INTERNATIONAL STANDARD

ISO 8322-4

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 4: Theodolites

Construction immobilière — Instruments de mesure — Procédures de détermination de l'exactitude d'utilisation —

Partie 4: Théodolites

Reference number
ISO 8322-4:1991(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8322-4 was prepared by Technical Committee ISO/TC 59, *Building construction*, Sub-Committee SC 4, *Limits and fits in building construction*.

ISO 8322 consists of the following parts, under the general title *Building construction — Measuring instruments — Procedures for determining accuracy in use*:

— *Part 1: Theory*

— *Part 2: Measuring tapes*

— *Part 3: Optical levelling instruments*

— *Part 4: Theodolites*

— *Part 5: Optical plumbing instruments*

— *Part 6: Laser instruments*

— *Part 7: Instruments when used for setting out*

— *Part 8: Electronic distance-measuring instruments up to 150 m*

— *Part 9: Electronic distance-measuring instruments up to 500 m*

— *Part 10: Testing short-range reflectors*

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Introduction

This International Standard consists of a series of parts specifying test procedures to be adopted when determining and assessing the accuracy in use of measuring instruments in building construction. The first part gives the theory; subsequent parts give the procedures for determining the accuracy in use of measuring instruments for measurements.

For testing measuring instruments for land surveying purposes and for measuring procedures in ordnance survey, other International Standards are in preparation.

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 4:
Theodolites

1 Scope

This part of ISO 8322 specifies test procedures to be adopted when determining and assessing the accuracy in use of theodolites for measurement of horizontal and vertical angles in the gon and degree system.

The procedures given in this part of ISO 8322 apply when these theodolites are used in building construction for surveying, check and compliance measurements and also when obtaining accuracy data.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8322. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8322 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3534:1977, *Statistics — Vocabulary and symbols.*

ISO 4463-1:1989, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria.*

ISO 7077:1981, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078:1985, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes.*

3 General

3.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigate whether the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carry out test measurements under field conditions to establish the accuracy achieved when he uses a particular measuring instrument and its ancillary equipment.

To ensure that the assessment takes account of various environmental influences, two series of measurements need to be carried out under different conditions. The particular conditions to be taken into account may vary depending on where the tasks are to be undertaken. These conditions will include variations in air temperature, wind speed, cloud cover and visibility. Note should also be made of the actual weather conditions at the time of measurement and the type of surface over which the measurements are made. The sets of conditions chosen for the tests should match those expected when the intended measuring task is actually carried out. See ISO 7077 and ISO 7078.

The procedures are designed so that the systematic errors are largely eliminated and assume that the particular instruments are in known and acceptable states of user adjustment according to methods detailed in the manufacturers' handbooks.

Assumptions: P is the permitted deviation of the measuring task

A is the accuracy in use, generally expressed as deviation $\pm A$; (both $\pm P$ and $\pm A$ are considered to include the dimensional variability associated with $\pm 2{,}5$ times the standard deviation σ)

s are the standard deviations obtained in field tests

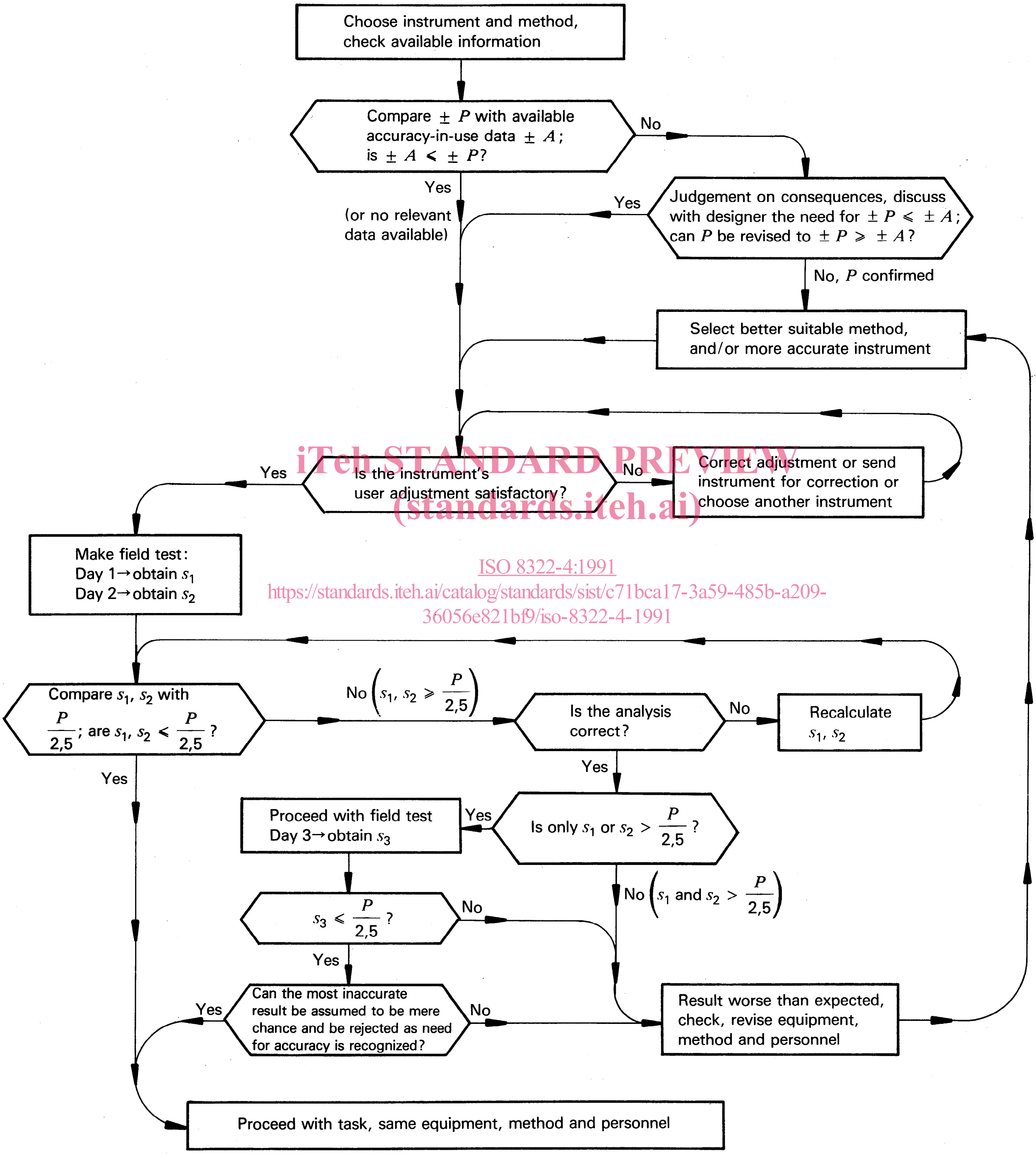

Figure 1 — Flow diagram for accuracy-in-use tests

Accuracy-in-use procedures require repeat tests to be made with the same instrumentation and the same observer, within a short interval of time. These are "repeatability conditions" as defined in ISO 3534.

The accuracy in use is expressed in terms of the standard deviation.

3.2 Figure 1 indicates schematically the decisions to be made when establishing that the accuracy associated with a given surveying method and particular measuring equipment is appropriate to the intended measuring task. In particular, the decisions apply when adopted by a particular operator under a range of environmental conditions which are likely to occur when the task is actually carried out. Where the contract documentation specifies the required tolerance for the intended measuring task, it is recommended that this tolerance, which is normally given in terms of the permitted deviation P ($P = 2{,}5\ \sigma$) of the measuring task, be compared with the accuracy-in-use data obtained either from previous accuracy-in-use tests or from general data A which indicate the expected accuracy in use of given measuring equipment. On those occasions that the previously obtained data indicate that the accuracy in use associated with the given measuring equipment does not meet the specified permitted deviation of the measuring task, consideration should be given to either selecting a different method and/or a more precise instrument or discussing with the designer the need for such a small permitted deviation. See ISO 4463-1.

Before obtaining an overall estimate of the accuracy in use, it is recommended that each standard deviation for a given series of measurements undertaken under particular environmental conditions be compared, as indicated in figure 1, to the specified permitted deviation. Where the comparison shows that the specified permitted deviation has not been achieved for one series of measurements, an additional series of measurements should be carried out under environmental conditions as near as possible similar to those which applied in that original series of measurements.

4 Procedures for theodolites

4.1 Accuracy test procedure

The following test procedure shall be adopted for determining the accuracy in use, by a particular survey team with a particular instrument and its ancillary equipment.

When setting up the theodolite for different series of observations, take special care when centring over the station. Achievable accuracies of centring expressed in terms of standard deviations are the following:

a) Plumb bob: 1 mm to 2 mm (worse in windy weather).

b) Optical plummet: 0,5 mm (to be checked for its own adjustment).

c) Centring rod: 1 mm.

With targets at 100 m distances a mis-centring of 2 mm could affect the observed angle by up to 1,2 mgon (4″). The shorter the distance the greater the effect.

If the targets have to be re-set for each series, similar care shall be taken with their centring.

4.2 Measurement of horizontal directions

The measurement results for horizontal directions should be given in a table (see table 1-B). An example of a completed table, with the results in gon, is given in table 1-A. The results with a sexagesimal theodolite are shown in table 2-A.

4.2.1 Observations

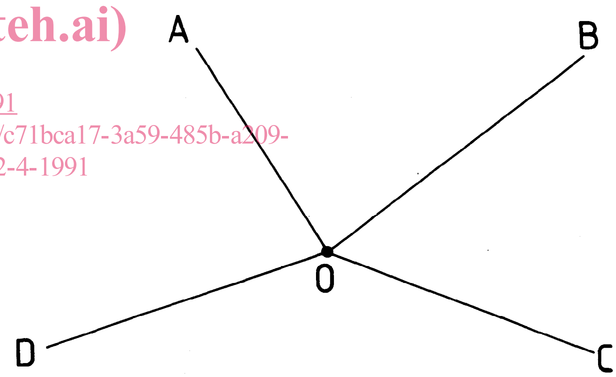

Figure 2 — Layout of four targets

4.2.1.1 Establish four targets A, B, C and D spread over as large an angle as possible, but at least 100 gon or 90°, at distances from a fixed theodolite station O, and of a form commensurate with that expected on the particular construction site. (See figure 2.) The positions of the targets and theodolite shall be precisely defined in stable locations for the duration of the test measurements and be such that the targets are readily visible from the theodolite station.

4.2.1.2 Each series of measurements shall consist of four separate sets of readings of directions OA, OB, OC and OD (see column 2 of table 1-B). The four points are observed with the telescope in the face-left position (see column 3) in the sequence

A—B—C—D and in the face-right position (see column 4) in the sequence D—C—B—A. After each set move the horizontal circle through about 50 gon or 45° and observe the same sequence for that set. Observe a second series on a different day.

4.2.1.3 Record the environmental conditions. Changes in environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.2.2 Calculation procedure

A complete example of the analysis is given in table 1-A for a universal theodolite using the measurements given in columns 3 and 4.

4.2.2.1 Reduce the directions of each set to direction OA as 0,0000 in the face-left position (see column 5) and in the face-right position (see column 6).

EXAMPLE

For set 1, target B, face left:
70,7958 − 8,9813 = 61,8145 gon

4.2.2.2 Calculate the means m (column 7) of the values in column 5 and the corresponding values of column 6. This gives four values to each target of which all those towards target A are 0,0000.

EXAMPLE

For set 1, target C:
1/2 (126,1652 + 126,1636) = 126,1644 gon

4.2.2.3 Calculate the averaged values M (column 8) of the groups of four values in column 7 to each target. These need not be repeated against each set.

EXAMPLE

For target B in all four sets:
1/4 (61,8146 + 61,8151 + 61,8165 + 61,8152)
= 61,8154 gon

4.2.2.4 Calculate the differences d (column 9) between the values of column 8 and the corresponding values in column 7.

EXAMPLE

For set 1, target B:
61,8154 − 61,8146 = +0,8 mgon

4.2.2.5 Calculate the arithmetic means $\bar{d}$ of the differences d (column 9) in each set.

EXAMPLE

For set 1:
1/4 (0,0 + 0,8 + 0,7 − 0,5) = +0,2 mgon

4.2.2.6 Calculate the deviations v (column 10) for each target direction as the differences d minus the relevant $\bar{d}$ for each set.

EXAMPLE

For set 1, target B:
0,8 − (+0,2) = +0,6 mgon

The sum of the deviations for each set shall be approximately zero. In this case $\bar{d}$ is not taken as the true value or as the value accepted as true, but as the value by which the calculated mean of each direction in a set misfits if the direction OA is set to zero. Therefore each difference shall be corrected by this value $\bar{d}$.

4.2.2.7 Calculate the squares (column 11) of all values in column 10 and the overall sum of the squares.

EXAMPLE

For set 1, target B:
$(+0,6)^2 = +0,36$ mgon²
The overall sum of squares = 3,33 mgon²

4.2.2.8 Calculate the standard deviation s_1 of a direction observed in both faces on the first day as the square root of the sum of squares divided by 9 (= number of redundant observations).

EXAMPLE

$$s_1 = \sqrt{\frac{3,33}{9}} = 0,6 \text{ mgon}$$

4.2.2.9 Repeat the procedures in 4.2.2.1 to 4.2.2.8 on the second day and obtain s_2.

4.2.2.10 The overall standard deviation, s, for the measurement of a direction on two faces from the two series is

$$s = \sqrt{\frac{s_1^2 + s_2^2}{2}}$$

EXAMPLE

If s_2 = 0,8 mgon

s = 0,7 mgon

Hence the overall standard deviation for the measurement of an angle on two faces is $s\sqrt{2}$ = 1,0 mgon.

4.3 Vertical angle measurement

4.3.1 Observations

The measurement results for vertical angles should be given in a table (see table 3-B). An example of a completed table, with the results in gon, is given in table 3-A. For sexagesimal theodolites, see table 4-B and table 4-A.

4.3.1.1 Select four clearly defined targets A, B, C and D, if possible at different levels. The horizontal distances from a fixed theodolite station O and the form of the targets shall be commensurate with those expected on the construction site. The positions of the targets and the theodolite shall be precisely defined in stable positions for the duration of the test measurements and such that the targets are readily visible from the theodolite station.

4.3.1.2 The observing sequence of the direction of each of the four targets is arbitrary. The targets are observed in (optional) order, first in face-left and then in face-right position. This is repeated a further three times (see columns 1 to 4).

4.3.1.3 Record the environmental conditions. Changes in environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under new conditions.

NOTE 1 Notice should be taken of the way in which the vertical circle of the instrument is graduated since this can vary from model to model.

4.3.2 Calculation procedure

A complete example of the analysis is given in table 3-A for a universal theodolite using the measurements given in columns 3 and 4.

4.3.2.1 Calculate the sum (column 5) from the face-left reading (column 3) and the difference 400 gon (or 360°) minus the face-right reading.

EXAMPLE

For set 1, target C:
100,566 2 + (400 − 299,447 9) = 201,118 3 gon

4.3.2.2 Divide the value in column 5 by 2.

EXAMPLE

For set 1, target C:
201,118 3:2 = 100,559 2 gon

4.3.2.3 Calculate the average values M (column 7) of the groups for four values in column 6 to each target. These need not be repeated against each set.

EXAMPLE

For target C in all four sets:
1/4 (100,559 2 + 100,559 6 + 100,560 6 +
+ 100,559 9) = 100,559 8 gon

4.3.2.4 Calculate the deviations v (column 8) between the values of column 7 and the corresponding values in column 6.

As an arithmetic check, the sum of the deviations should be approximately zero.

EXAMPLE

For set 1, target C:
100,559 2 − 100,559 8 gon = −0,6 mgon

4.3.2.5 Calculate the squares (column 9) of all values in column 8 and the overall sum of the squares.

EXAMPLE

For set 1, target C:
$(+0,6)^2 = 0,36$ mgon^2
The overall sum of the squares = 1,65 mgon^2

4.3.2.6 Calculate the standard deviation s_1 of an observed vertical angle observed in both faces on the first day as the square root of the sum of squares divided by 12 (= number of redundant observations).

EXAMPLE

$$s_1 = \sqrt{\frac{1,65}{12}} = 0,37 \text{ mgon} \approx 0,4 \text{ mgon}$$

4.3.2.7 Repeat the procedures in 4.3.2.1 to 4.3.2.6 on the second day and obtain s_2.

4.3.2.8 The overall standard deviation s for the measurement of a vertical angle on two faces from the two series is

$$s = \sqrt{\frac{s_1^2 + s_2^2}{2}}$$

EXAMPLE

If $s_2 = 0,3$ mgon

$s = 0,35$ mgon $\approx 0,4$ mgon

Table 1-A — Measurement of horizontal angles, gon-system — Example of field observations and calculation

Date:

Location:

Observer:

Instrument: universal theodolite

Conditions: temperature 15 °C, relative humidity 45 %, atmospheric pressure 1 000 mbar, time of measurement 11.30, road surface

Series: I

Set	Target	Face left gon	Face right gon	Reduced face left gon	Reduced face right gon	Mean of set, m gon	Mean of station, M gon	d mgon	v mgon	v^2 mgon²
1	2	3	4	5	6	7	8	9	10	11
1	A	8,981 3	208,981 7	0,000 0	0,000 0	0,000 0	0,000 0	0,0	−0,2	0,04
	B	70,795 8	270,796 3	61,814 5	61,814 6	61,814 6	61,815 4	+0,8	+0,6	0,36
	C	135,146 5	335,145 3	126,165 2	126,163 6	126,164 4	126,165 1	+0,7	+0,5	0,25
	D	221,541 3	21,541 0	212,560 0	212,559 3	212,559 6	212,559 1	−0,5	−0,7	0,49
							Σ	+1,0	+0,2	1,14
							$\bar{d} = \frac{\Sigma d}{4}$	+0,2		
2	A	59,054 6	259,055 8	0,000 0	0,000 0	0,000 0		0,0	0,0	0,00
	B	120,869 7	320,870 9	61,815 1	61,815 1	61,815 1		+0,3	+0,3	0,09
	C	185,220 8	385,221 1	126,166 2	126,165 3	126,165 8		−0,7	−0,7	0,49
	D	271,613 8	71,614 3	212,559 2	212,558 5	212,558 8		+0,3	+0,3	0,09
							Σ	−0,1	0,0	0,67
								0,0		
3	A	109,304 8	309,304 4	0,000 0	0,000 0	0,000 0		0,0	+0,6	0,36
	B	171,121 0	371,121 2	61,816 2	61,816 8	61,816 5		−1,1	−0,5	0,25
	C	235,471 1	35,470 4	126,166 3	126,166 0	126,166 2		−1,1	−0,5	0,25
	D	321,864 3	121,863 8	212,559 5	212,559 4	212,559 4		−0,3	+0,3	0,09
							Σ	−2,5	−0,1	0,95
								−0,6		
4	A	159,291 1	359,290 0	0,000 0	0,000 0	0,000 0		0,0	−0,4	0,16
	B	221,105 7	21,105 9	61,814 6	61,815 9	61,815 2		+0,2	−0,2	0,04
	C	285,455 0	85,454 3	126,163 9	126,164 3	126,164 1		+1,0	+0,6	0,36
	D	371,849 7	171,848 6	212,558 6	212,558 6	212,558 6		+0,5	+0,1	0,01
							Σ	+1,7	+0,1	0,57
								+0,4		
										Σv^2 = 3,33 mgon²

$$s_1 = \sqrt{\frac{3,33}{9}} = 0,6 \text{ mgon}$$

$s_2 = 0,8$ mgon (measured on another day)

$$s = \sqrt{\frac{0,6^2 + 0,8^2}{2}} = 0,7 \text{ mgon}$$

$$s_{angle} = 0,7 \times \sqrt{2} = 1,0 \text{ mgon}$$

Table 1-B — Measurement of horizontal angles, gon-system — Field observations and calculation

Date:

Location:

Observer:

Instrument:

Conditions:

Series:

Set	Target	Face left gon	Face right gon	Reduced face left gon	Reduced face right gon	Mean of set, m gon	Mean of station, M gon	d mgon	v mgon	v^2 mgon²
1	2	3	4	5	6	7	8	9	10	11
1	A B C D						Σ $\bar{d} = \frac{\Sigma d}{4}$			
2	A B C D									
3	A B C D									
4	A B C D									
									$\Sigma v^2 =$	

$s_1 = \sqrt{\frac{\Sigma v^2}{9}} =$

$s_2 =$ (measured on another day)

$s = \sqrt{\frac{s_1^2 + s_2^2}{2}} =$

$s_{angle} = s \times \sqrt{2} =$