UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF SURVEYING

29.001 SURVEYING I

FIELD EXERCISE: HAND INSTRUMENTS (OPTICAL SQUARE/CLINOMETER PRISMATIC COMPASS)

1. AIM

To familiarise students with three hand held instruments (Optical square/ Abney level, clinometer/Prismatic compass) their use, their testing and their accuracy.

2. EQUIPMENT

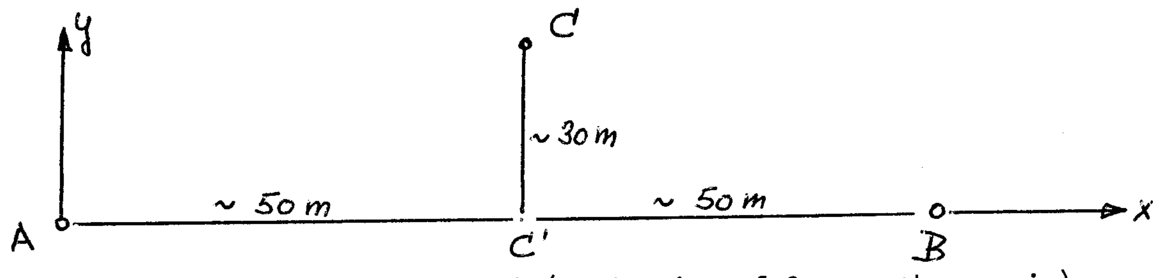
1 x Double Pentagonal Prism (ZEISS or FIELDER or SOKKISHA)
1 x Plumbing rod for double pentagonal prism
5 x Ranging rods (with steel shod)
1 x 100 m band
4 x Small nails (thumb nails)
1 x Hammer
1 x Clinometer BREITHAUPT 'NECLI' (2) or SUUNTO 'PM-5' (5) or Abney Level
1 x Prismatic compass SUUNTO KB-14
3 x Carbon papers (blue)
6 x Sheets with 1 mm divisions
1 x Cardboard A4 (21 x 30 cm)
2 x Plumbobs
4 x Paper Clips
1 x Survey umbrella (in rainy weather)
2 x Pegs

SUPERVISOR:

4 x Ranging Rods
4 x Sighting tripods
1 x Plumb-bob

3. EXERCISE: PART A

3.1 Set two ranging rods 100 m apart (in A and B) on a surface of even slope and plumb them.



3.2 Determine approximately Point C' (projection of C onto the x-axis) with the optical square (using the centring rod) and mark it on the ground.

3.3 Put your cardboard on C', so that its centre is over the mark. Turn the cardboard around its centre point till the longer sides are parallel to the x-axis. Drive pegs at two corners of the cardboard flush into the ground and fix cardboard with small nails.

3.4 (Each student): Put a mm division paper titled "3.4" and, on top of this, a carbon paper on the cardboard and fix the two with paper clips. Determine then C' 15 times by ranging yourself into the line AB and perpendicular to C and, after each determination, letting fall down carefully the optical square's plumbing rod on the paper to record the point. Mark your name, the directions of the x and y axis as well as the directions towards A, B, C on the mm division paper and remove it after having done this.

3.5 (Each student): Fix another mm division paper titled "3.5" (together with the carbon paper) exactly in the same position as in 3.4 on top of the cardboard. Stand now on the other side of the cardboard, so that point C is in your back. Range yourself 15 times into the line AB, looking that the bottom of the optical square's centring rod remains above the carbon paper. Record the obtained positions by touching the carbon with the steel shod. Remove the paper with the 15 dots on it after having marked your name and "ranging only" and the directions of x, y, A, B on the sheet.

3.6 Measure the distances AC', BC', CC' and book them in the fieldbook. Draw a sketch, showing all four points and the two axis.

4. EXERCISE: PART B

4.1 On a steep slope, stick two ranging rods at a distance of about 50 m into the ground and plumb them. Look for two handkerchiefs and fix them at your eye height on the two rods.

4.2 (Each student): Using the clinometer, measure as accurately as possible (to 1 minute of arc), the vertical angles ten times uphill and ten times downhill, from handerchief to handkerchief. The angles of elevation at the lower station have a positive sign, the angles of depression at the upper station a negative one. Make an appropriate table in the fieldbook for all bookings.

5. EXERCISE: PART C

Find the instrument constant of your compass which converts observed magnetic bearings into grid bearings (Grid = ISG, Zone 56/I).

5.1 (Each student): Place yourself with the prismatic compass on a control point of the campus network given by the demonstrator and measure the magnetic bearings to three different targets A, B, C four times each. Follow the operating instructions given in the appendix and check for the heterophoria effect (5 times). Read compass to 0.1 degree. Sequence of observations: A - B - C - A - B - C - A .... See appendix 2 for booking.

5.2 (Each student): As 5.1, but on another station.

5.3 List of (given) grid bearings (ISG, Zone 56/1: CAMPUS NETWORK 1980)

Station	Target	Grid Bearing	(Remarks on Target)
SSM 4775	T.S.133*	306°35'	Monastery
"	T.S.103	349°00'	Applied Science
"	T.S.1	65°51'	Civil Engineering
	T.S.138*	58°55'	Library
G 104	T.S.133*	304°36'	Monastery
"	T.S.103	336°16'	Applied Science
"	T.S.15	41°44'	Mechanical Engineering
SSM 4779	T.S.103	324°16'	Applied Science
"	T.S.15	15°48'	Mechanical Engineering
"	T.S.1	50°54'	Civil Engineering
	T.S.133	302°29'	Monastery
U6	T.S.103	29°42'	Applied Science
	T.S.138	73°24'	Library
	T.S.1	80°53'	Civil Engineering

* = through trees

6. REPORT

Each student will do the following computations with his own measurements:

6.1 Part A

Take your sheet ("3.4") made first and choose the origin of a cartesian coordinate system in the corner of the paper, indicated by the axis directions on your sheet. Measure the coordinates (x, y) in mm of all 15 dots and write them into a table similar to the one shown in appendix 1. Calculate (again as shown in appendix 1) the arithmetic means $\overline{X}$ and $\overline{Y}$, as well as the standard deviations (S_x, S_y) of one single x respectively y observation. Plot the centre of gravity of your sample of dots (coordinates $\overline{X}$, $\overline{Y}$) on sheet "3.4".

Take your second sheet ("3.5") and fix the origin of the coordinate systems in the same corner as on sheet "3.4". Measure the y coordinates only (in mm) and write them in a table. Calculate the arithmetic mean $\overline{Y}$ and the standard deviation s_y of one single y-observation. (The x values are of no interest this time!). Plot the line $\overline{Y}$ on this sheet.

To get the error $\Delta\varepsilon$ in the (expected) 180°-angle ε of the optical square, calculate:

$$\Delta Y = \overline{Y} \text{ (from 3.4)} - \overline{Y} \text{ (from 3.5)}$$

$$\Delta\varepsilon = \frac{\Delta\overline{Y}\ (50+50)\text{m}}{2\,(50\text{m})^2} = \frac{\Delta\overline{Y}}{50\text{m}} \qquad \Delta\varepsilon \text{ in rad},\ \Delta\overline{Y} \text{ in m}$$

$$\Delta\varepsilon' = \frac{\Delta\varepsilon^{rad}}{\sin 1'} \qquad \Delta\varepsilon' \text{ in minutes}$$

To get the accuracy of an optical square used as a line-ranger (standard deviation of setting out the 180° angle ε) calculate:

$$S_\varepsilon^{rad} = \frac{S_y}{25\text{m}} \qquad (S_y \text{ in metres},\ S_\varepsilon \text{ in rad})$$

$$S_\varepsilon' = \frac{S_\varepsilon^{rad}}{\sin 1'}, \qquad (S_\varepsilon' \text{ in minutes})$$

So these calculations twice (with S_y from "3.4" respectively "3.5") and compare the results of your work with standard deviations mentioned in literature:

$$S\varepsilon = \pm 1^\circ \qquad \text{(W.S. Whyte)}$$

$$S\varepsilon = \pm 4' \qquad \text{(W. Grossmann)}$$

6.2 Part B

Calculate the arithmetic mean $\overline{\alpha}$ and the standard deviation of one single Abney level observation s_α for both sets of vertical angles. (αe = angle of elevation, αd = angle of depression (being negative)).

The index error free vertical angle is $\alpha = \frac{\alpha e - \alpha d}{2}$, and the index error of the Abney level is $i = \frac{\alpha e + \alpha d}{2}$

6.3 Part C

As shown in Appendix 2, you should compute the mean of all sets of 4 observations to targets and the standard deviations of one single bearing observation for all sets. Calculate the additional constant for each target separately. Discuss possible differences and give the overall mean, too.

J.M. RUEGER
Lecturer.

January, 1981

APPENDIX 1 (Optical Square)

Accuracy of ranging and offsets (Exercise No. 3.4)

i	x_i	v_x	v_x^2	y_i	v_y	v_y^2	remarks
1							
2							
.							
.							
15							
	$\bar{X}=$			$\bar{Y}=$			

$\Sigma v_x = 0$ ↑ Σv_x^2 $\Sigma v_y = 0$ ↑ Σv_y^2

i = number of dots

n = number of observartions = 15

v = residuals

s_x, s_y = standard deviation of one single x respectively y "observation"

$$\bar{X} = \frac{\sum x_i}{n} \qquad v_x = \bar{X} - x_i$$

$$\bar{Y} = \frac{\sum y_i}{n} \qquad v_y = \bar{Y} - y_i$$

$$s_x = \pm \sqrt{\frac{\sum v_x^2}{n - 1}} \qquad s_y = \pm \sqrt{\frac{\sum v_y^2}{n - 1}}$$

APPENDIX 2 (Prismatic Compass)

Determination of a compass instrument constant

STATION	INSTR Make:			Type:			No.		
i	TARGET A			TARGET B			TARGET C		
	β	v_β	v_β^2	β	v_β	v_β^2	β	v_β	v_β^2
1									
2									
3									
4									
$\bar{\beta}$									
β_{Grid}									
I.Const.									
s_β									
LOCALITY		DATE		TIME			OBSERVER		
GRID (DATUM): ISG, Zone 56/1							BOOKER		

β = observed, magnetic bearing

i = number of observation

$\bar{\beta}$ = arithmetic mean = $\frac{\sum \beta_i}{n}$

n = total number of obs.

β_{Grid} = Calculated (given) Grid bearing (ISG, Zone 56/1)

I.Const.= Instrument Constant of Compass No. .....= $\beta_{Grid} - \bar{\beta}$

$v_\beta = \bar{\beta} - \beta_i$ = residual

s_β = standard deviation of one single observed magnetic bearing

$$s_\beta = \pm \sqrt{\frac{\sum v^2}{n - 1}}$$

APPENDIX 3

Liquid filled Precision Bearing Compass

SUUNTO KB-14

Construction

The SUUNTO Precision Bearing Compass is designed to combine extreme accuracy with ease and speed of operation. Compact and flat, the pocket-size housing has no protruding or adjustable parts, and will stand up to heavy duty.

Handheld, this instrument will give readings with an accuracy of 10 minutes of arc (1/6 degree), approaching the performance of an expensive theodolite.

The housing is solid, noncorrosive, anodized lightweight alloy.

The card is immersed in a dampening fluid, giving vibrationless, smooth movement.

Inclination—Balancing

The card of the KB-14 is balanced at the factory against magnetic inclination for the locality of use. Without balancing the card may not rest horizontally, but will dip toward either of the magnetic poles. *When ordering, please state locality of use, and proper balancing will be carried out at the factory at no extra cost.* Compasses delivered to our dealers are already properly balanced.

Balancing can only be done in connection with the production process.

Declination

The card is set at the factory for Magnetic North, to a precision of ± 3 arc minutes. However, the magnetic poles are situated beneath the earth's surface and do not coincide with the geographical poles. They also move, slowly but unpredictably. Consequently, the compass shows magnetic north, which differs from map north by the amount of the local declination which is printed on your map.

In order to lay out on a map a bearing obtained with the compass, the plus or minus declination for the locality in question must be added to the compass bearing.

When a bearing is taken from the map and a corresponding sighting is wanted with the compass, the procedure must be reversed. Sailors use the term "variation" for magnetic declination.

Deviation

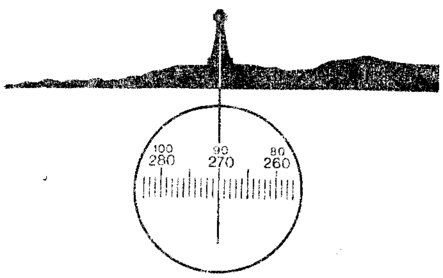
Iron and steel objects close to the compass, like a wrist-watch or steel-rimmed eyeglasses, may cause deviation. Whenever possible, remove such objects to a safe distance. Large structures like buildings, reinforced concrete quays etc. will cause deviation at some distance. A reverse sighting from the opposite end of the target line will show up any deviation present.

Operation

With both eyes open, aim the compass so that the hairline is superimposed on the target, when viewed through the lens.

Use the left of the right eye as preferred. With both eyes open, an optical illusion makes the hairline appear to continue above the instrument frame, superimposed on the target. This improves reading accuracy and speed.

Because of an eye condition called heterophoria, the reading accuracy of some users may be impaired. Check for this as follows:

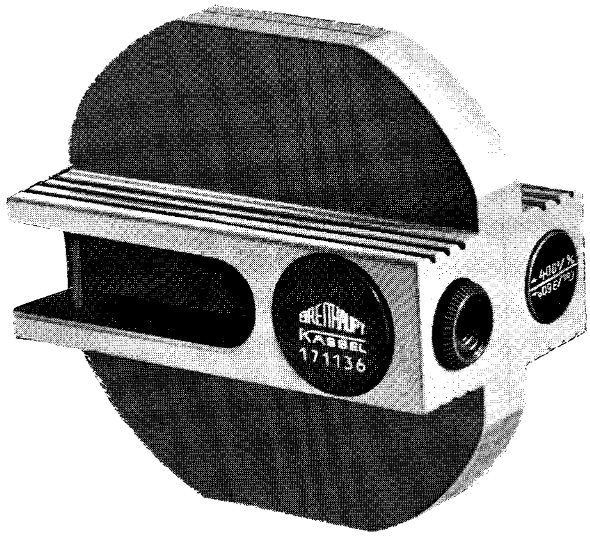


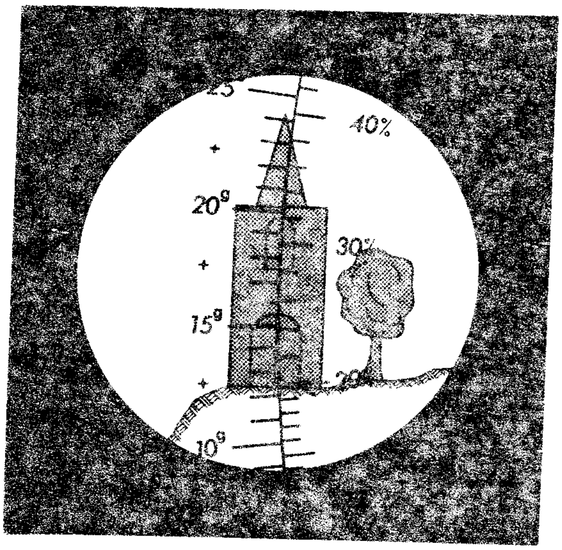
Take a reading with both eyes open and then close the free eye. If the reading does not change appreciably there is no disalignment of the eye axes, and both eyes can be kept open. Should there be a difference in the readings, keep the other eye closed and sight half-way above the instrument body. The hairline now rises above the instrument body and is seen against the target.

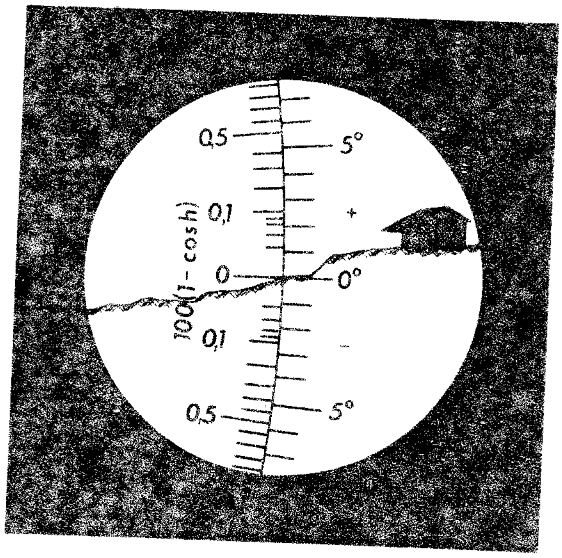
APPENDIX 4

Optical Hand Clinometer

The Optical Hand Clinometer is suitable for geological, topographic and underground measurements, for simple levelling of low accuracy, for fast and easy measurement of the inclination of lines of sight, and for reduction of inclined distances to the horizontal.
4 graduations: 400^g, %, reduction scale, 360°; precise reading due to highly precise optics and simultaneous reading of 2 graduations each and observation of the objective through the eyepiece.







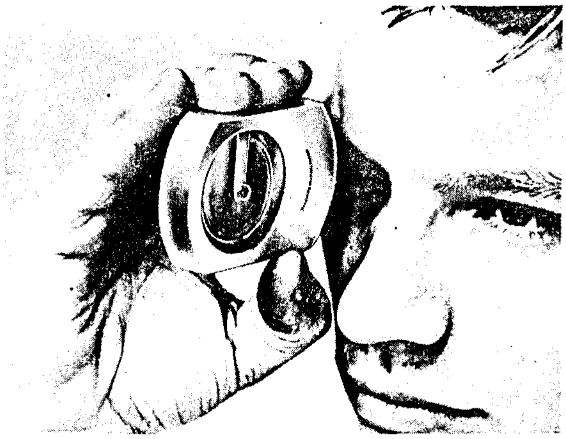
Essential and new points:

Two of these graduations each and the image of the object appear **simultaneously** in the field of view of the telescope. The centesimal graduation and the graduation in per cent appear in the first position (eyepiece on the l.h. side). The sexagesimal graduation and the reduction scale appear in the second position (eyepiece on the r.h. side). The graduations are marked by symbols, thus eliminating confusion.

Prepared by J.M. Rueger, May 1977

APPENDIX 5

SUUNTO OPTICAL READING CLINOMETER PM-5/360 PC



The sturdy pocket-size construction renders the SUUNTO CLINOMETER most suitable for every type of work. Easy of rapid reading through a parallax-free lens is incorporated into the design.
Sighting and scale reading are done simultaneously. There are no screws to turn, no bubbles to center, and nothing to adjust.
This is a one-hand operation.

Construction features: The framework is of corrosion resistant light-weight metal.
The scale card is supported by a jewel bearing assembly and all moving parts are immersed in a damping liquid inside a high strength hermetically sealed plastic container. The liquid dampens all undue scale vibrations and permits a smooth shockless movement of the scale card.
The material of the container is not attacked by sunlight or water. The liquid does not freeze in the arctic or evaporate in the tropics.

Fig. 1 here illustrates the features that are important in its use.

Specification: Weight: 4,2 ounces. Dimensions: 2 3/4" x 2" x 5/8". The optical scales are graduated in degrees from 0° to + 90° and from 0° to —90°, and from 0 % to + 150 % and from 0 % to — 150 %.
All instruments are supplied in a skylon case, by special request they can be supplied with leather case which has a belt loop. A table of cosines is imprinted on the back of the instrument.
Accuracy: Can be read directly to one degree or one per cent. Can be estimated to 10 minutes or 1/5 of 1 per cent, the latter naturally applying to readings around the zero level.

IMPORTANT NOTICE

The axes of the eyes of some people are not parallel, a condition called heterophoria. This can even vary in time and be dependant on different factors too. Therefore, in order to be sure that said phenomenon does not affect the accuracy of readings, it is suggested that the operator checks this possibility before taking the actual readings as follows:

> **Take a reading with both eyes open and then close the free eye. If the reading does not change appreciably there is no disalignment of the eye axes, and both eyes can be kept open.**
>
> **Should there be a difference in the readings, one has to keep the other eye closed and to sight partly past the instrument body making use of the optical illusion**

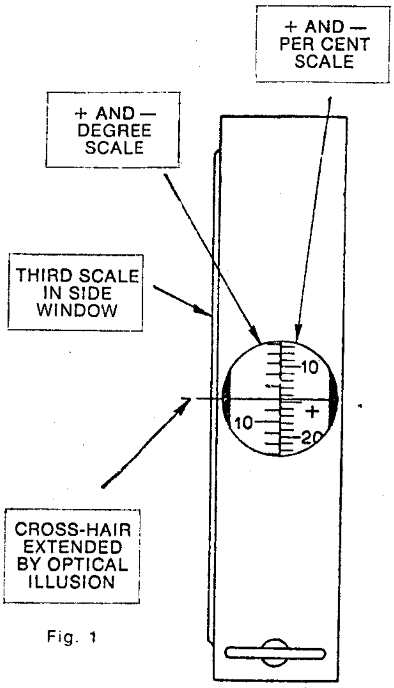


Fig. 1

Instructions for use

Readings are usually taken with the right eye as shown on the title page. Owing to differences in the keenness of the sight of the eyes and because of personal preferences the use of the left eye is sometimes easier. It is of prime importance that **both eyes are kept open.** The supporting hand must not obstruct the vision of the other eye.
The instrument is held before the reading eye so that the scale can be read through the optics, and the round side-window faces to the left. The instrument is aimed at the object by raising or lowering it until the hair line is sighted against the point to be measured. At the same time the position of the hair line against the scale gives the reading. Owing to an optical illusion the hair line (crosshair) seems to continue outside the frame and is thus easily observed against the terrain of the object, **Fig. 1.**

The left-hand scale gives the slope angle in degrees from the horizontal plane at eye level. The right-hand scale gives the height of the point of sight from the same horizontal eye level, and it is expressed in per cent of the horizontal distance. The following example illustrates the procedure.
The task is to measure the height of a tree at a distance of 82 ft. on level ground **(Fig. 2).** The instrument is tilted so that the hair line is seen against the tree-top (apex). The reading obtained will be 48 per cent (ca 25 1/2°). As the distance is 82 ft. the height of the tree is 48/100 x 82 ft. = ca. 39 ft. To this must be added the eye's height from the ground, e.g. 5 1/2 ft. Their sum is 44 1/2 ft., the height of the free.

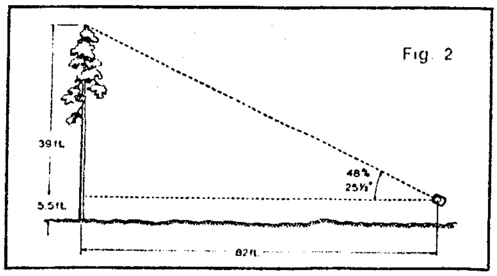
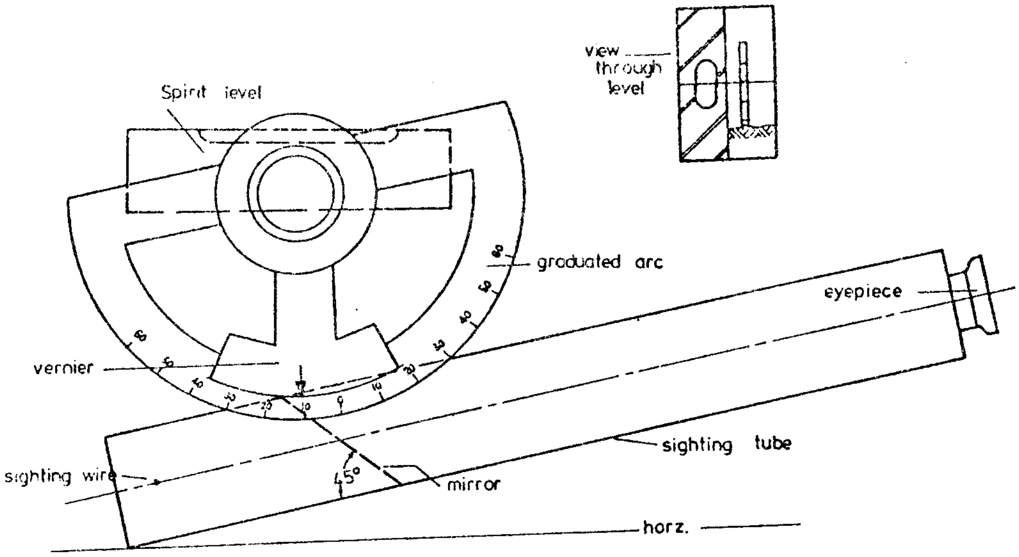


Fig 2

Prepared by J.M. Rüeger, January 1981

APPENDIX 6

ABNEY LEVEL



Prepared by

A. Stolz

21 March, 1977