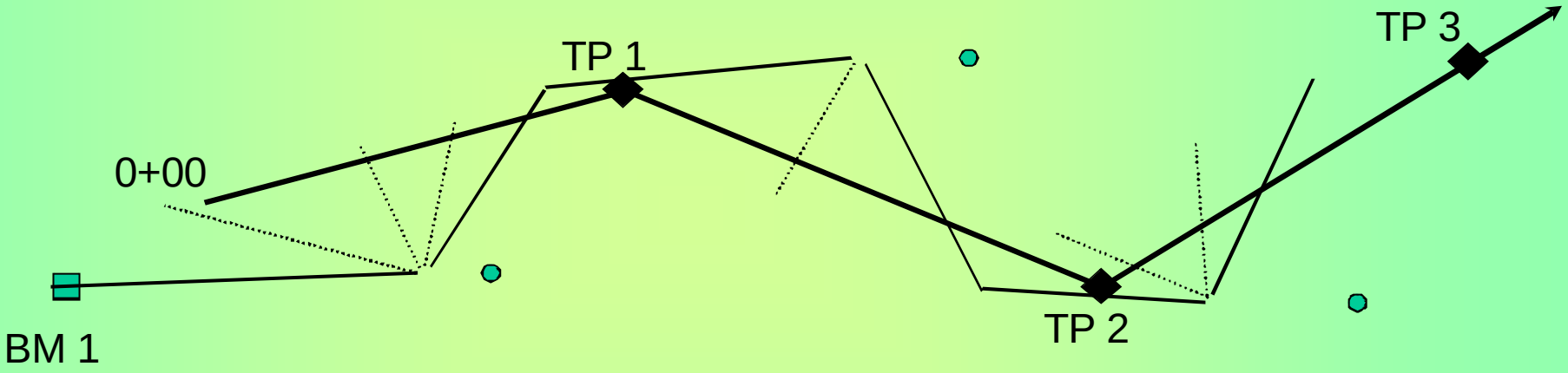
Point	Elev.	Correction	Corrected Elev.
BM A	134.685m		134.685m
TP 1	134.289m	-0.001 m	134.288m
TP 2	133.921m	-0.002 m	133.919m
B	132.799m	-0.004 m	132.795m
TP 3	133.638m	-0.005 m	133.633m
TP 4	134.330m	-0.006 m	134.324m
BM A	134.692m	-0.007 m	134.685m

- Computed closure = 0.007m
- 6 setups → increments of 0.007m/6 = -0.0012m

Profile Leveling

- Process
- Variation of differential leveling
- Issues

Profile Leveling



- Turning points
- Instrument location
- Benchmark

- Backsight/Foresight
- Intermediate sight

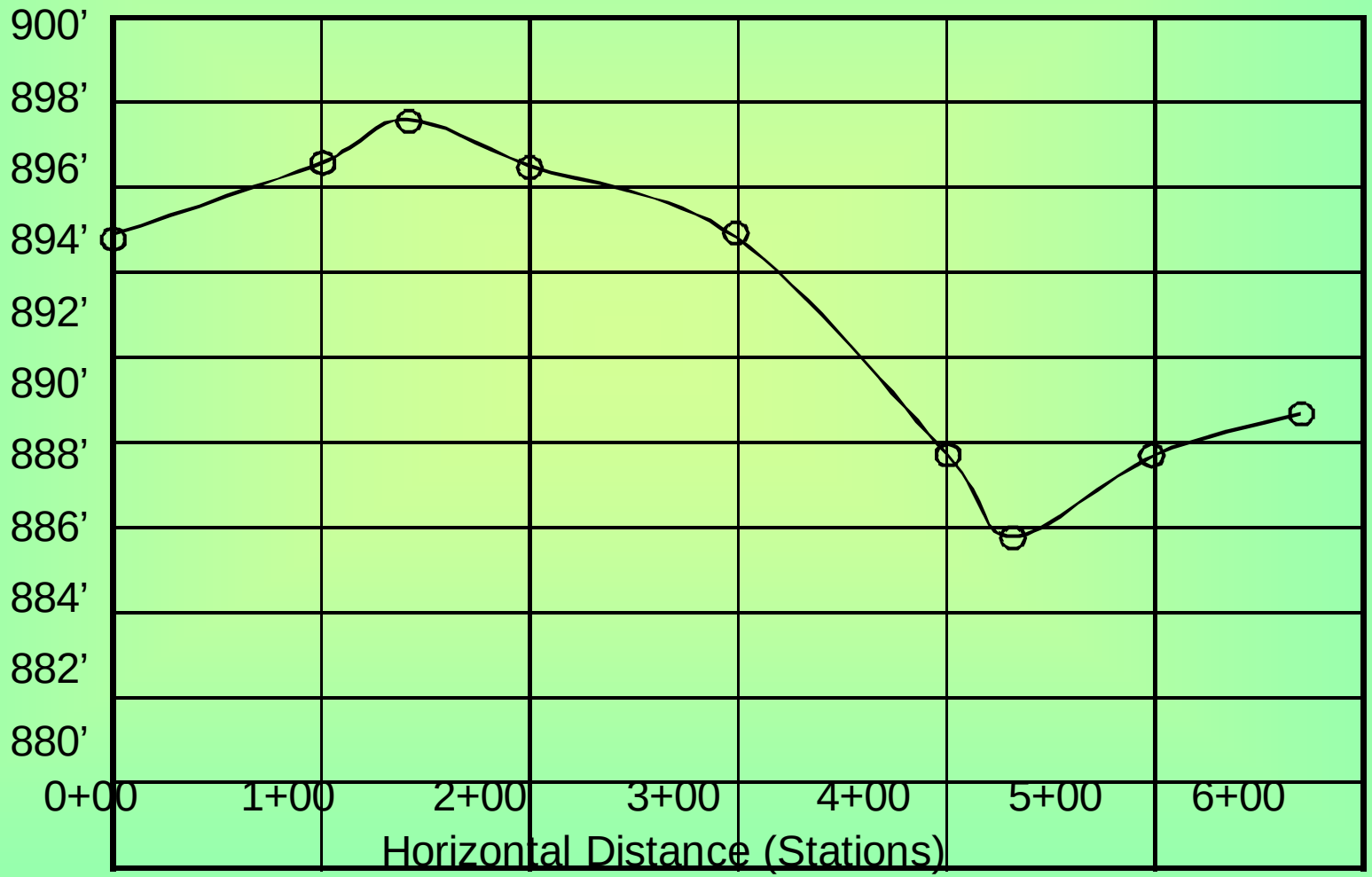
Profile Notes and Plots

- Notes
- Profile plots
- Cross-section leveling very similar

Profile Leveling Notes

Station	BS(+)	HI	FS(-)	IS	Elev.
BM 1	4.18’				895.06’
0+00		899.24’		5.1’	894.1
1+00				3.2’	896.0
1+43.52				2.0’	897.2
TP 1	2.25’		3.31’		895.93
3+00		898.18’		4.1’	894.1
TP 2	4.37’		10.13’		888.05
4+26.89		892.42’		6.6’	885.8

Profile Leveling



Thanks