

UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF SURVEYING

29.002 SURVEYING 1B

FULL TIME COURSE 1977

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

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1. AIM

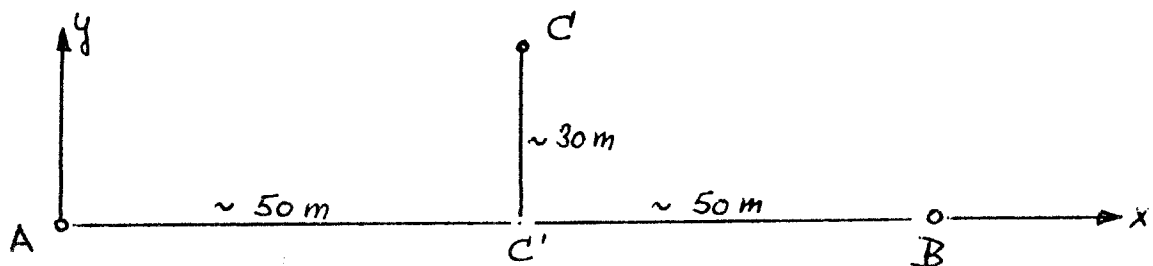
To familiarise students with three hand held instruments (Optical square/ Abney level clinometer/Prismatic compass) their use, their testing and their accuracy.

2. EQUIPMENT

- 1 x Optical square (double-prism type)
- 1 x Plumbing rod for optical square
- 5 x Ranging rods (with steel shod)
- 1 x 100 m band
- 4 x small nails
- 1 x Hammer
- 1 x Abney level clinometer
- 1 x Prismatic compass SUUNTO KB-14
- 1 x Carbon paper
- 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)

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 Abney level clinometer, measure as accurately as possible (to 1 minute of arc), the vertical angles ten times uphill and ten times downhill, from handkerchief 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 converting observed magnetic bearings into grid bearings (Grid = ISG, Zone 56/1).

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)

<u>Station</u>	<u>Target</u>	<u>Grid Bearing</u>	<u>(Remarks on Target)</u>
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
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  $\bar{X}$  and  $\bar{Y}$ , 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  $\bar{X}$ ,  $\bar{Y}$ ) 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  $\bar{Y}$  and the standard deviation  $s_y$  of one single y-observation. (The x values are of no interest this time!). Plot the line  $\bar{Y}$  on this sheet.

To get the error  $\Delta\epsilon$  in the (expected)  $180^\circ$ -angle  $\epsilon$  of the optical square, calculate:

$$\begin{aligned}\Delta Y &= \bar{Y} \text{ (from 3.4)} - \bar{Y} \text{ (from 3.5)} \\ \Delta\epsilon &= \frac{\Delta\bar{Y} \cdot (50+50)\text{m}}{(2.50\text{m}) \cdot (50\text{m})} = \frac{\Delta\bar{Y}}{50\text{m}} \quad \frac{\Delta\epsilon \text{ in rad}}{\Delta\bar{Y} \text{ in m}} \\ \Delta\epsilon' &= \frac{\Delta\epsilon^{\text{rad}}}{\sin 1'} \quad \Delta\epsilon' \text{ in minutes}\end{aligned}$$

To get the accuracy of an optical square used as a line-ranger (standard deviation of setting out the  $180^\circ$  angle  $\epsilon$ ) calculate:

$$\begin{aligned}S_\epsilon^{\text{rad}} &= \frac{S_y}{25\text{m}} \quad (S_y \text{ in metres, } S_\epsilon \text{ in rad)} \\ S_\epsilon' &= \frac{S_\epsilon^{\text{rad}}}{\sin 1'} \quad (S_\epsilon' \text{ in minutes})\end{aligned}$$

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:

$$\begin{aligned}S_\epsilon &= \pm 1^\circ \quad (\text{W.S. Whyte}) \\ S_\epsilon &= \pm 4' \quad (\text{W. Grossmann})\end{aligned}$$

### 6.2 Part B

Calculate the arithmetic mean  $\bar{\alpha}$  and the standard deviation of one single Abney level observation  $s_\alpha$  for both sets of vertical angles. ( $\alpha_e$  = angle of elevation,  $\alpha_d$  = 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  
June 1977

APPENDIX 1 (Optical Square) <sup>-4-</sup>

Accuracy of ranging and offsets (Exercise No. 3.4)

i	x <sub>i</sub>	v <sub>x</sub>	v <sub>x</sub> <sup>2</sup>	y <sub>i</sub>	v <sub>y</sub>	v <sub>y</sub> <sup>2</sup>	remarks
1	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---
.	---	---	---	---	---	---	---
.	---	---	---	---	---	---	---
15	---	---	---	---	---	---	---
	$\bar{X} =$			$\bar{Y} =$			

$$\sum v_x = 0 \uparrow$$

$$\sum v_x^2$$

$$\sum v_y = 0 \uparrow$$

$$\sum v_y^2$$

i = number of dots

n = number of observations = 15

v = residuals

s<sub>x</sub>, s<sub>y</sub> = standard deviation of one single x respectively y "observation"

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

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

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

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

APPENDIX 2 (Prismatic Compass)

Determination of a compass instrument constant

STATION		INSTR Make:		Type:		No.			
i	TARGET A		TARGET B			TARGET C			
	$\beta$	v <sub>β</sub>	v <sub>β</sub> <sup>2</sup>	$\beta$	v <sub>β</sub>	v <sub>β</sub> <sup>2</sup>	$\beta$	v <sub>β</sub>	v <sub>β</sub> <sup>2</sup>
1	---	---	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---	---	---
3	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---	---	---
$\bar{\beta}$									
$\beta_{Grid}$									
I.Const.									
$s_\beta$									
LOCALITY		DATE		TIME		OBSERVER			
GRID (DATUM): ISG, Zone 56/1						BOOKER			

$\beta$  = observed, magnetic bearing

i = number of observation

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

n = total number of obs.

$\beta_{Grid}$  = 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

$s_\beta$  = 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

### 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.

## SUUNTO KB-14

### 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  $\pm 3$  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.

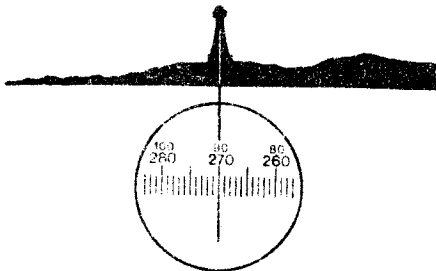
### Operation

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.