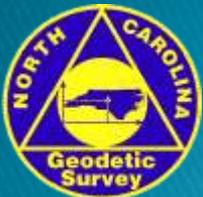


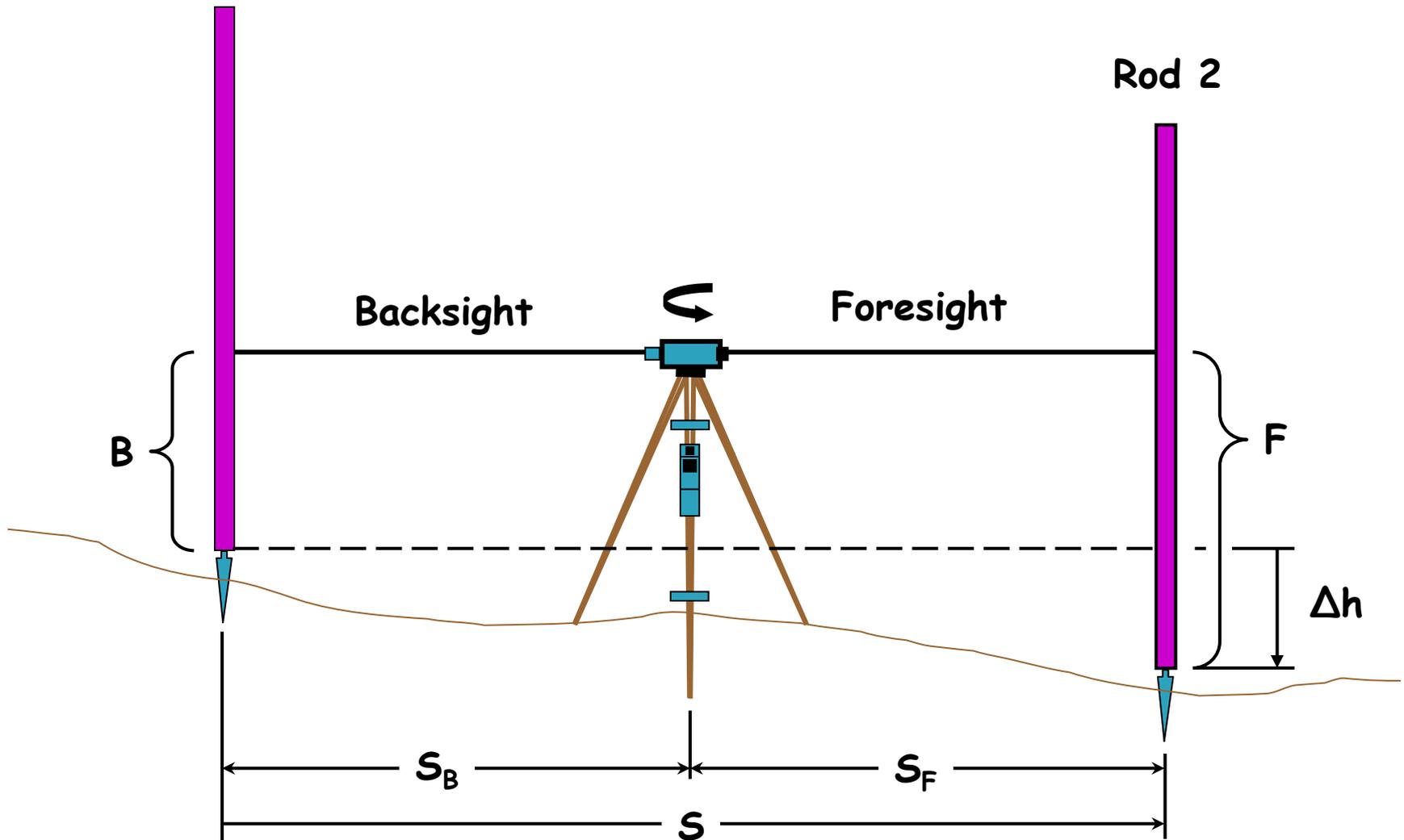
Introduction to Leveling

Differential and Trigonometric

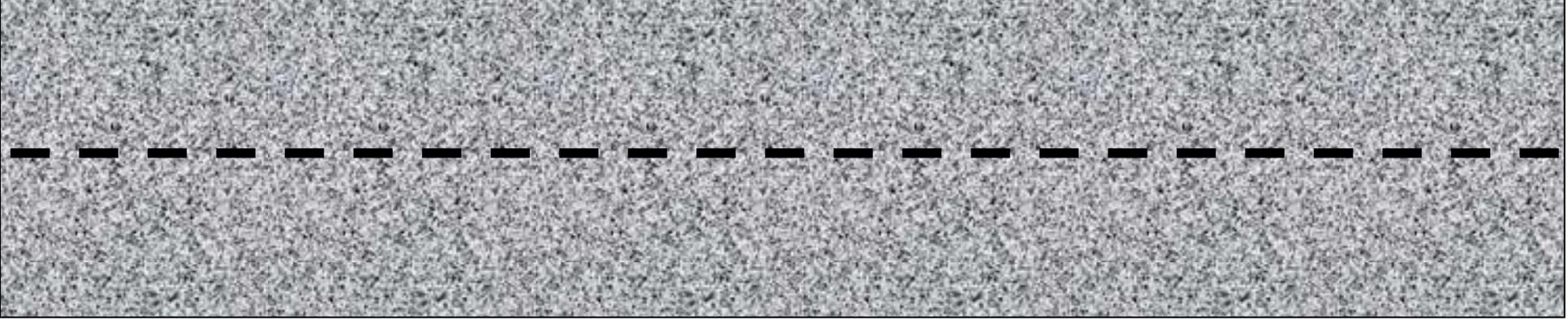
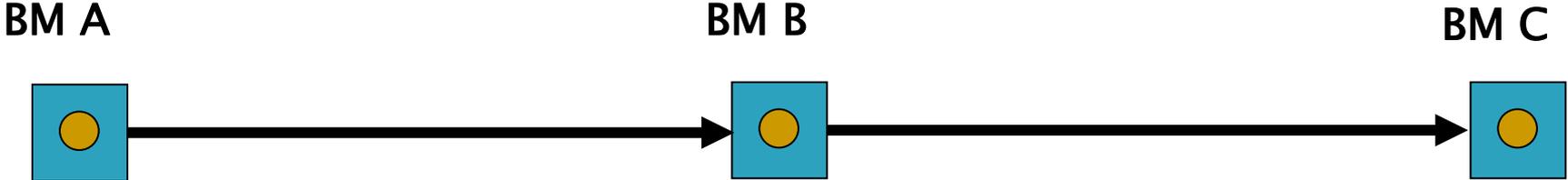


Setup of Leveling, $\Delta h = B - F$ and $S = S_B + S_F$

Rod 1

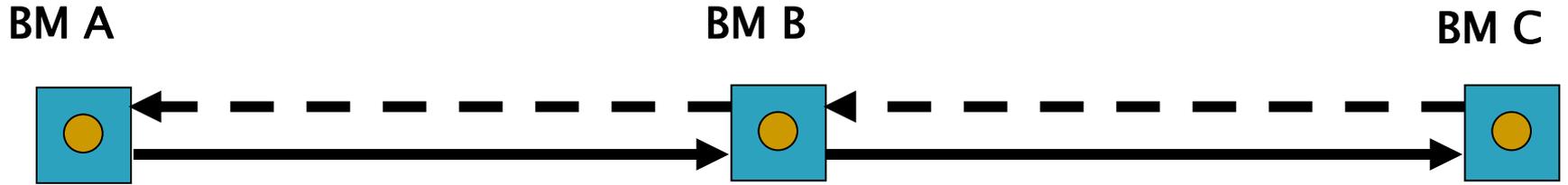


Single Run



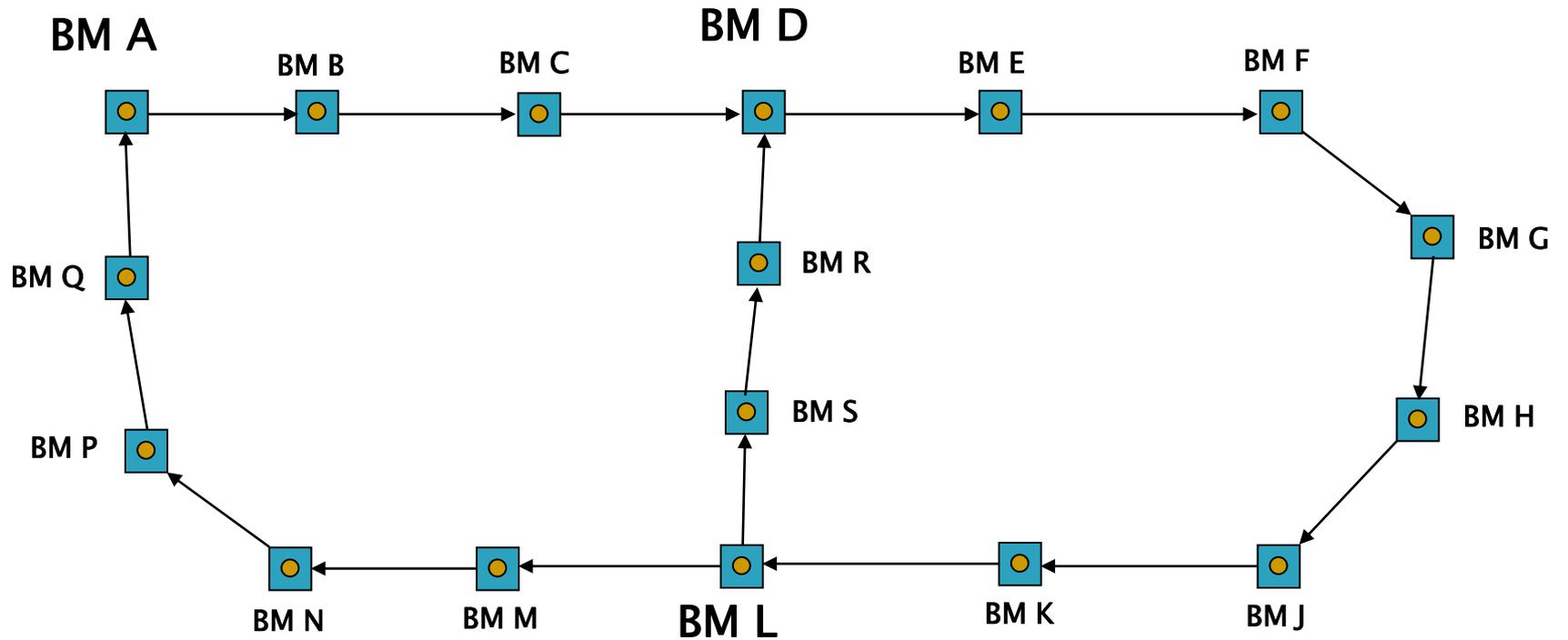
 BM = Bench Mark
 = One Way Leveling

Double Run



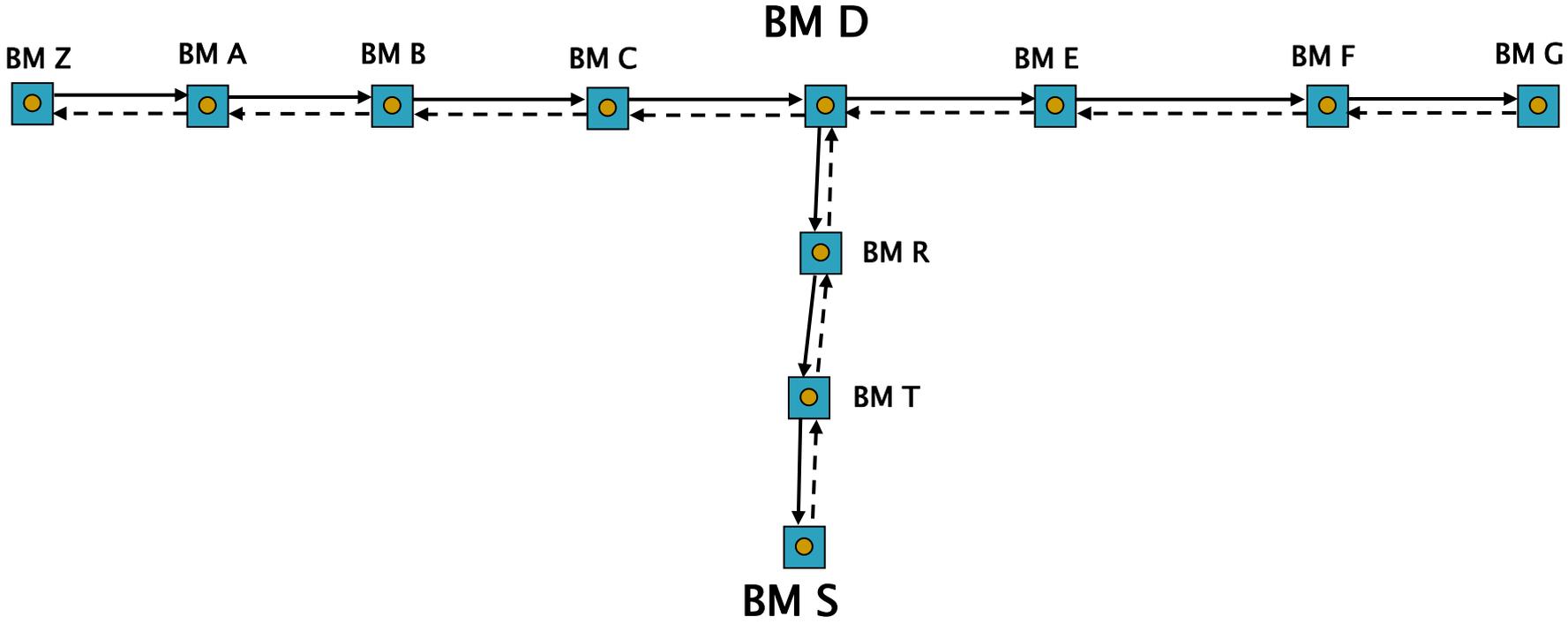
-  BM = Bench Mark
-  = Forward Running
-  = Backward Running

Level Loop(s)



 BM = Bench Mark
→ = Forward Running

Level Spur



- BM = Bench Mark
- = Forward Running
- ← - - = Backward Running



Turning Pin - Cap Off



Turning Pin - Cap On



Turning Pin Setup - Cap Off



**Rod on Turning Pin
Using Centering Guide**



“Turtle” with Removable Pointed Feet

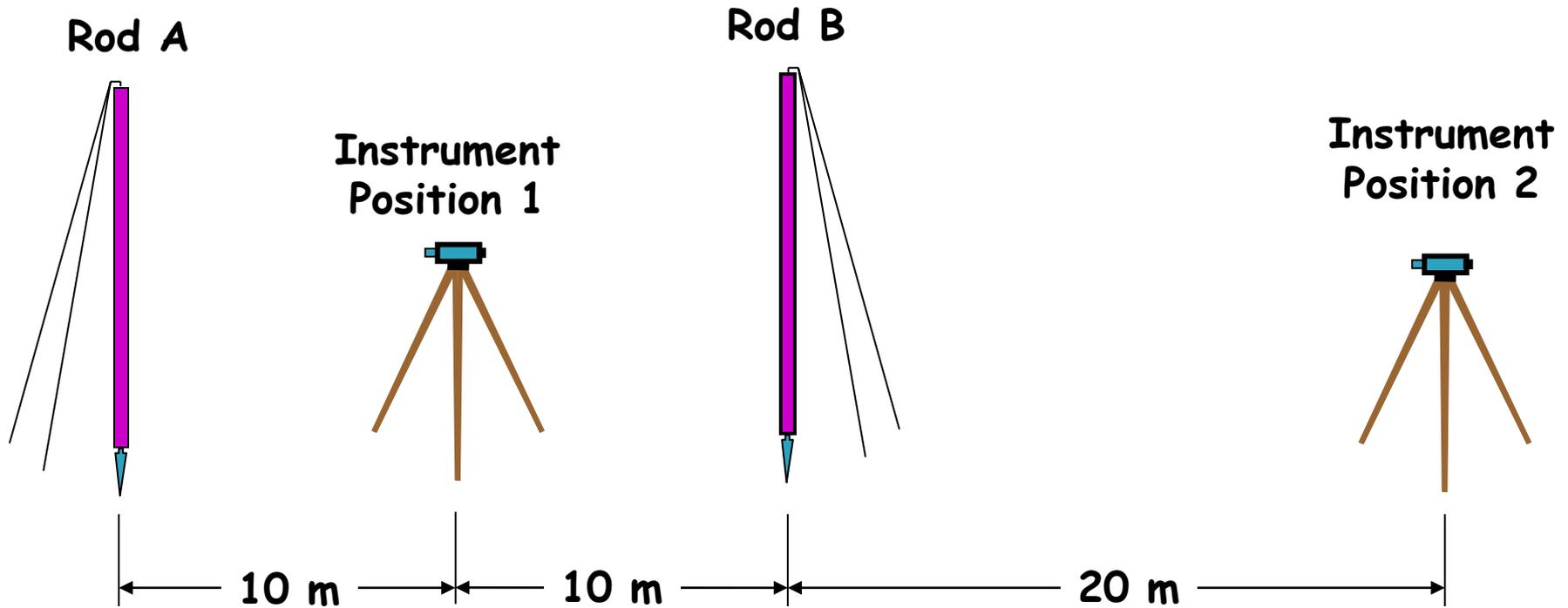


Collimation Check

- Allow instrument and rods to acclimate prior to performing the collimation and/or leveling (allow equipment to adjust to the working environment for 10 minutes or more)
- Perform Collimation Check on level ground at the work site in the work environment
- Perform a Collimation Check at the beginning of every day that geodetic leveling is performed or when the level is jarred or any time there is a question about the instrument

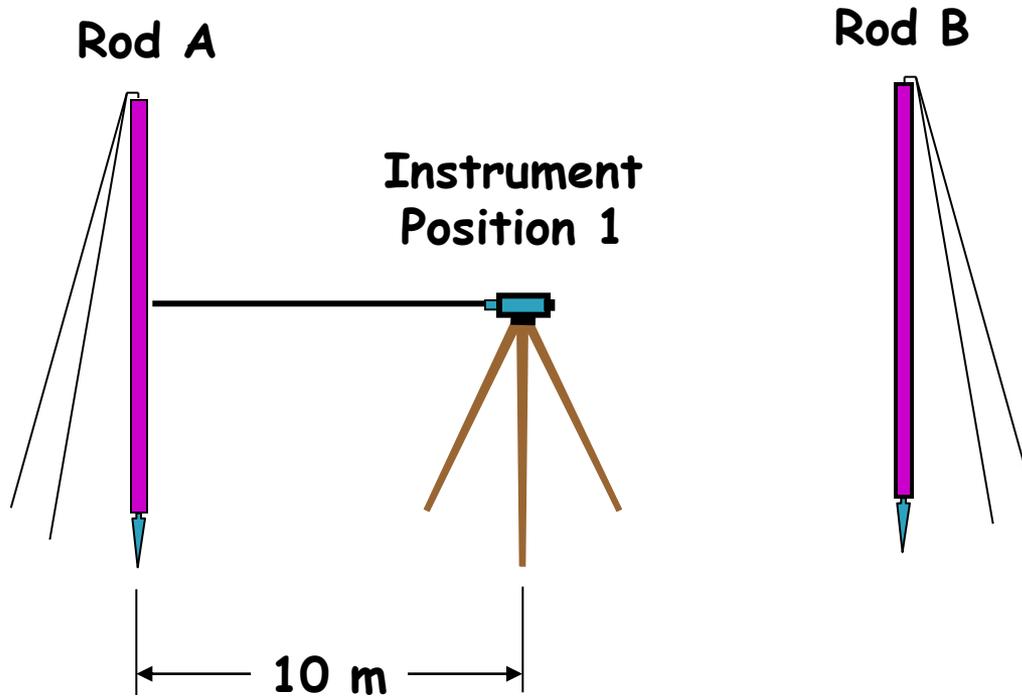
Collimation Check - Kukkamaki Method

$A \times B \times$



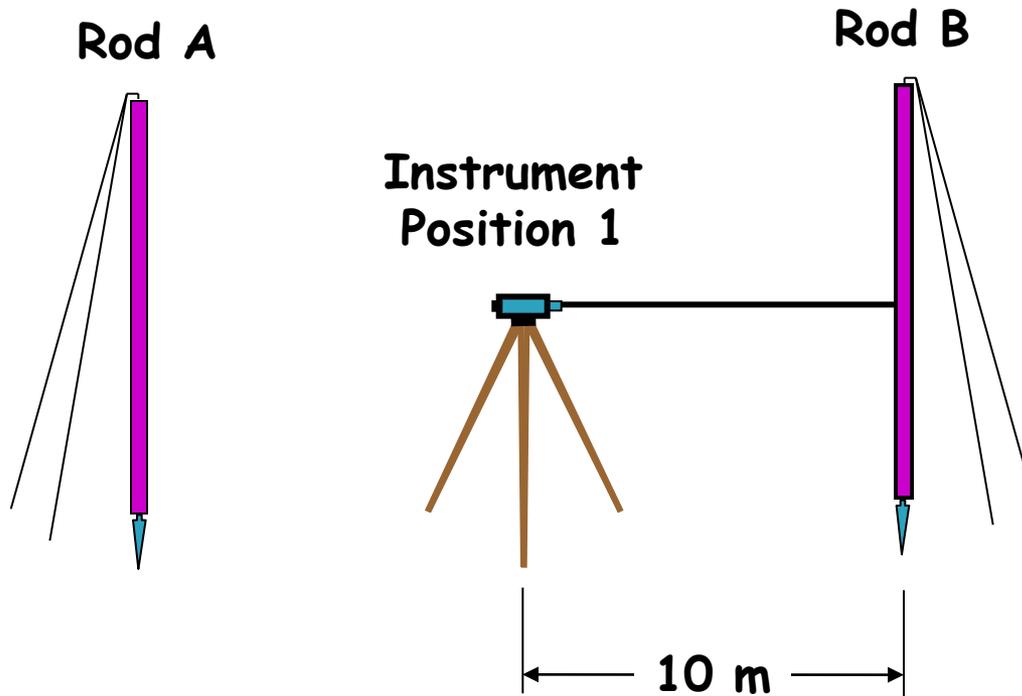
Collimation Check - Kukkamaki Method

A x B x



Collimation Check - Kukkamaki Method

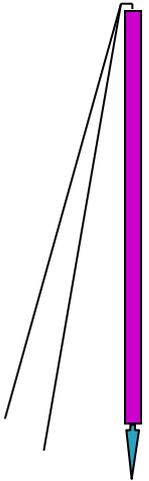
$A \times B \times$



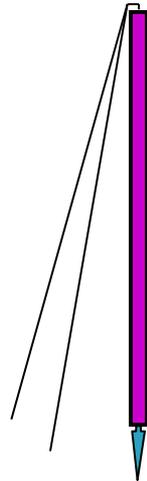
Collimation Check - Kukkamaki Method

A x B x

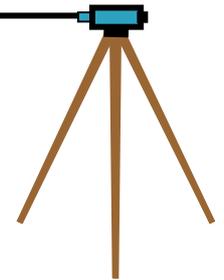
Rod A



Rod B



Instrument
Position 2

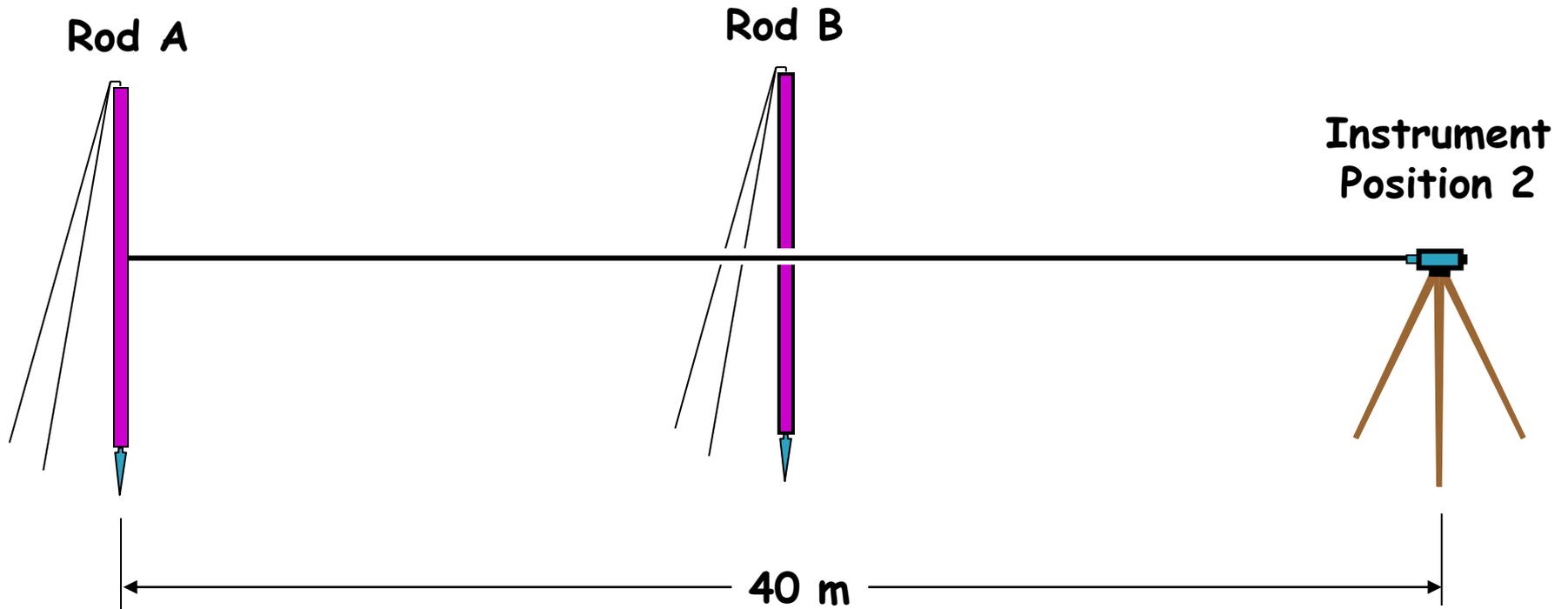


20 m



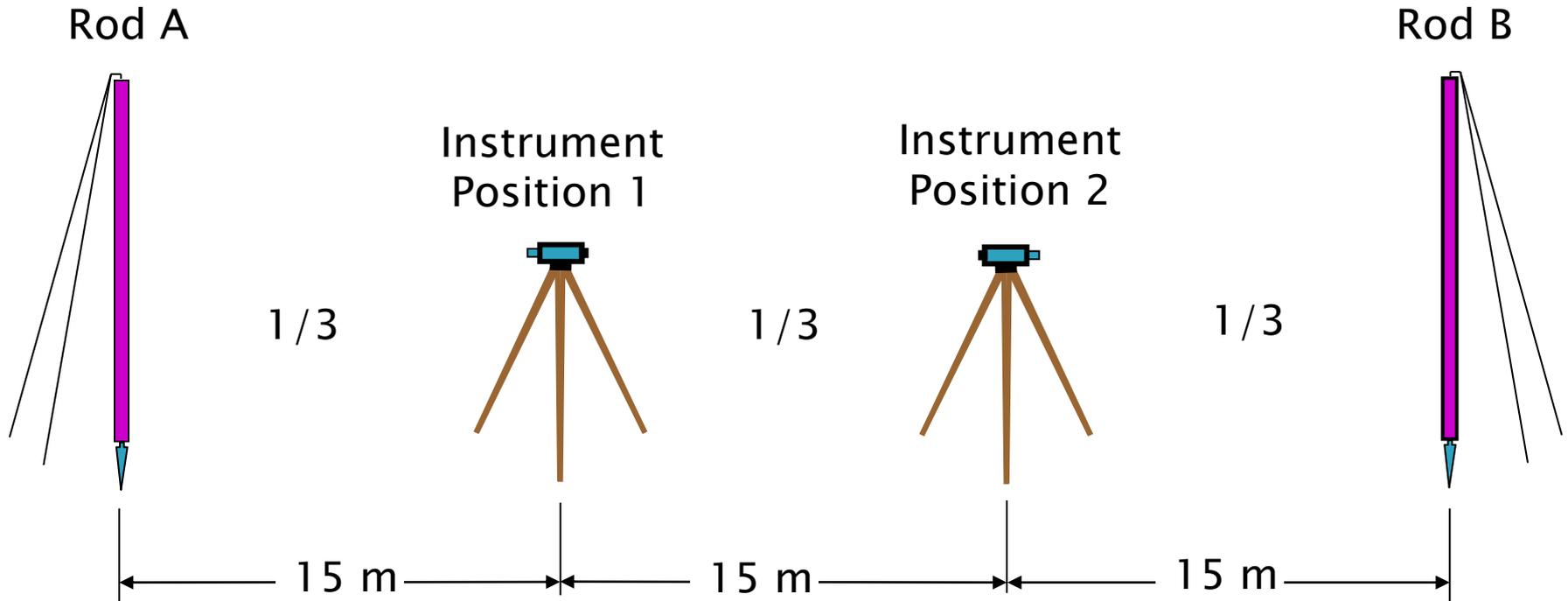
Collimation Check - Kukkamaki Method

A x B x



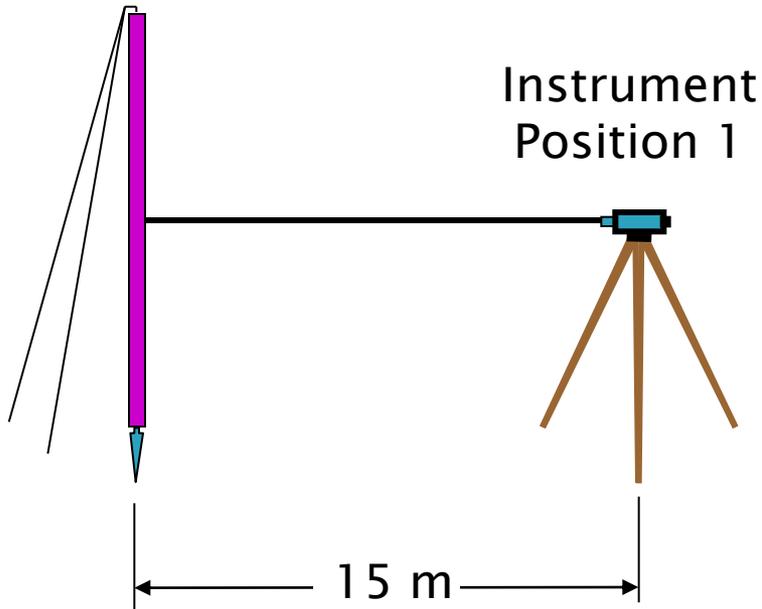
Collimation Check – Förstner Method

A x x B

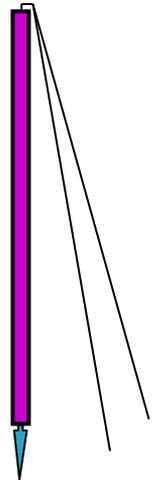


Collimation Check – Förstner Method A x x B

Rod A



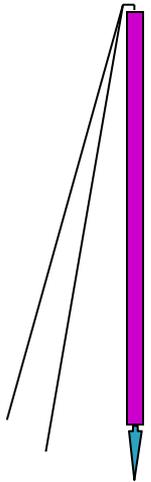
Rod B



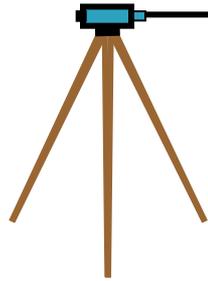
Collimation Check – Förstner Method

A x x B

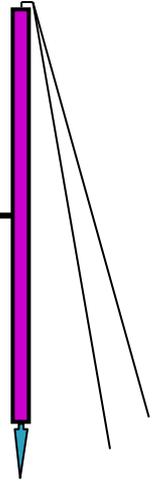
Rod A



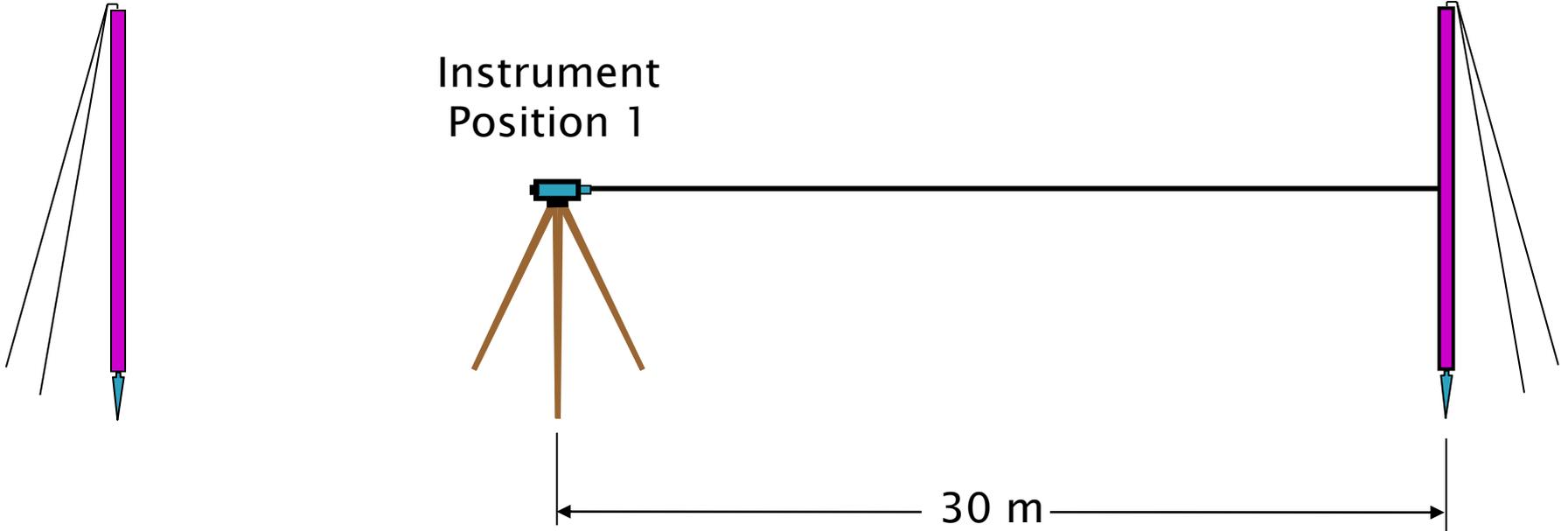
Instrument
Position 1



Rod B

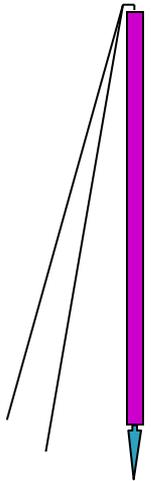


30 m



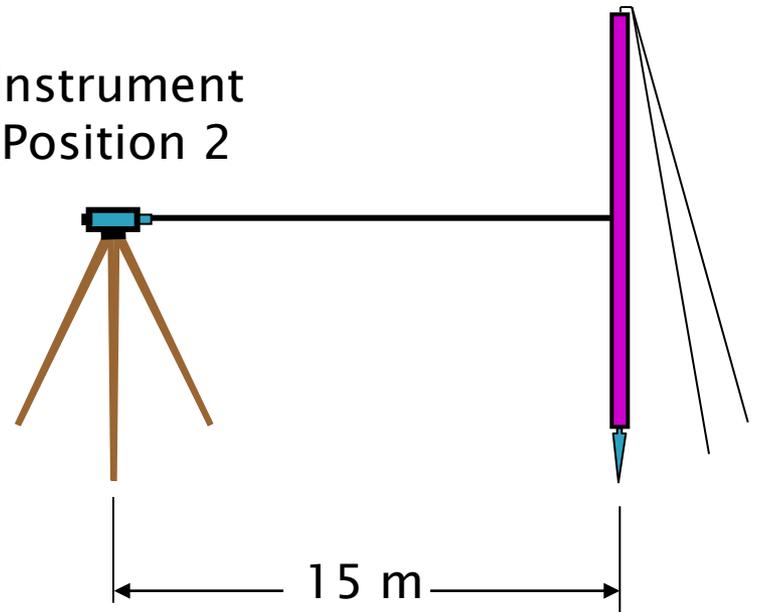
Collimation Check – Förstner Method A x x B

Rod A

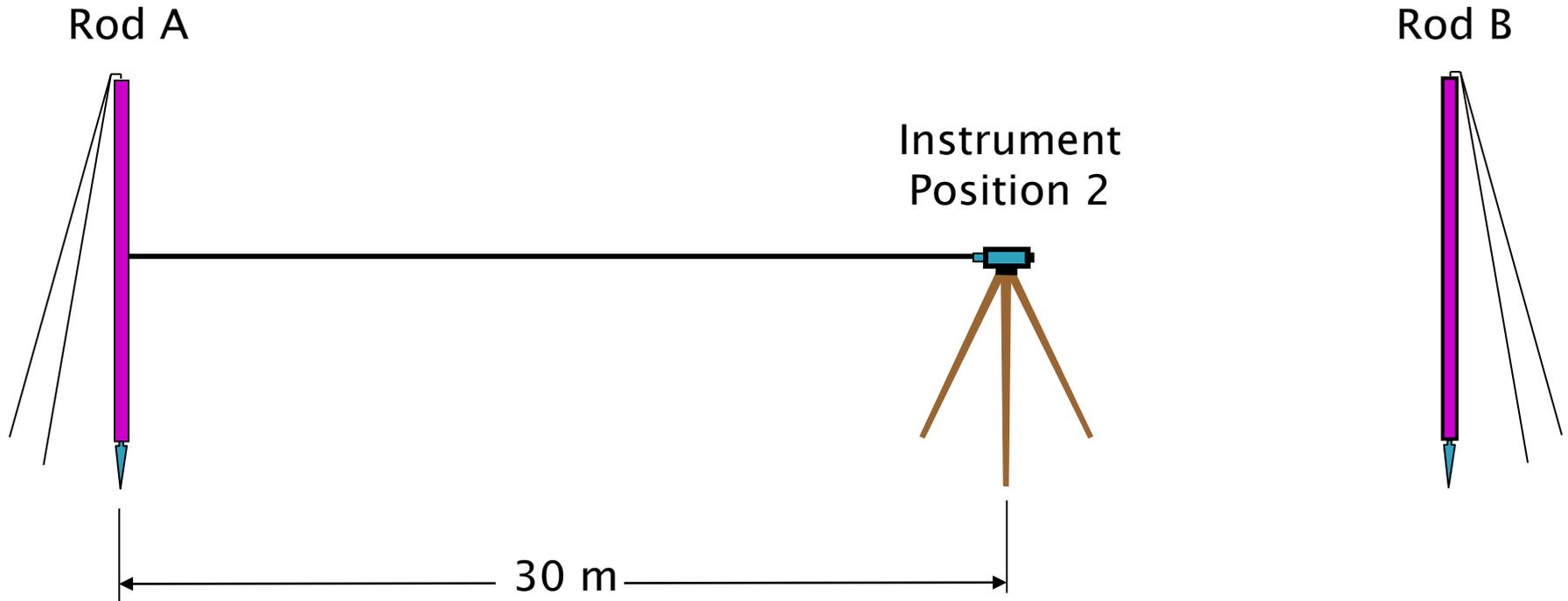


Rod B

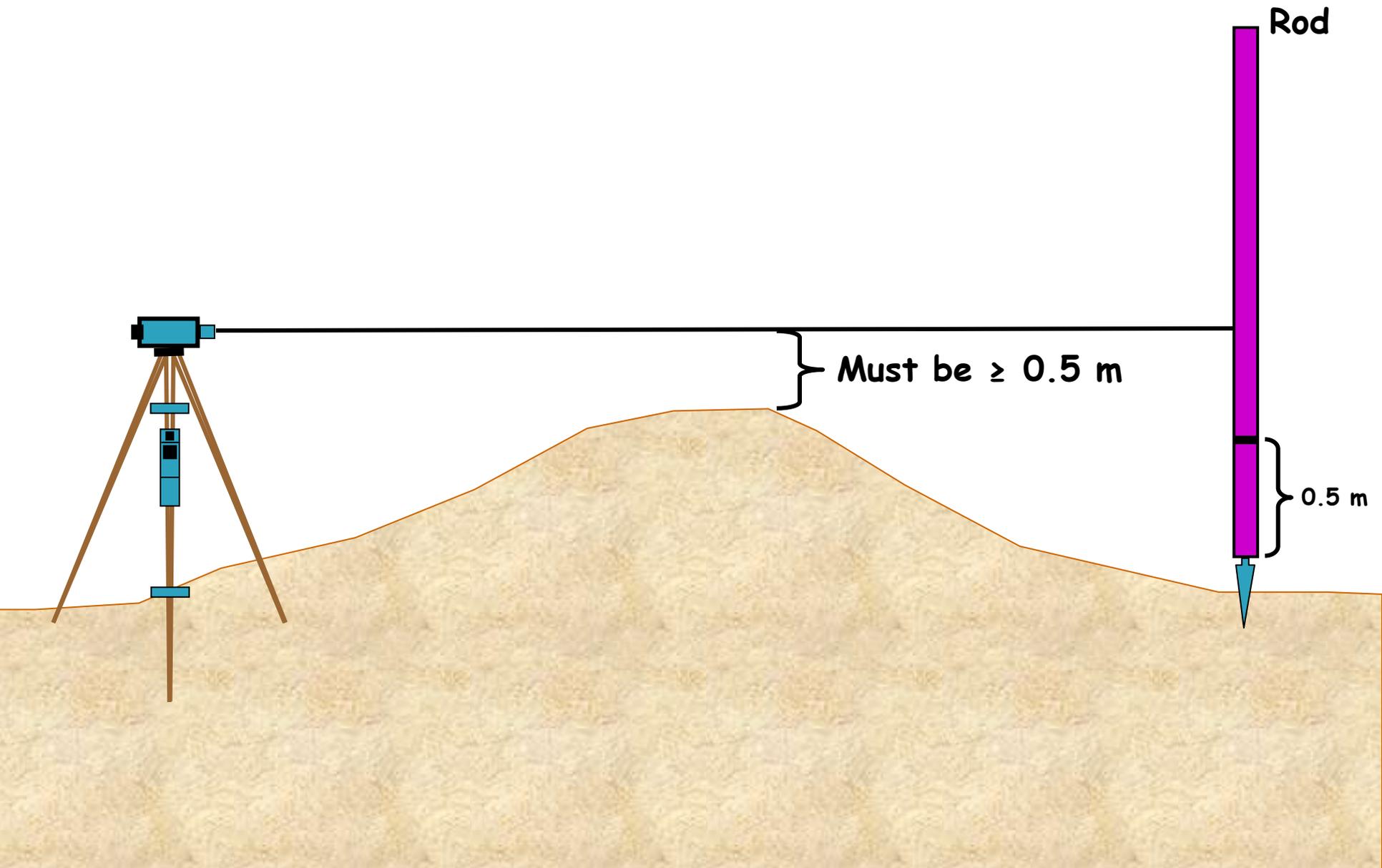
Instrument
Position 2



Collimation Check – Förstner Method A x x B

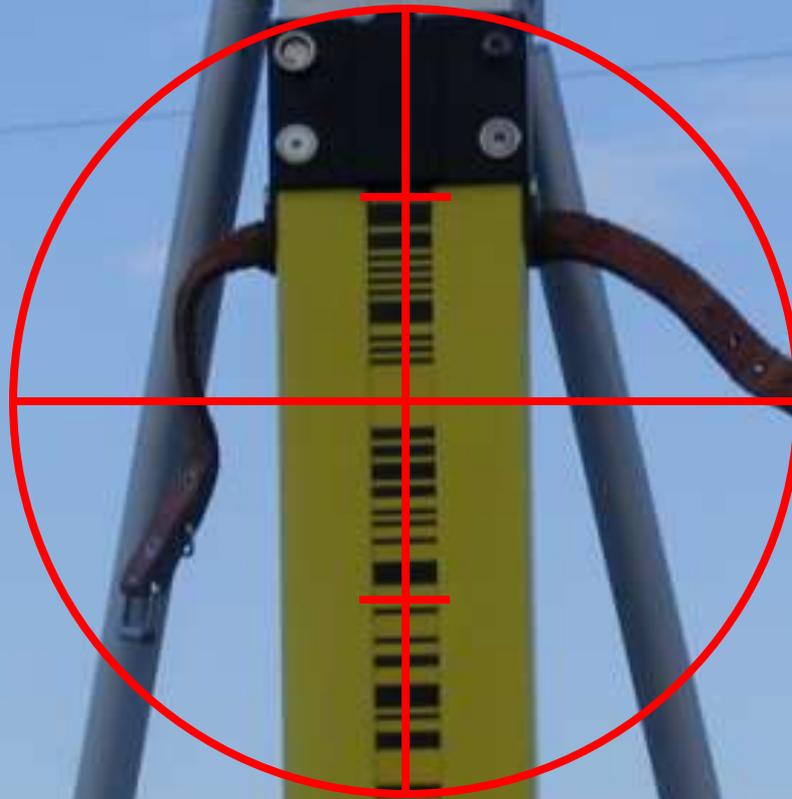


Maintain Line of Sight 0.5 m Above Ground





**Middle crosshair
must be above 0.5 m**

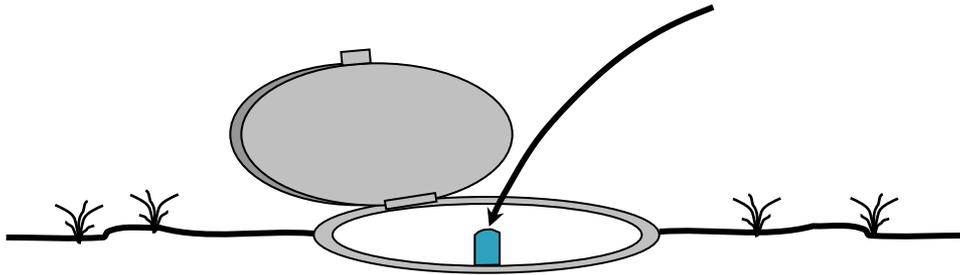


Keep all three crosshairs on rod scale!

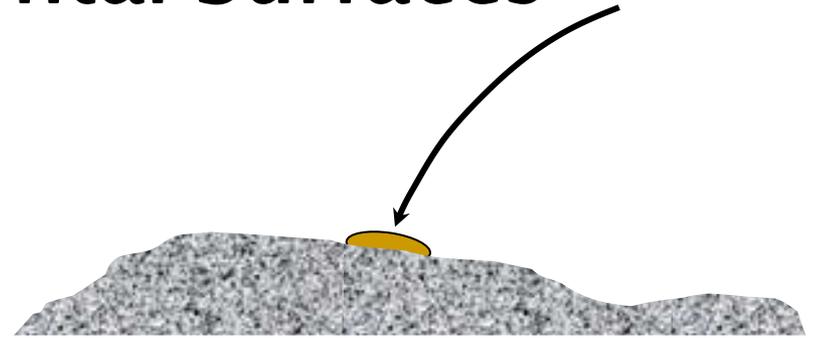
Rules - Short List

- **Never Setup on Asphalt**
- **Double Run Everything**
- **Never Read Below 0.5 Meter on Rod**
- **All Three Crosshairs Must be on rod scale**
- **Same Rod on Starting and Ending BM**
- **Use High Quality Turning Points**

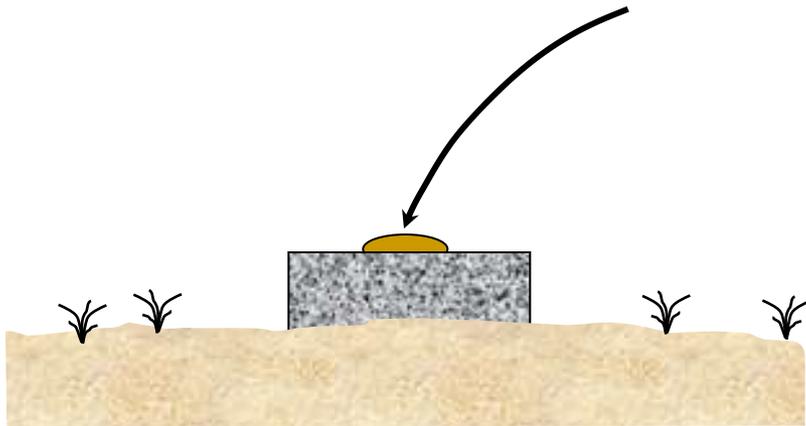
Control on Horizontal Surfaces



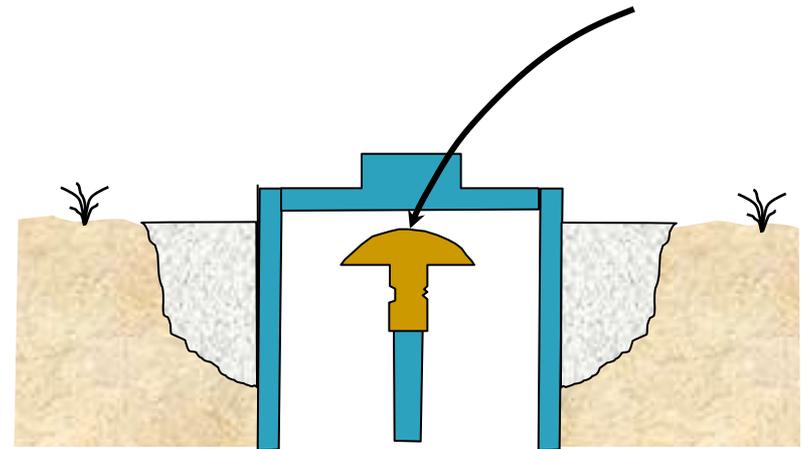
Class A and B Rod Mark



Disk in Bedrock



Concrete Post



Rod Mark With Disk

GPS
Where do you measure HI
from?

The bottom of the
recessed cross!

Note where the mark was
leveled to in the in written
station description.

Leveling
A "Flat" disk and the way
it's set the High Point is
located between the "S"
and "U" of Survey

Where do you level to?

8/2003



VERTICAL CONTROL

GENERAL ELECTRIC

1960

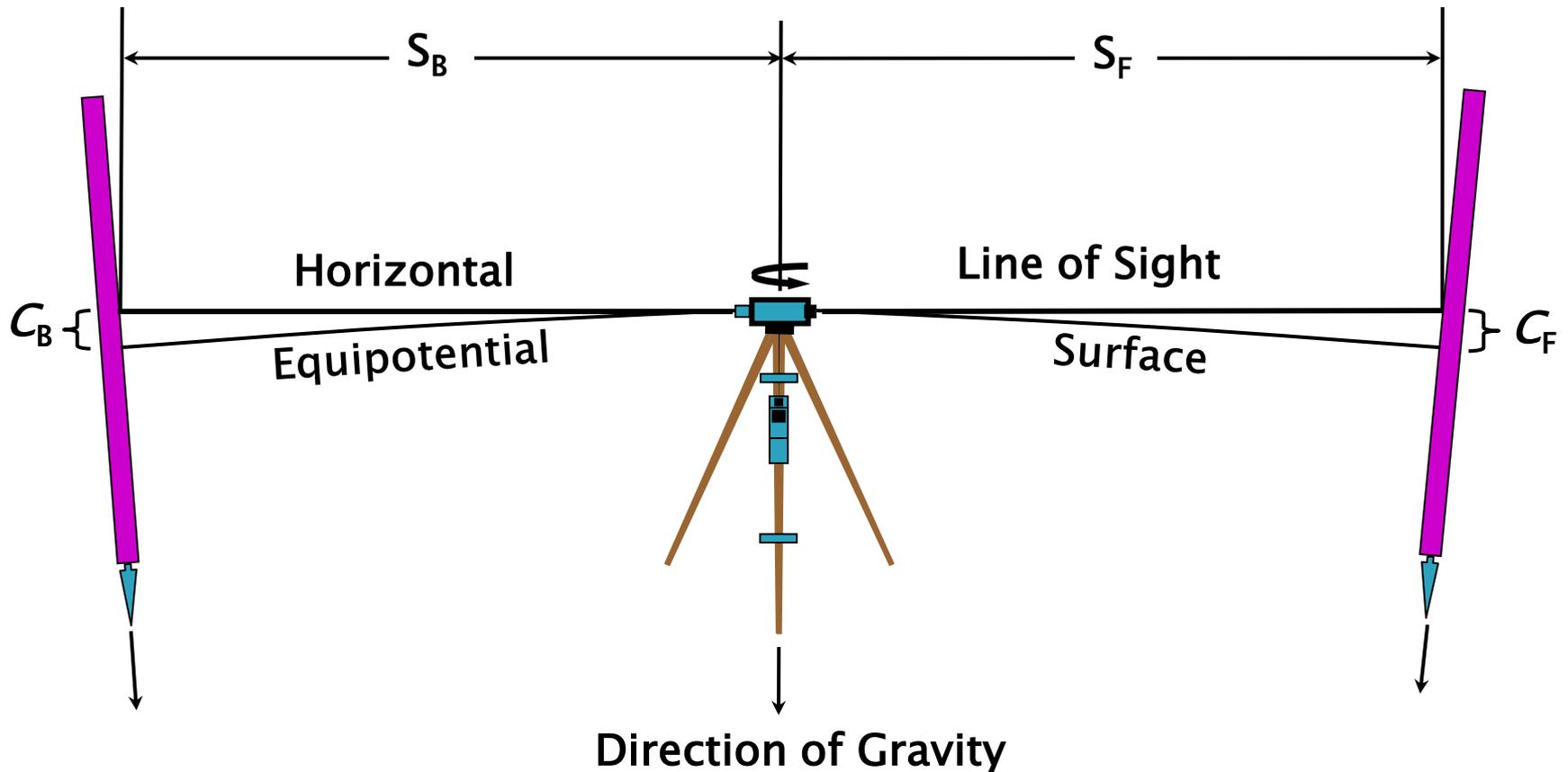


Vertically Set Bench Mark



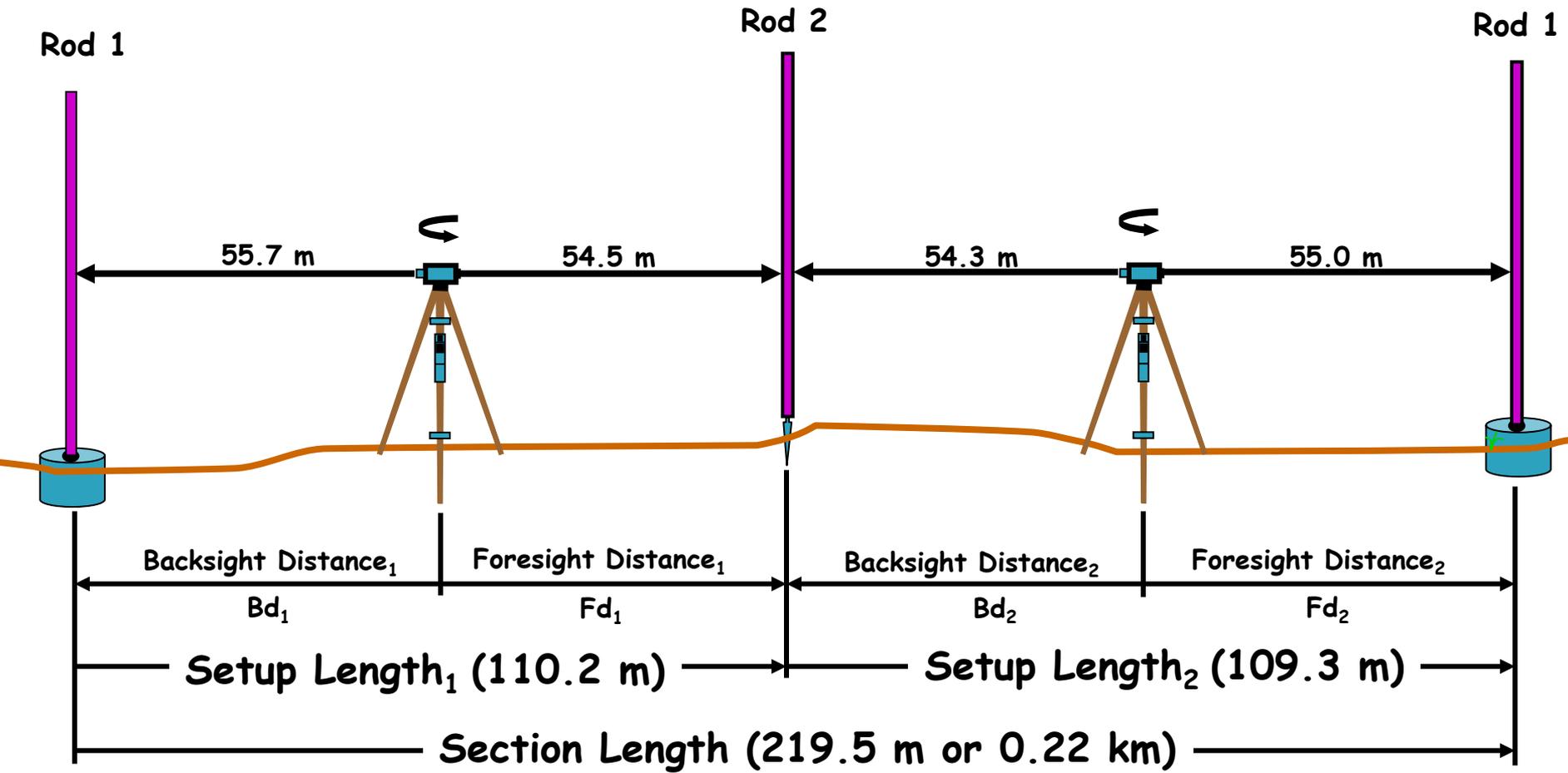


Curvature Error, C , Where the Line of Sight Is not Parallel to an Equipotential Surface Cancels if $S_B = S_F$



Accumulated Distance Imbalance

$$D_{bal} = (Bd_1 + Bd_2 + \dots + B_n) - (Fd_1 + Fd_2 + \dots + F_n)$$

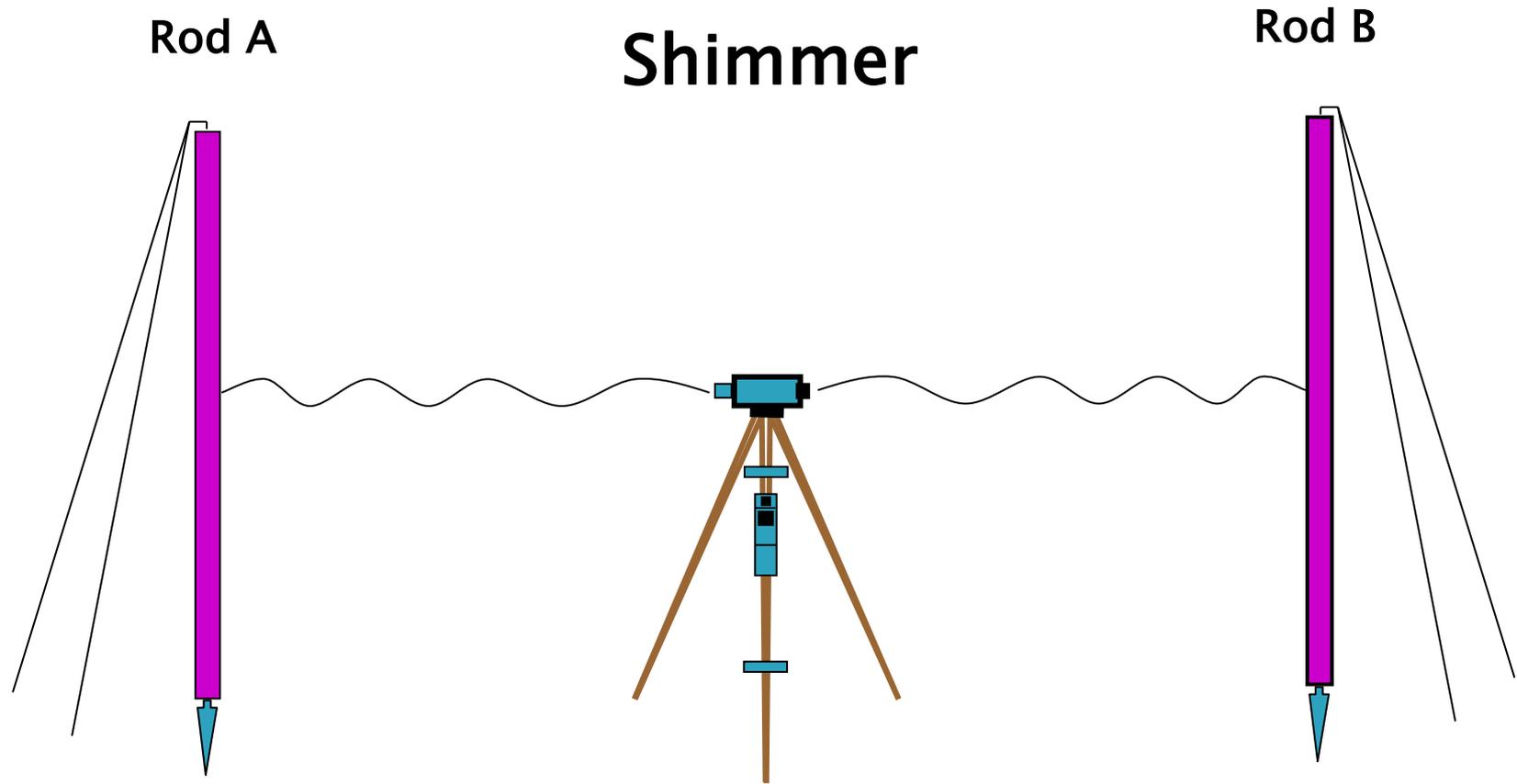


Example:

$Bd_1 = 55.7$ m; $Fd_1 = 54.5$ m Setup Imbalance = +1.2 m (short)

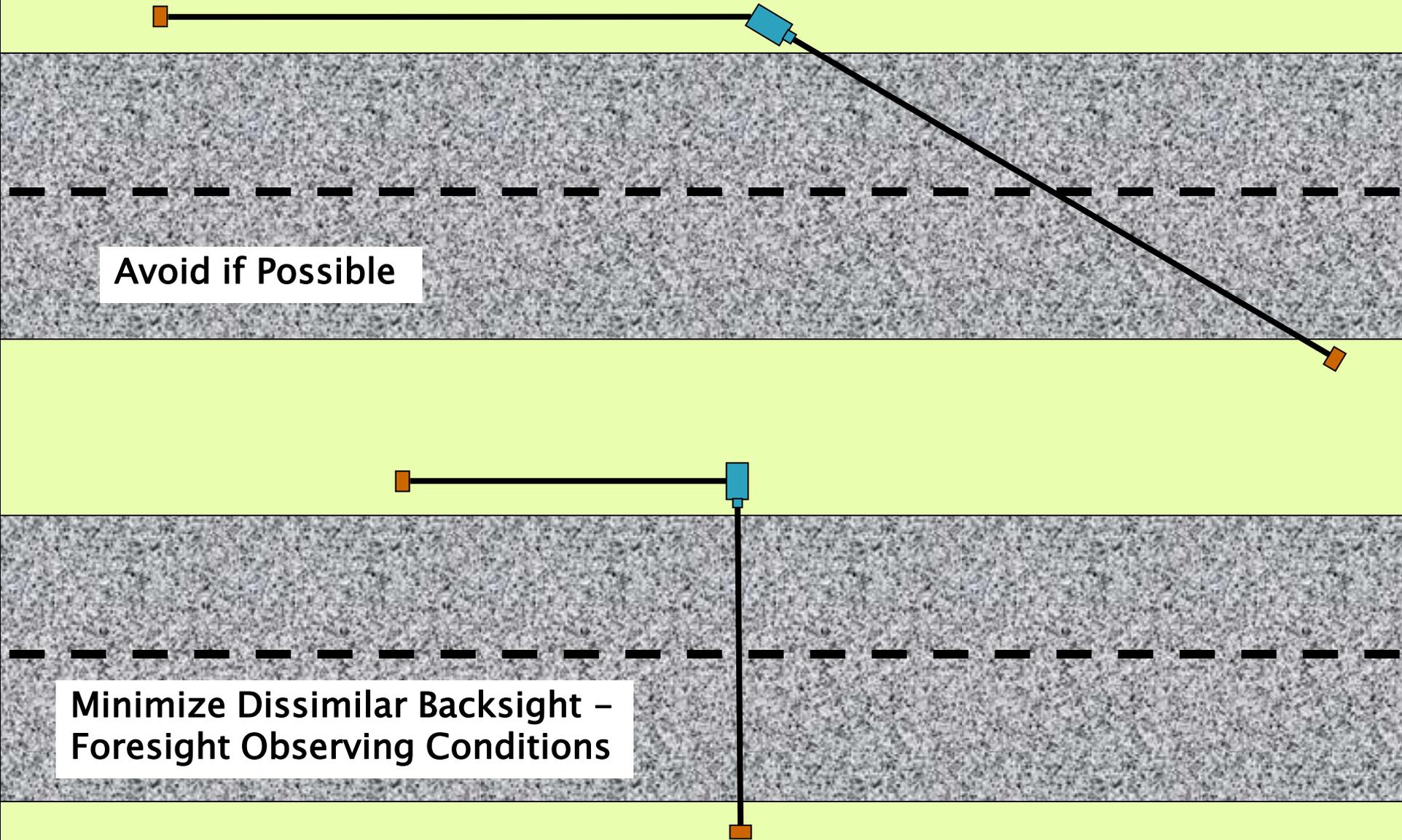
$Bd_2 = 54.3$ m; $Fd_2 = 55.0$ m Setup Imbalance = -0.7 m (long)

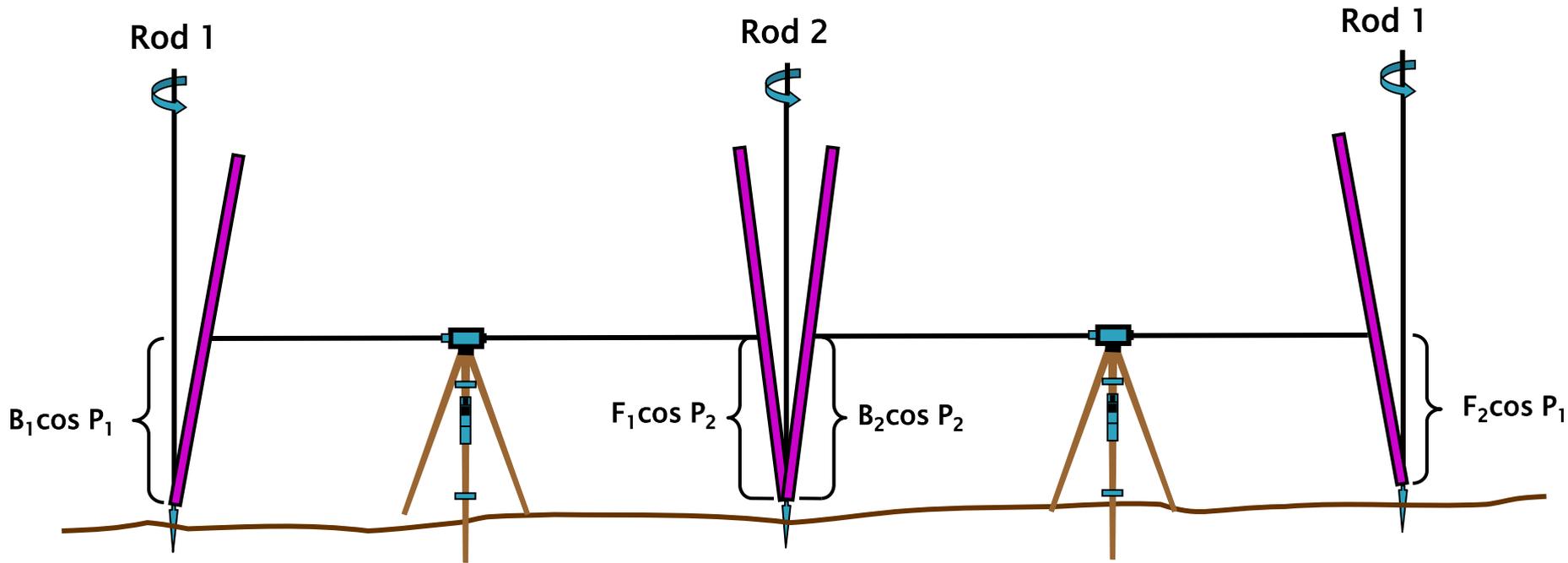
Section Accumulated Imbalance = +0.5 m (short)



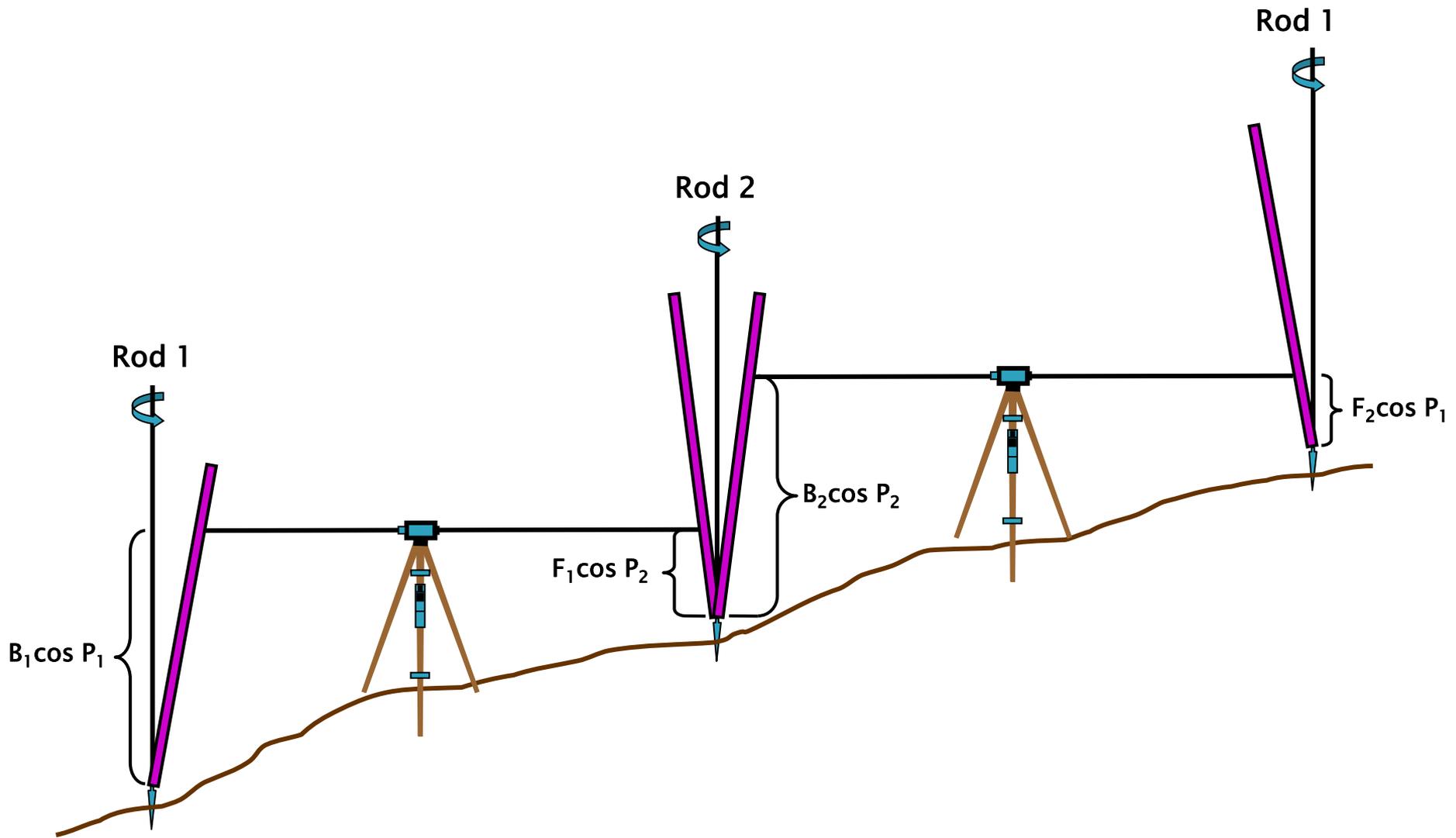
Shorten setup distances – instrument to rod
Balance setups – minimize differences
Observe over similar surfaces

Crossing a Highway





Systematic effect of plumbing error (and scale errors) is small on flat terrain, since $B_1 \approx F_2$ and $F_1 \approx B_2$



Systematic effect of plumbing error (and scale errors) accumulates on sloping terrain, since $B_1 \neq F_2$ and $F_1 \neq B_2$

Leveling Tips

- **Always practice – SAFETY FIRST!!!!**
- **Apparent Heat Waves – reduce sight lengths**
- **Wind effects – block wind with body – place a light hand on tripod leg – reduce sight lengths**
- **Difficult to obtain standard deviation – reduce sight light**
- **Carry instrument upright between setups**
- **Check rods' and instrument's circular levels once a week to ensure they're in adjustment**
- **Transfer elevation to instrument when foresight is ready – minimize settlement**
- **Do not leave the instrument setup unattended**

Leveling Tips (continued)

- **Cross pavement (roadway) at right angles to minimize uneven sight conditions**
- **Clearly focus level instrument before measurement**
- **Stabilize both turning points and tripod every setup**
- **Never read below 0.5 meters on rod**
- **Ensure upper stadia crosshair is not above rod scale when reading near the top of the rod**
- **Maintain tight setup imbalances**
- **Don't point the instrument into the sun**
- **Orchestrate setups so instrument is not pointing into low sun angle**

Leveling Tips (continued)

- **DO NOT DROP RODS!!**
- **Keep one hand on rod at all times**
- **Keep rod faces clean – do not touch Invar**
- **Always protect base of rod – keep off ground**
- **Never setup rod or instrument on asphalt**
- **Turn rod to change shadows if measurement fails**
- **Rod person calls out BM designation for check**
- **Start and end with the same rod on mark**
- **Backsight rod person does not move until foresight has been recorded and observer directs**

Leveling Tips (continued)

- **Make sure base of rod is directly on the turning point or BM not on centering guide**
- **Be aware of your surroundings carrying rod**
- **Double run all sections**
- **Plan reverse leveling during a different time of day from the first level run**
- **Place visible mark on rod to indicate 0.5 m**

Trigonometric Leveling

- **Equipment**
 - Electronic theodolite
 - Electronic Distance Measuring Instrument (EDMI)
 - 5 mm + 3 ppm or better
 - Zenith distance and EDM I slope distance measured to or reduced to the same point
 - Target poles (same design and construction)
 - High quality turning pin
 - Adjusted and stable tripod
- **Calibration**
 - EDM I
 - Checked at a NGS baseline at a minimum annually
- **Electronic Theodolite**
 - Vertical index error checked daily
- **Target poles**
 - Keep circular bubble in adjustment

Observation Procedure

- Set one
 - Backsight – circle left
 - Foresight – circle left
 - Foresight – circle right
 - Backsight – circle right
- Set two (re–point on backsight)
 - Backsight – circle right
 - Foresight – circle right
 - Foresight – circle left
 - Backsight – circle left

Observation Procedure

- What information is recorded?
 - Vertical distances
 - Slope distances
 - Apply all corrections
 - Temperature
 - Pressure
 - Prism constant
 - Curvature and refraction

Geodetic Leveling to CORS

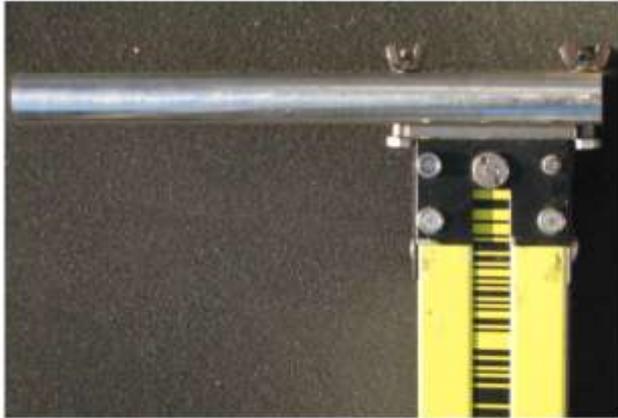


Figure 5. Leveling bar properly attached to rod. Bolt heads grip the rod's base plate.



SSN	Designation	Geodetic Leveling (m)	Mean Trig (m)	Level - Trig (mm)	
1	WAS 54	100.00000	100.00000	0.00	mm
2	WAS 55	100.61099	100.61096	0.03	mm
3	WAS 53	100.80876	100.80842	0.34	mm
100	COR VPR	106.10873	106.10898	-0.25	mm

Trigonometric Leveling

- Reference Sources

- California DOT Draft Interim Specifications for Trigonometric Leveling

- http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/leveling_specs.pdf

- Electronic Total Stations are Levels To

- Author Jesse Kozlowski, PLS

- http://www.ncdot.org/doh/preconstruct/highway/location/support/support_files/library_doc/Precise_Trig_Leveling_PPT_Rev010731.pdf



September 14, 2008 near Appomattox, Virginia

Call Before You Dig!



September 14, 2008 near Appomattox, Virginia

Call Before You Dig!

http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf

The screenshot shows a Windows Internet Explorer browser window. The address bar contains the URL http://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf. The browser's menu bar includes File, Edit, Go To, Favorites, and Help. The search bar features the Google logo and a search button. Below the search bar are various utility icons for Shopping, Games, Travel, Mail, Amazon, eBay, Facebook, and Twitter. The main content area displays a PDF document with the following text:

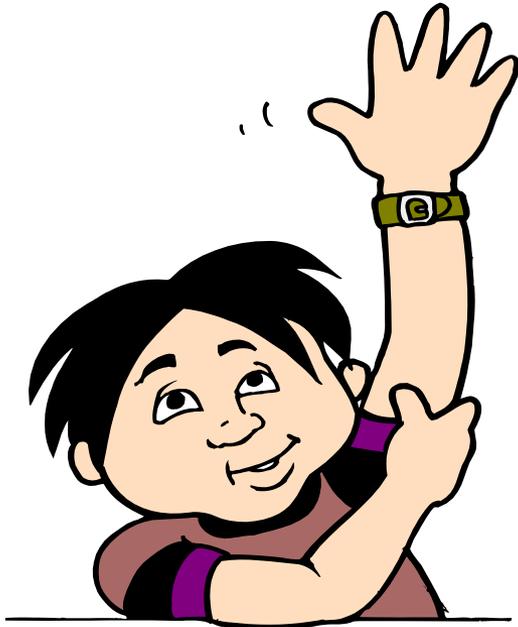
Bench Mark Reset Procedures

Guidelines to preserve elevation data for a *soon-to-be disturbed* or *soon-to-be destroyed* bench mark

Documented by
Curtis L. Smith
National Geodetic Survey
Silver Spring MD 20910
September 2010

The PDF content includes a photograph of two men in outdoor attire. One man, wearing a white cap and sunglasses, is operating a green surveying instrument mounted on a tripod. The other man, in a blue jacket, stands beside him. The background of the photo shows a wooded area. The browser's status bar at the bottom indicates 'Done' and 'Unknown Zone'.

Questions?



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