National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Levelling Exercise

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Sea Level Training Course, St Lucia, 17-21 October 2016

Levelling

Levelling is the method of determining height differences using a horizontal line of sight. In hydrographic surveying, levelling is used most commonly to connect tide poles and tide gauge Contact Points to benchmarks on the nearby land.

Levelling Exercise

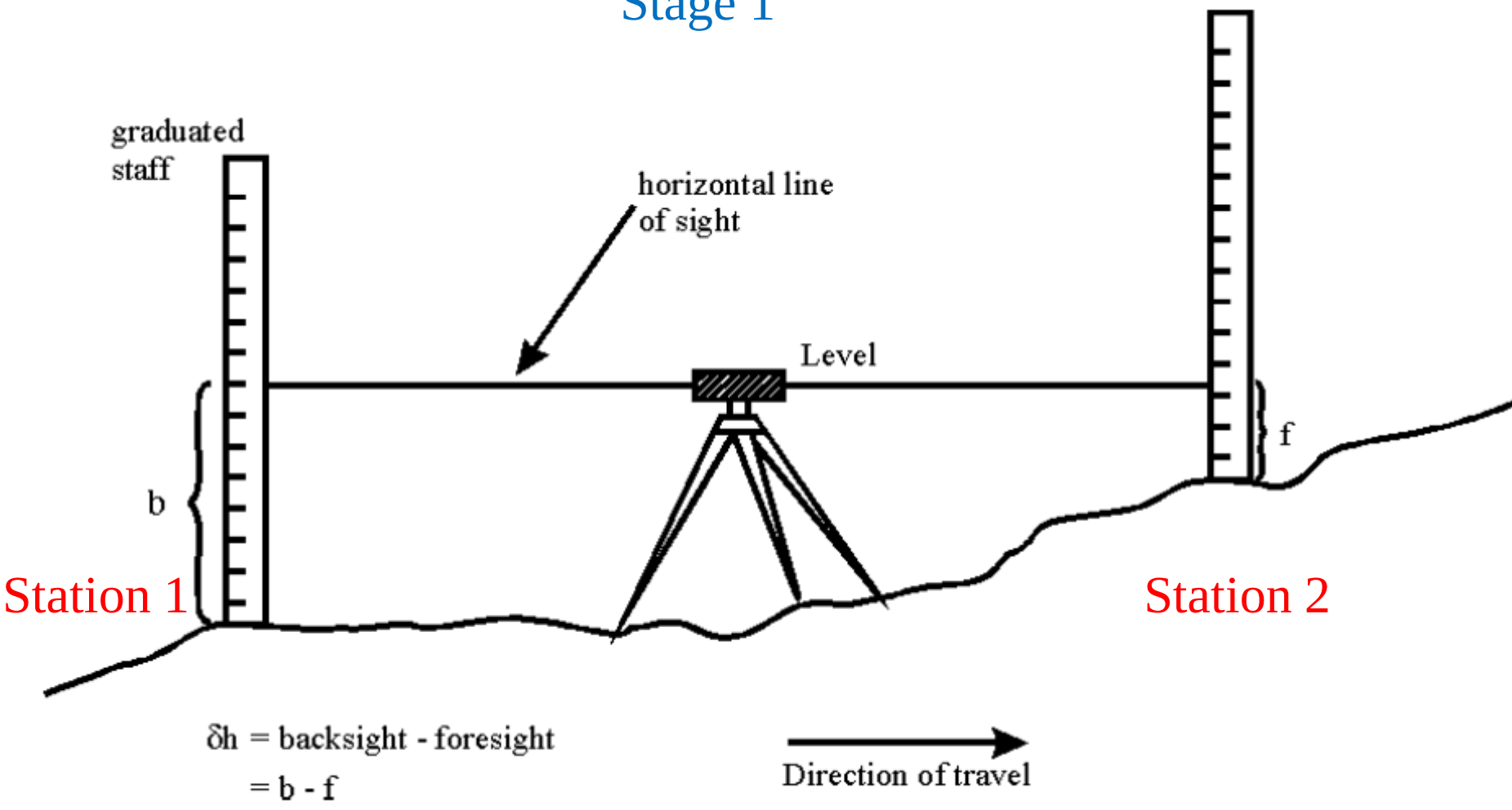
- We want to relate the heights of various marks, such as a tide gauge Contact Point or TGBM and ancillary marks to each other, to check the stability of the local height relationships.
- Also we need to relate the TGBM and GPS BM heights, if there is a GPS, as described in previous lecture.
- Also we may need to relate tide gauge heights to national levelling systems.
- Relating heights over short distances (i.e. metres to 100s metres) is performed by conventional levelling.

Charles Merry Notes

- This information is based primarily on the short note written for PSMSL/GLOSS by Prof. Charles Merry (Univ. Cape Town). Available from www.psmsl.org.

- There is a lot of levelling information on the web – some very detailed for professional surveyors – these notes are for tide gauge people where levelling is over short distances around a tide gauge (e.g. 10s-100s metres)

Stage 1



Usually maximum sight length restricted to 50-60 m

NOAA COOPS

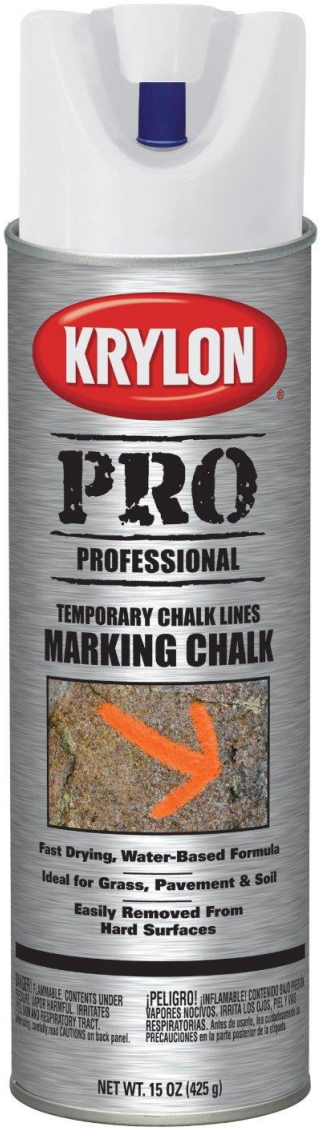
What are the station marks? They can be:

- Permanent benchmarks
- Temporary round-headed pins which you can hammer into concrete or solid ground
- A prominent solid feature (lump) in rock or on the pavement that you can mark with chalk or paint.
- On very rough ground one can use a ‘change plate’ or ‘levelling foot’

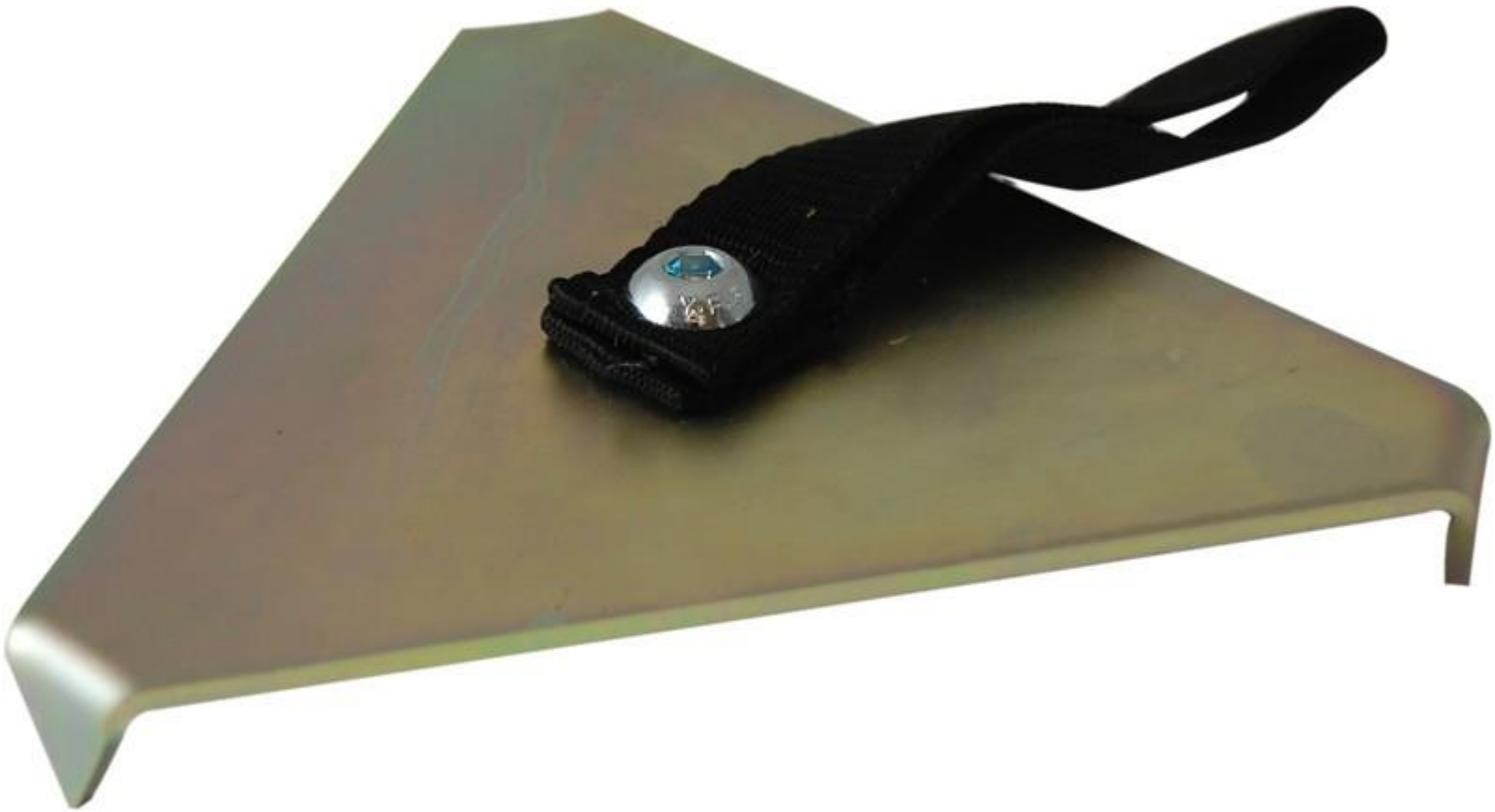
Permanent Benchmark

Permanent BM at Port Louis in the Falklands

Surveying pin (not round-headed in this case) which can be hammered into the ground or softer concrete.

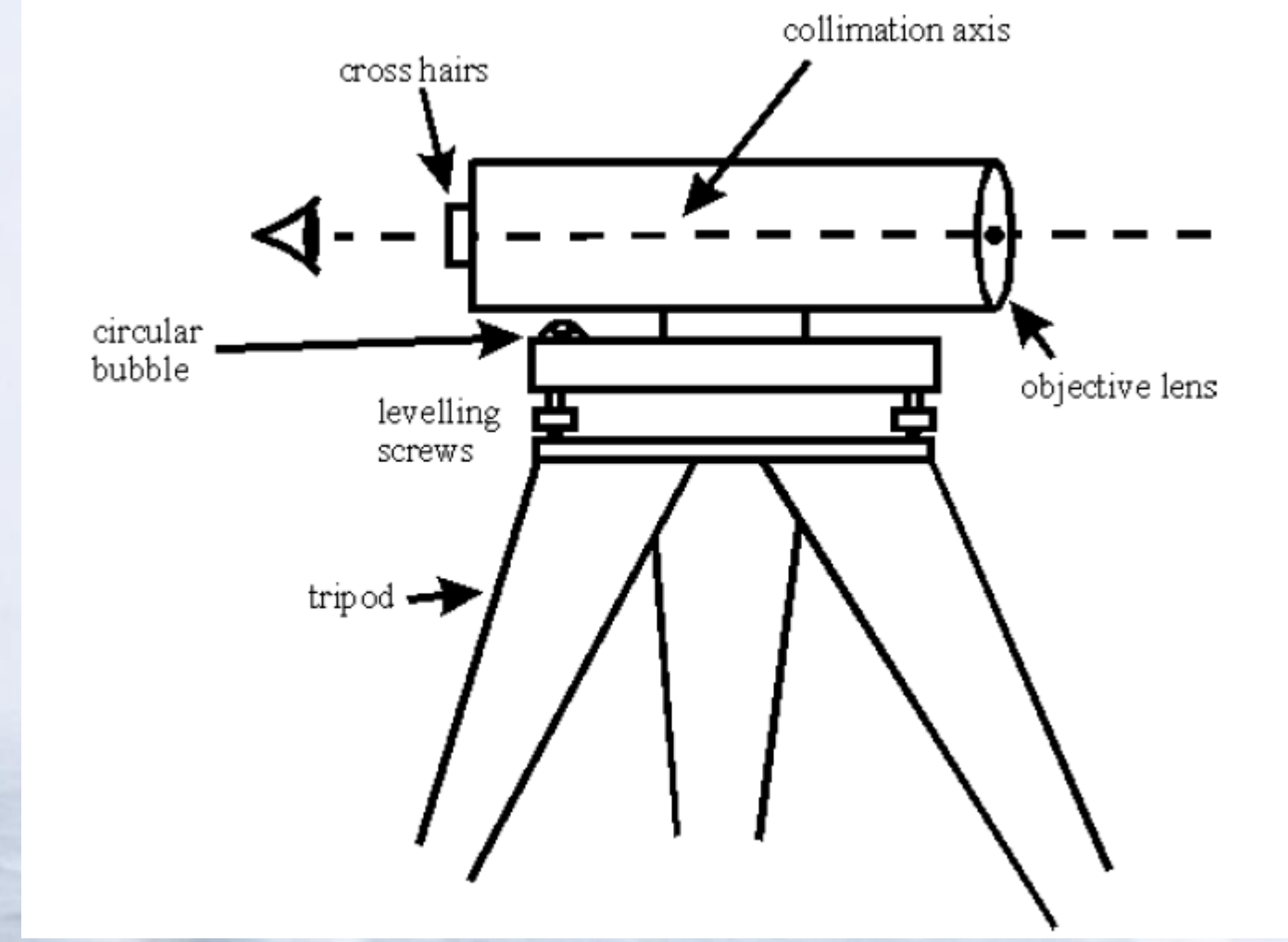


Chalk cross
On a
Pavement



Change Plate (Levelling Foot)

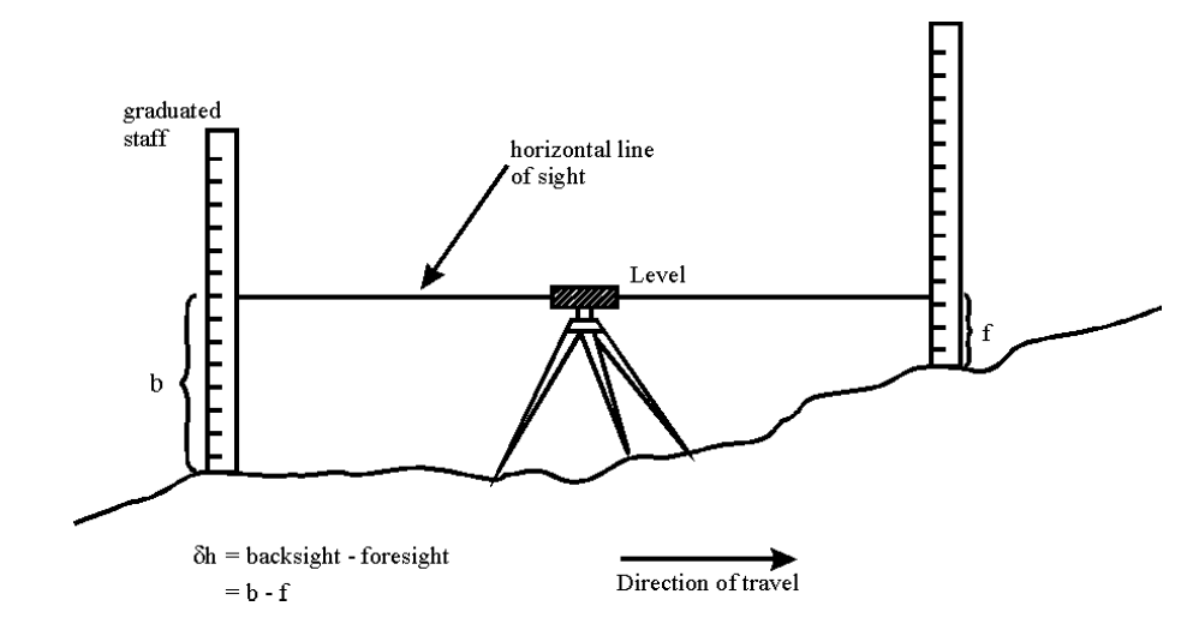
To provide a Station BM on rough ground



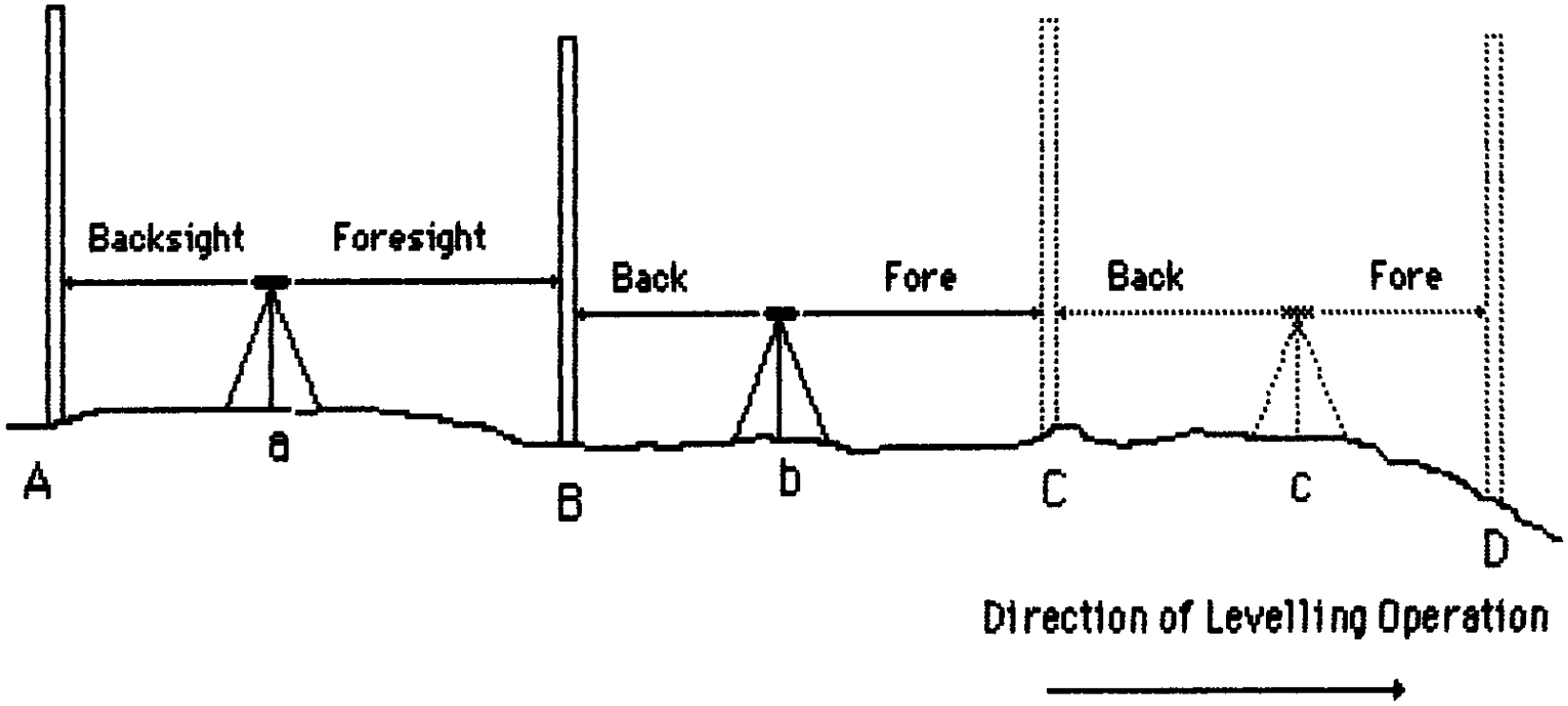
Set the tripod legs (about 60 deg) so that level is approximately level, then use the three levelling screws to centre the bubble such that the level is exactly level (for our purposes). THE TRIPOD MUST NOT MOVE.

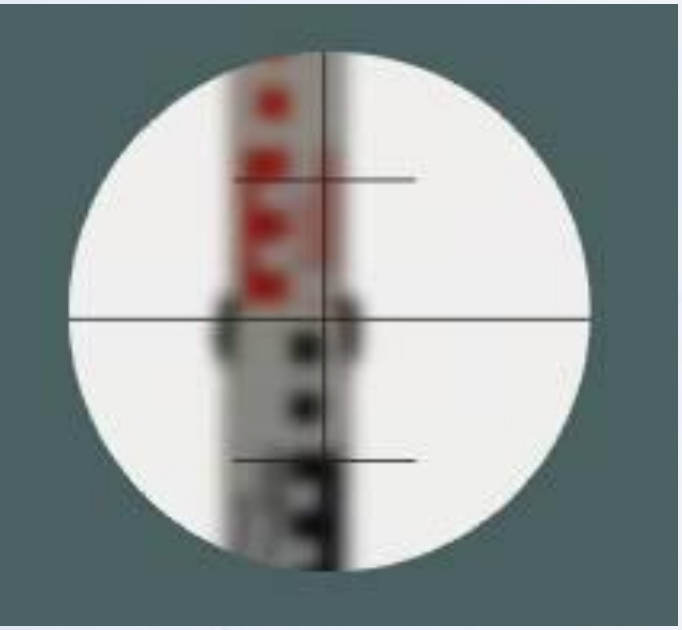
- When the level is level:
- The telescopic tube has an objective lens to bring the staff into focus, and an eye-piece with a cross-hair.
- The aim is to line up the cross-hair with the marks on the staff.
- Meanwhile the person holding the staff has to ensure that it is vertical using its own attached bubble. The staff must be held firmly to avoid swaying in the wind, and not be extended more than necessary.

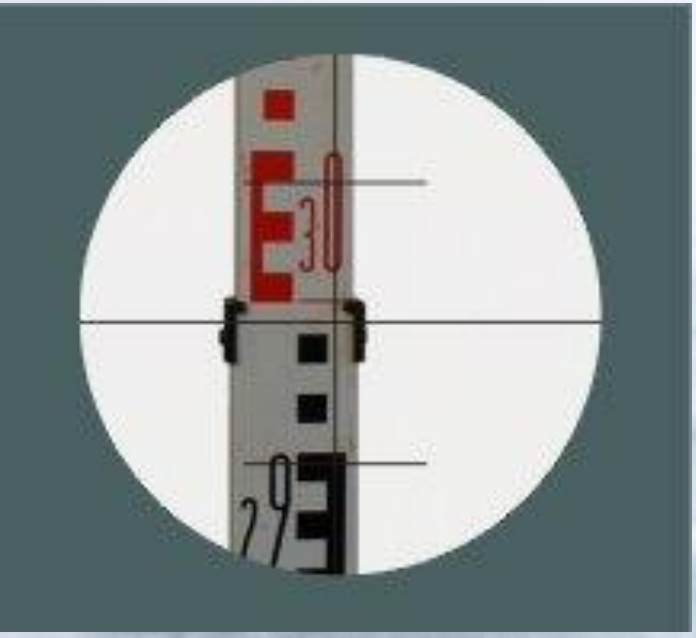
- Let’s call the ‘operator’ the person who looks through the level and makes the measurements (and records them in his notebook)
- Let’s call the ‘assistant’ the person who holds the staff



- Assistant places the staff at the backsight point (B) at Station 1, and the Operator measures the height ‘b’.
- The Assistant moves to place the staff at the foresight point (F) at Station 2, and the Operator measures height ‘f’.
- We now know ‘b-f’.
- The Assistant stays at F which becomes the new B, the Operator moves to set up the level at a new mid-way point for Stage 2 between Stations 2 and 3 (which are now the new B and new F).


Backsight
Foresight
Back
Fore
Back
Fore
A
a
B
b
C
c
D
Direction of Levelling Operation

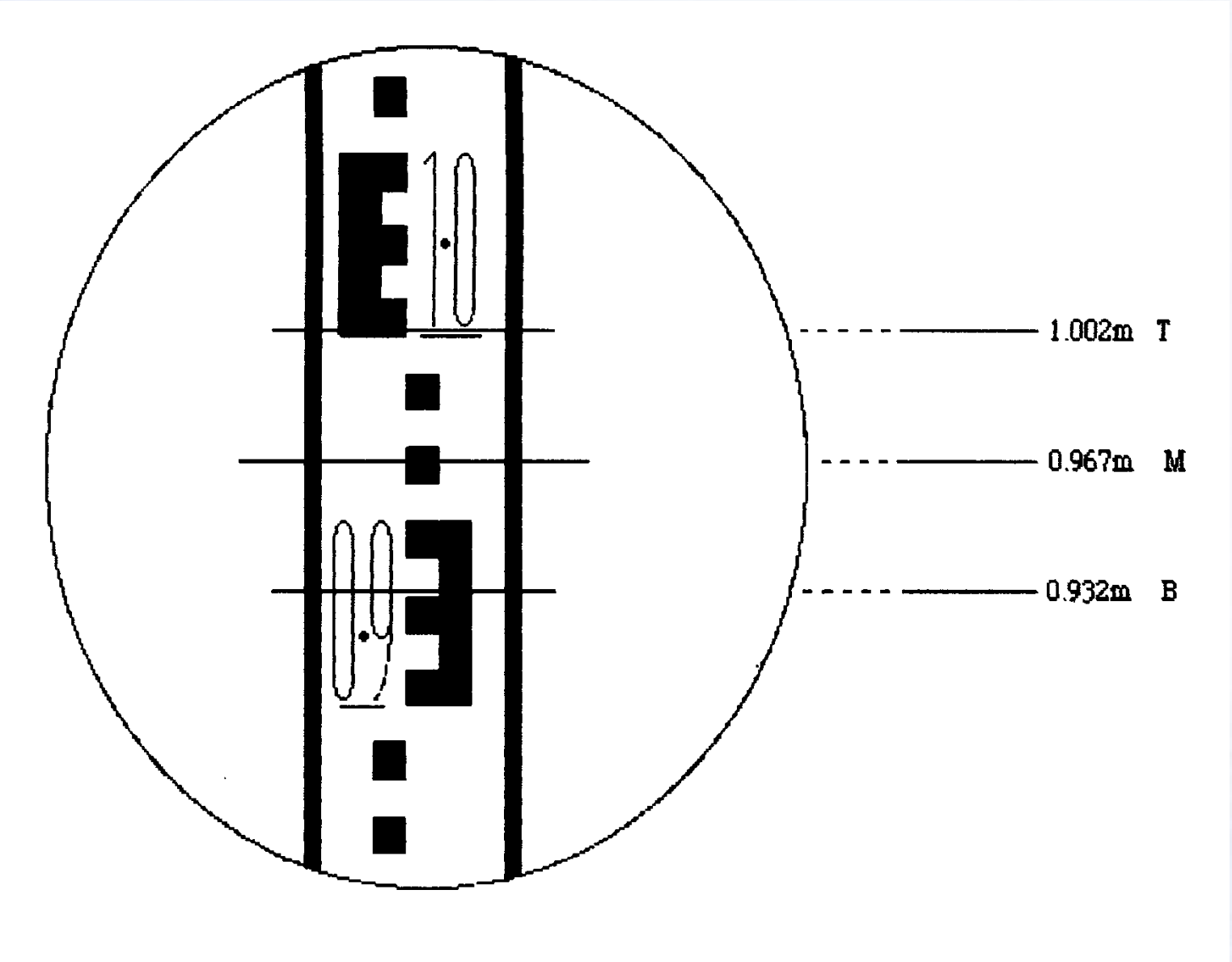




First familiarise yourself with the staff markings.

Level level and staff vertical.
Bring the staff and cross-hair into sharp focus.

Staff reading is 2.993
Upper stadia = 3.040
Lower stadia = 2.946
Average = 2.993



Metric upright staff as seen through a level telescope

Repeat the above for as many stages as necessary so as to measure the height difference between the start and end stations

We now have a set of measurements (taken by the Operator) such as:

Stage	b	f	b-f	Stations
1	1.61	1.20	0.41	1 and 2
2	2.44	1.77	0.67	2 and 3
3	1.12	0.8	0.32	3 and 4
Total			1.40	

i.e. the final Station 4, after stage 3, is 1.40 m above the starting Station 1.

(2)

op
2.317

[illegible] grid
Erw Fair
1.155

op
1.723

Monarto
grid
1.013

op
[illegible] 1.922

grid
Glen Arbor
1.155

op
1.660

end of yellow
option
1.233

op
1.928

top grid
Coe Creek 1825
0.858

op
2.179

[illegible] grid
opposite group
0.430

op
2.633

split in end
in corner

SURVEY		DATE		OBSERVER	
SHIP		TIME		RECORDER	
LOCALITY		WEATHER		LEVEL TYPE & SERIAL NO	
BENCH MARKS		MAP		STAFF TYPE & SERIAL NO	

STAFF STATION	DISTANCE	STADIA WIRE	BACK READING	T-M,M-B DIFF(<2 mm)		FORWARD READING	(+) RISE	(-) FALL	REDUCED LEVEL	REMARKS (INCLUDING BRIEF BM DESCRIPTION)
OCEAN 1		T	1.166	0.098					1.8851	
		C	1.068							
	19.40	B	0.972	0.096						
CP1	24.00	T	1.559	0.125	0.120	1.535		-0.347	1.5381	
		C	1.434			1.415				
	25.20	B	1.307	0.127	0.120	1.295				
TBM	24.60	T	0.720	0.122	0.124	0.724			2.3721	
		C	0.598			0.600	0.834			
	24.60	B	0.474	0.124	0.122	0.478				
CP2	25.20	T	1.639	0.102	0.127	1.559		-0.834	1.5381	
		C	1.537			1.432				
	20.30	B	1.436	0.101	0.125	1.307				
OCEAN 1	21.90	T			0.110	1.299				
		C				1.189	0.348		1.8861	
		B			0.109	1.080				
		T								
		C								
		B								
		T								
		C								
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		B								
		T								
		C								
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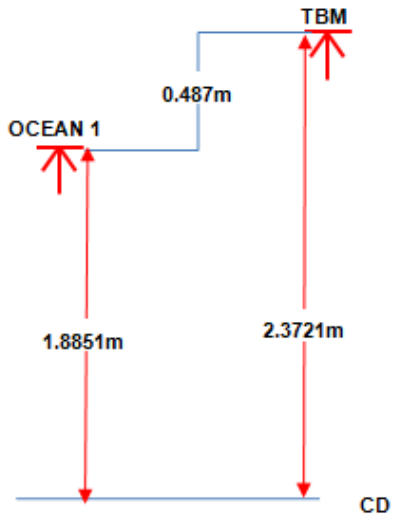

Total dist. (km)	**185.200**		**4.637**	**0.895**	**0.957**	**4.636**	**1.182**	**-1.181**	**0.001**	Traverse Length (K) **0.1852** km
Height				**-0.062**		**0.001**	**0.001**			Reduced By
										Checked By

Allowable Misclose (12 /K mm) **5.2** mm

Actual Misclose **1.0** mm

Next:

- Repeat the procedure going in the opposite direction.
- (Or, if the levelling has been done in a circle, check that you end up with zero net Total height change.)
- Do the Total values agree in the two directions? Over a few 100 m, even unskilled people should be able to measure the Total height differences to a couple of mm.
- If they don’t agree, do it again. And again!

Next:

- Take a pdf of your rough notes, and copy your measurements to a spreadsheet.
- If required, send the results of the levelling to PSMSL and/or SONEL.

Some Tips:

- Choose points for the staff to stand on which are well defined, so if you have to revisit them you can place the staff again and again on the same point so it is at the same height.
- Best is to insert round-headed levelling pins (a sort of cheap disposable benchmark)
- Otherwise choose nobbles of rock or pavement which you can mark with chalk or paint.
- Best is to repeat the exercise the two directions using the same points for the staff, then errors in one of the stages can easily be identified.

Some Tips:

- Over rough ground it may not be possible to use the same stations for the staff, so a different route may be taken in the 2 directions. But you should get agreement.
- Over rough ground, it is necessary to use a ‘change plate’ (levelling foot) to make a temporary Station mark.
- If possible, keep the sight lengths about the same (say 50 m), which will reduce ‘collimation error’. (See Charles Merry note for discussion of other error sources).
- There are now many fancy levels and staffs that make automatic measurements, but for this exercise we will stick to the traditional method.

Some Tips:

- Level to marks that are not on the ground. Hold the staff on a mark that is adjacent on the ground and hold a ruler (or better a spirit level) from the vertical mark to the staff. Measure the staff reading to determine the height of the mark off the ground.

What do you need?

- Level
- Tripod
- Staff
- Ruler or spirit level for vertical marks

- Notebook (not loose bits of paper)
- Pen
- Lots of pockets

- Round-headed pins (or chalk or paint) or change plate

More advice (there is a lot out there)

- https://en.wikipedia.org/wiki/Levelling
- http://www.comet.ucar.edu/
- IOC Manual 5