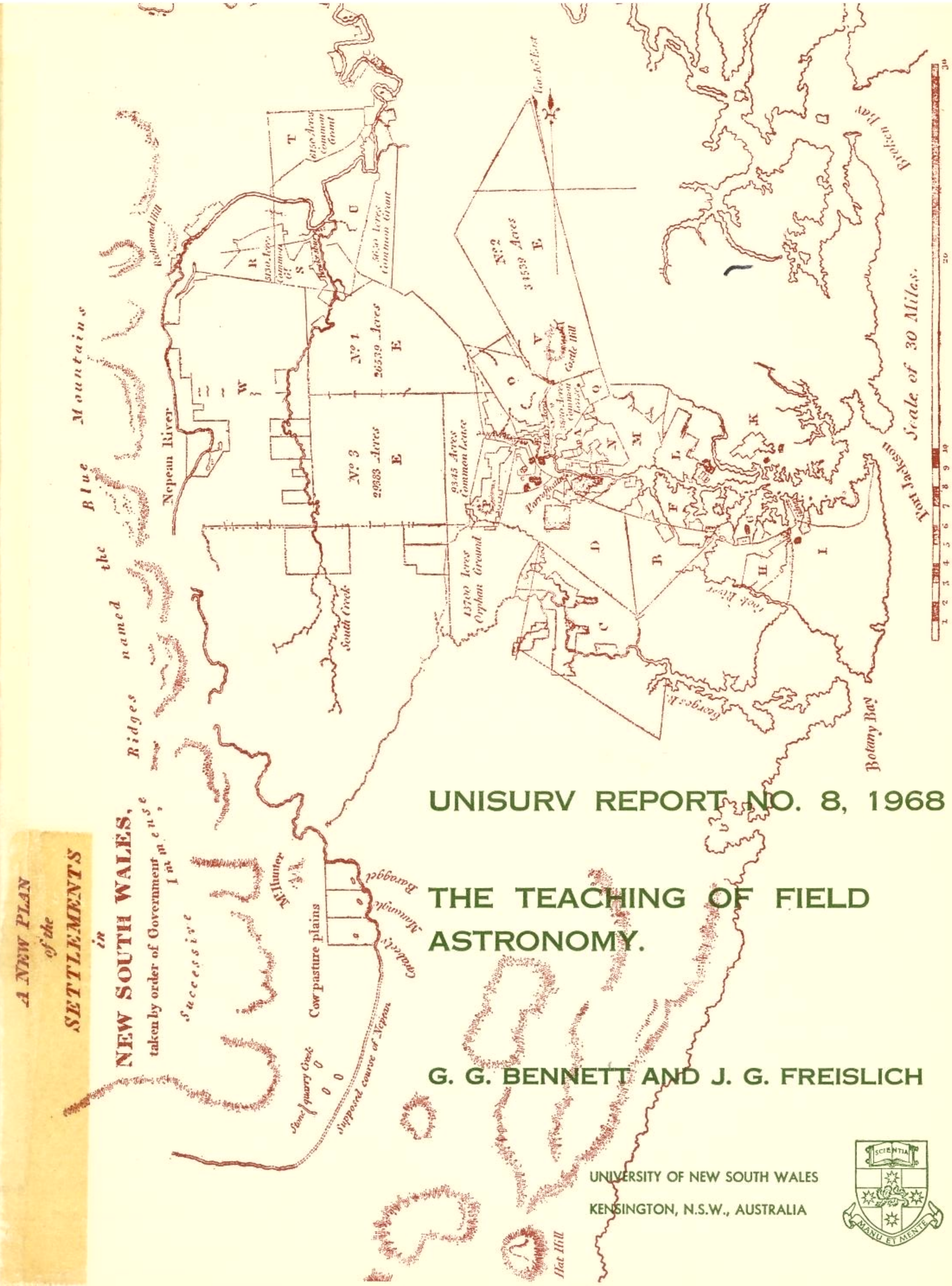

UNISURV REPORT NO. 8, 1968

THE TEACHING OF FIELD ASTRONOMY.

G. G. BENNETT AND J. G. FREISLICH

UNIVERSITY OF NEW SOUTH WALES
KENSINGTON, N.S.W., AUSTRALIA

Reference to Districts.

A Northern Boundaries

B Liberty Plains

C Banks Town

D Parramatta

EEEE Ground reserved
for Govt. purposes

F Concord

G Petersham

H Bulanaming

I Sydney

K Hunters Hills

L Eastern Farms

M Field of Mars

N Ponds

O Toongabbey

P Prospect

Q

R Richmond Hill

S Green Hills

T Phillip

U Nelson

V Castle Hill

W Evan

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THE TEACHING OF FIELD ASTRONOMY.

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Received February, 1968.

SUMMARY: The teaching of Field Astronomy as a survey subject at a particular university is given with some detail about course structure and content. A system of conventions is postulated to enable complicated calculation to be achieved without ambiguity. Teaching aspects are discussed and the facilities and equipment available are described.

School of Civil Engineering, University of New South Wales

1. General.

Field astronomy is of particular importance to the land surveyor in a country such as Australia where our National and State survey control stations are sparse judged by European standards. Where survey control is dense, position and azimuth are readily available and it is on rare occasions only that the surveyor is called upon to establish an astronomical azimuth. It is primarily for this reason that the subject of astronomy is emphasised in courses of survey instruction at Australian Universities and Technical Colleges.

In addition to the practical advantages of a good understanding of field astronomy, the subject matter itself is ideally suited for tertiary level teaching. The concepts are clear, concise and readily explained, and they are built upon the students' knowledge acquired in physics, mathematics (including statistics), geodesy and surveying. The theory is reinforced by practical work, in which most students achieve a remarkable measure of success. Perhaps one of the reasons for the popularity of the subject lies in the fascination of being able to derive fundamental survey information from observations of the heavenly bodies.

Since 1956 the University of N.S.W. has offered a four year full-time and an equivalent seven year part-time course leading to the degree of Bachelor of Surveying. From its inception the course has contained astronomy subjects in the last two years. Astronomy I consists of 42 hours of lectures and 21 hours of practical work and Astronomy II of 45 hours of lectures and 30 hours of practical work. The first course is devoted to teaching the fundamentals of spherical trigonometry, relationships on the celestial sphere, time and its measurement and simple observations for latitude, longitude and azimuth. The second course builds upon the first, developing the theory and practice for simultaneous determinations, equal altitude techniques and the more precise methods of determining latitude, longitude and azimuth. Besides the practical work at the University each student predicts, observes and calculates a star programme under field conditions at a survey camp which is held at the end of the third year.

In 1966 the Department of Surveying inaugurated a two year post-graduate course leading to the degree of Master of Survey Science. The formal study programme consists of five subjects of which four must be selected from a list of surveying subjects, one of which is Astronomy. In the astronomy subject, the work done in the under-graduate course is extended and includes an examination of modern trends in astronomy coupled with a detailed analysis of errors of observation. In addition to the formal course work, each student is required to carry out work on a substantial surveying project involving advanced design, investigation or research.

2. Conventions and Symbols.

The system of definitions and conventions given below have been worked out over a long period of teaching Field Astronomy. It has proved to be successful and students have no great difficulty in understanding the system as well as its implications. (Freislich, 1953, Lee, 1954)

The spherical triangle and its properties are dealt with as a starting point and the relationships between the elements in this triangle are derived. Calculations of some examples serve to consolidate the student's knowledge. The differential relationships are derived next.

The Astronomical Triangle is introduced as being the Spherical Triangle on the celestial sphere having the celestial pole, the observer's zenith and the star as apex points. The conventions given below are stressed at this stage. The fact that the Astronomical Triangle is not restricted to angles of less than 180^{o} is brought out and the generalisation of the spherical trigonometry relationships is worked out. The definitions and conventions associated with the Astronomical Triangle are given below. These make it possible to compute the Astronomical Triangle without any ambiguity in the quantity sought even if the calculation is a complex one, provided the signs of the various trigonometrical functions are carefully followed. Either of the two Astronomical Triangles shown in Fig. 1 can be used and in each case the same result is achieved.

3. Definitions and Conventions.

Name	Symbol	Definition and sign	Quadrant in which quantity exists.
Altitude	h	Vertical angle, positive above and negative below the horizon	1, 4
Zenith distance	z	Vertical angle measured downwards from the zenith as zero to 180° at the nadir	1, 2
Longitude	λ	Angle at terrestrial poles between the meridian of Greenwich and that of a particular place. It is measured positive westwards from Greenwich	1, 2, 3, 4
Right Ascension	RA or α	Angle at celestial poles between hour circle of the First Point of Aries and that of a particular point on the sky. It is measured positive eastwards from the First Point of Aries	1, 2, 3, 4

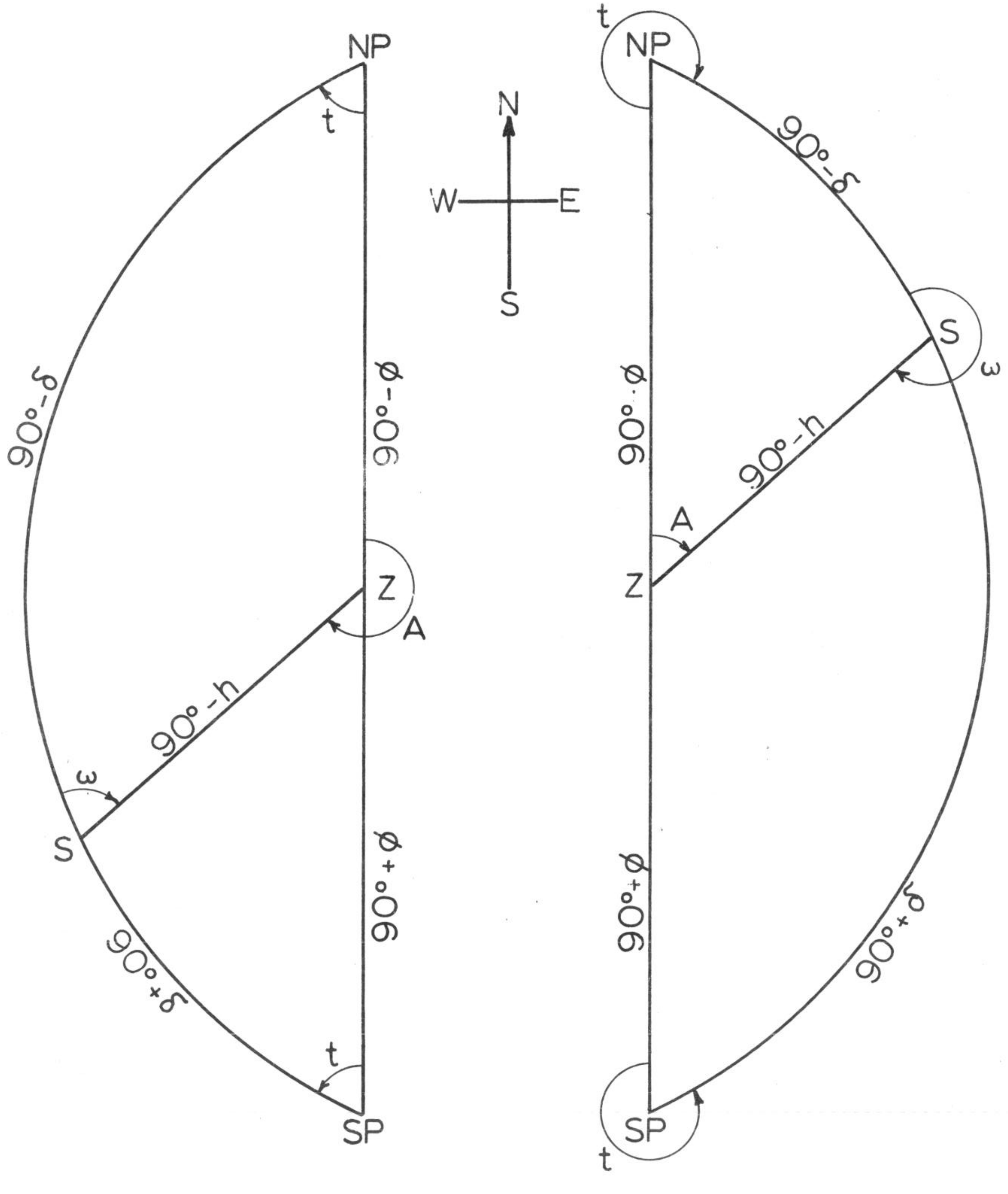

FIG. 1. THE NORTHERN AND THE SOUTHERN ASTRONOMICAL TRIANGLES.

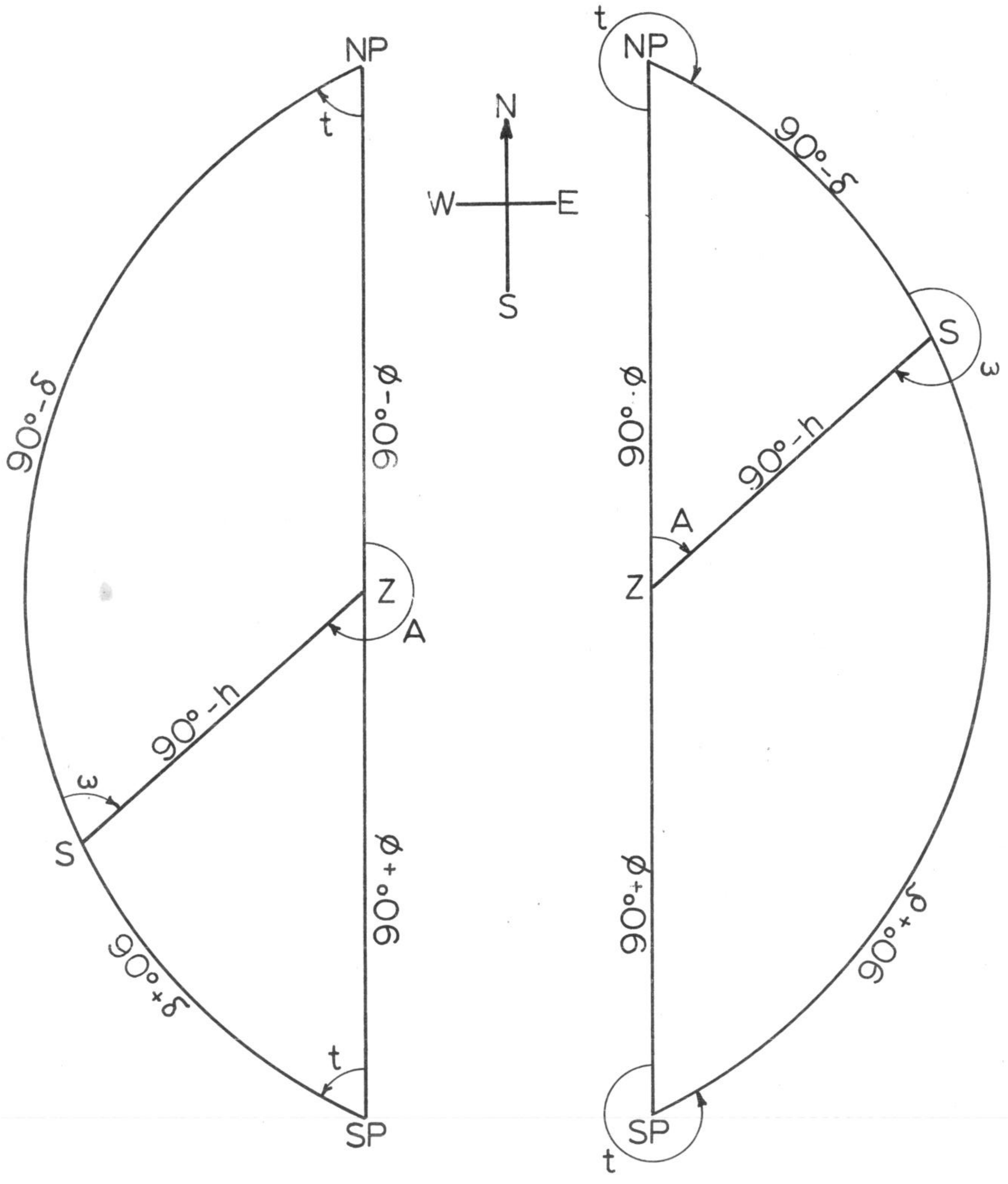

FIG. 1. THE NORTHERN AND THE SOUTHERN ASTRONOMICAL TRIANGLES.

Name	Symbol	Definition and sign	Quadrant in which quantity exists.
Hour Angle	t	Angle at celestial poles from the upper branch of the meridian of a particular place on the earth to the hour circle of a particular star. It is measured positive to the west.	1, 2, 3, 4
Latitude	ϕ	Angular distance from the equator to the zenith of a particular terrestrial point. It is measured along the meridian, positive northwards and negative southwards	1, 4
Declination	δ	Angular distance from the celestial equator to a particular point on the sky along its hour circle. It is measured positive northwards and negative southwards	1, 4
Azimuth	A	Clockwise* horizontal angle from north to the vertical circle through a point	1, 2, 3, 4
Parallactic	ω	Clockwise* angle from the northern branch of the hour circle of a point on the sky to the vertical circle through this point	1, 2, 3, 4

*NOTE: Clockwise is the direction shown in Fig. 1 in which a view is given as seen by an observer "outside" the Celestial Sphere looking down on to the earth.

Example 1. The Sine Formula in the spherical triangle WXY (Chauvenet, 1960, Todhunter and Leathem 1901) is given by:-

$$\frac{\sin W}{\sin w} = \frac{\sin X}{\sin x} = \frac{\sin Y}{\sin y}$$

In the Northern Astronomical Triangle this becomes

(a) to the West

$$\frac{\sin t}{\sin(90-h)} = \frac{\sin(360-A)}{\sin(90-\delta)} = \frac{\sin \omega}{\sin(90-\phi}$$

$$\frac{\sin t}{\cos h} = \frac{\sin A}{\cos \delta} = \frac{\sin \omega}{\cos \phi}$$

(b) to the East

$$\frac{\sin(360-t)}{\sin(90-h)} = \frac{\sin A}{\sin(90-\delta)} = \frac{\sin(360-\omega)}{\sin(90-\phi)}$$

$$\frac{\sin t}{\cos h} = -\frac{\sin A}{\cos \delta} = \frac{\sin \omega}{\cos \phi}$$

in the Southern Astronomical Triangle this becomes

(c) to the West

$$\frac{\sin t}{\sin(90-h)} = \frac{\sin(A-180)}{\sin(90+\delta)} = \frac{\sin(180-\omega)}{\sin(90+\phi)}$$

$$\frac{\sin t}{\cos h} = -\frac{\sin A}{\cos \delta} = \frac{\sin \omega}{\cos \phi}$$

(d) to the East

$$\frac{\sin(360-t)}{\sin(90-h)} = \frac{\sin(180-A)}{\sin(90+\delta)} = \frac{\sin(\omega-180)}{\sin(90+\phi)}$$

$$\frac{\sin t}{\cos h} = -\frac{\sin A}{\cos \delta} = \frac{\sin \omega}{\cos \phi}$$

Example 2. Solve the Astronomical Triangle in which $\phi = 26^{o}$North, $\delta = 50^{o}$ South and $t = 45^{o}$ East $= 315^{o}$

(a) The Cosine Formula in the spherical triangle WXY is given by

$$\cos w = \cos x \cos y + \sin x \sin y \cos W$$

In the Northern Astronomical Triangle, in which W is equated to the North Pole, X to the Zenith and Y to the Star, this becomes

$$\cos(90-h) = \cos(90-\delta).\cos(90-\phi)+\sin(90-\delta).\sin(90-\phi).\cos t$$

$$\sin h = \sin \delta.\sin \phi+\cos \delta.\cos \phi.\cos t$$

$$= \sin(-50).\sin(+26)+\cos(-50).\cos(+26).\cos(+315)$$

$$= (-0.76604)(+0.43837)$$

$$+(+0.64279)(+0.89879)(+0.70711)$$

$$= -0.33581 + 0.40852$$

$$= +0.07271$$

$$h = +04^{o}\ 10'\ 10'' \text{ or } + 175^{o}\ 49'\ 50''$$

But, by definition, h can lie only in the 1st or the 5th quadrants.

$\therefore$ $h = + 04^{o}\ 10'\ 10''$ or $4^{o}\ 10'\ 10''$ above the horizon

(b) The Four Parts Formula in the spherical triangle WXY is given by

$$\sin W \cot X = \sin y \cot x - \cos y \cos W$$

The Southern Astronomical Triangle will now be used to illustrate the generality of the conventions and the formulae derived. It will be lettered with W equated to the South Pole and as before with X equated to the Zenith and Y to the Star. The above relationship therefore becomes

$$\sin t . \cot (A-180) = \sin(90+\phi) . \cot(90+\delta) - \cos(90+\phi) . \cos t$$

$$\sin t . \cot A = -\cos \phi . \tan \delta + \sin \phi . \cos t$$

$$\cot A = \sin \phi . \cot t - \cos \phi . \tan \delta . \operatorname{cosec} t$$

$$= \sin (+26) . \cot(+315) - \cos(+26) . \tan(-50) . \operatorname{cosec}(+315)$$

$$= (+0.43837)(-1.00000) - (+0.89879)(-1.19175)(-1.41421)$$

$$= -0.43837 - 1.51480$$

$$= -1.95317$$

$$A = 332^{\circ}\ 53''\ 18'' \text{ or } 152^{\circ}\ 53'\ 18''$$

$$\text{But } \sin A = -\frac{\cos \delta}{\cos h} . \sin t$$

In this expression $\cos \delta$ and $\cos h$ are always positive since δ and h exist only in the 1st and 4th quadrants. Therefore $\sin A$ has opposite sign to that of $\sin t$. Since here $\sin t$ is negative, $\sin A$ is therefore positive and A must therefore lie in either the 1st or the 2nd quadrant.

$$\therefore A = 152^{\circ}\ 53'\ 18''$$

After the computer has some experience this rather long process of reasoning is much reduced since he knows that the hour angle tells whether the star is east or west of the meridian and the azimuth quadrants are therefore defined.

(c) The Four Parts Formula in the spherical triangle WXY is given by

$$\text{Sin } W \cot Y = \sin x \cot y - \cos x \cos W$$

The Four Parts formula in the Northern Astronomical Triangle, lettered as in 2(a) becomes

$$\sin t.\cot \omega = \sin(90-\delta).\cot(90-\phi)-\cos(90-\delta).\cos t$$

$$\cot \omega = \cos \delta.\tan \phi.\text{cosec } t - \sin \delta .\cot t$$

$$= \cos(-50).\tan(+26).\text{cosec}(315)-\sin(-50).\cot 315$$

$$= -1.20940$$

$$\therefore \omega = 320^{\circ}\ 24'\ 50''$$

This quadrant is selected as lies in the 3rd or the 4th quadrant when the star is east of the meridian.

(d) Checking by the Sine Formula gives

$$\frac{\sin t}{\cos h} = \frac{\sin \omega}{\cos \phi} = -\frac{\sin A}{\cos \delta}$$

$$\frac{\sin(315)}{\cos(+4^{\circ}10'10'')} = \frac{\sin(320^{\circ}24'50'')}{\cos(+26)} = -\frac{\sin(152^{\circ}53'18'')}{\cos(-50)}$$

$$-0.70898 = -0.70900 = -0.70897$$

Example 3. From the data of the above examples, find the azimuth at an instant 20 minutes of time earlier, i.e. $\nabla t= -5^{\circ}=-18000''$ i.e. $t=310^{\circ}$

From a Taylor expansion

$$A_{310} = A_{315} + \frac{\partial A}{\partial t}_{315} . \nabla t + \frac{1}{2} . \frac{\partial_2 A}{\partial t^2}_{315} (\nabla t)^2 \ldots\ldots.$$

In the Spherical triangle WXY, the following differential relationships (Chauvenet, 1960, Todhunter and Leathem, 1901,) hold

$$dw = \sin x.\sin Y.dW + \cos Y.dx + \cos X.dy$$

$$\sin w.dY = -\cos X.\sin y.dW - \cos w.\sin Y.dx + \sin X.dy$$

$$\sin w.dX = -\cos Y.\sin x.dW - \cos w.\sin X.dy + \sin Y.dx$$

The third of these gives the following in the Southern Astronomical Triangle

$$\sin(90-h).d(A-180) = -\cos(180-\omega).\sin(90+\delta).dt$$
$$-\cos(90-h).\sin(A-180).d(90+\phi)$$
$$+\sin(180-\omega).d(90+\delta)$$

$$\cos h.dA = +\cos\omega.\cos\delta.dt + \sin h.\sin A.d\phi + \sin\omega.d\delta$$

With ϕ and δ held constant, the first differential coefficient becomes

$$\frac{\delta A}{\delta t} = \cos\omega.\sec h.\cos\delta$$

By differentiation of this, the second differential coefficient becomes

$$\frac{\partial_2 A}{\partial t^2} = -\sin\omega.\sec h.\cos\delta.\ \frac{\partial\omega}{\partial t}$$
$$+\cos\delta.\cos\omega.\sec h.\tan h.\ \frac{\partial h}{\partial t}$$

since, even if ϕ and δ are held constant, when t is changed, ω and h are altered. Similar substitution from the two other relationships gives

$$\frac{\partial h}{\partial t} = \cos\phi\ .\sin A$$

$$\cos h.\frac{\partial\omega}{\partial t} = -\cos A.\cos\phi$$

when ϕ and δ are held constant.

$$\frac{\partial_2 A}{\partial t^2} = \sin \omega . \sec h . \cos \delta . \cos A . \cos \phi . \sec h$$

$$+ \cos \omega . \sec h . \tan h . \cos \delta . \cos \phi . \sin A$$

$$= \cos \delta . \sec^2 h . \cos \phi \, (\sin \omega . \cos A$$

$$+ \cos \omega . \sin h . \sin A)$$

Substituting numerical values from Example 2 gives

$$\frac{\partial A}{\partial t} = \cos(320^\circ 25'). \sec(+4^\circ 10'). \cos(-50)$$

$$= +0.49670$$

$$\frac{\partial_2 A}{\partial t^2} = \cos(-50). \sec^2(4^\circ 10'). \cos(+26)$$

$$\{ \sin(320^\circ 25'). \cos(152^\circ 53')$$

$$+\cos(320^\circ 25'). \sin(+4^\circ 10'). \sin(152^\circ 53') \}$$

$$= +0.3441$$

$$A_{310} = 152^\circ 53' 18'' + (+0.49670)(-18000'')$$

$$+\tfrac{1}{2}.(0.3441)(-18000'')^2. \sin 1''$$

$$= 152^\circ 53' 18'' - 2^\circ 29' 01'' + 0^\circ 04' 30''$$

$$= 150^\circ 28' 47''$$

This value by direct solution is 150° 28' 50".

Simple calculations in the spherical triangle can be carried out reasonably well if polar distance and co-latitude are used. The answers obtained must then be converted into the corresponding astronomical quantities. When, however, the more usual quantities,

Fig. 2. Perspex Globe and McCormick Star Globe

declination and latitude, are used difficulties arise, as for instance, when they are of opposite sign. A set of rules must therefore be postulated, or a diagram drawn or visualised mentally. When the conventions given above are used, however, the astronomical quantities sought are obtained without ambiguity if the signs of the trigonometrical functions are followed. This is not difficult for anyone, who has some experience in computing.

For the more complex calculation, such as for instance that shown in Example 3, the system of conventions has undoubted advantages since the quantities sought are obtained with certainty. All second order curvature corrections fall into this category and, if the spherical triangle is used, one must make up a special set of rules in order to find the sign of the correction.

4. Teaching Aspects.

In the Astronomy I course, the lectures are used to introduce the students to the basic concepts of this subject at the start of the year. After this had been thoroughly achieved, the methods of latitude, longitude and azimuth determination are dealt with. Practical work is undertaken concurrently with the lectures. In the early practicals, the student finds out how a star moves across the field of view of the theodolite telescope, how a pointing is made to a moving object and how such an observation is timed. In the later practicals, he makes actual determinations of position and azimuth.

Lectures and practicals progress at different rates. This difference in progress quickly brings up the question whether the student should know the theory behind a method before he tries it out. The lecturer often regrets very keenly that he did not push the observing far ahead of the corresponding theory in the early part of the year because the Sydney weather in winter so often prevents the possibility of observing. The rate at which lectures proceed in the early stages of the course is very difficult to predict because the concepts are completely new to the student and often require further amplification and sometimes even repetition of certain portions of the course.

The main sections of the course of lectures comprise spherical trigonometry, definitions and conventions, the astronomical triangle (as distinct from the spherical triangle) and time. Every effort is made to determine whether the student grasps the introductory concepts and understands their implications. This is achieved by means of tests and the use of tutorial periods and the setting of assignments of work to be done in the student's own time. A very useful teaching aid at this stage consists of a perspex globe on which it is possible to draw with coloured chinagraph pencils (see Fig. 2). After this the lectures deal with the methods for determining latitude, longitude and azimuth and various aspects associated with these methods. At this stage the course runs much more smoothly because the students understand what is required and also because they have the added interest of dealing with their own observational data.

At the start of the year the students are not familiar with the single second theodolites used in the practical exercises. To help in overcoming this difficulty, practical work in the other subjects of their course is so arranged that the students use these theodolites early in the year in order to become familiar with them in daylight and therefore to use them efficiently in the Astronomy practicals in the dark.

Observations are made for latitude from circum-meridian altitudes, azimuth from time and altitude measurements and then the much more difficult task of longitude observations on an east or a west star is explained and carried out. Timing to the nearest second for the first two quantities is easily and quickly learned but timing to fractions of a second by means of a stop watch is found to be a very much more difficult task. Similarly reversal of face for the first two is easily and quickly mastered whereas reversal for picking up a longitude star after observing on one face requires much more skill.

Fig. 3. Planisphere

After some experience has been gained in these methods, the next stage is the observation of a predicted programme for latitude, longitude and azimuth. It is here that the lecturer is placed in a difficult position on account of the different rates of progress in theory and practical work because the student has usually not had enough of the theory to undertake his own prediction, which after all is a fairly skilled job, especially when it is to be carried out from first principles without the use of aids such as, for instance, the planisphere. It is therefore usually necessary for the lecturer to supply the prediction data at this stage. This is justifiable because each student is later required to carry out his own prediction for use at Survey Camp which is held immediately after his examinations at the end of the year.

The predicted programme during the term requires each student to observe two longitude, two circum-meridian latitude and two circum-elongation azimuth stars. The two azimuth stars are purposely chosen so that their distances from the pole are about 30° in order to show up the correcting term for reduction to the point of elongation. This requires two nights of observing. Latitude and longitude stars are observed on one night and the azimuth stars on another.

Observations to the sun for latitude, longitude and azimuth determinations are made during the year. The corrections pertaining to these, because the sun is not infinitely distant and because it keeps irregular time, are emphasised in the course of the lectures. Each student computes his own observations. Emphasis is placed on the testing of the observations by some simple method before calculating is done so that poor observations can be excluded from the actual reduction. Emphasis is also placed on checking calculations and on the presentation of results.

It can be seen, from this resume, that the first course in astronomy aims at an introduction followed up by a good general training in the straight-forward methods of determination of position and azimuth.

In the Astronomy II course the student is introduced to simultaneous determinations of latitude and longitude by timed altitude observations. Practical work can be started without delay because of the experience gained in the first course. After the concepts of position circle and position line are understood, the Modified Sumner Marc St. Hilaire and Latitude Intercept methods are developed. Besides position line determinations, observations are made to close circumpolar stars for azimuth and to East-West stars at equal altitudes for longitude.

In order to reduce the time spent on the laborious preparation of predicted star programmes, much use is made of the planisphere (Freislich, 1951), (see Fig. 3). The Department has 15 of these which were originally purchased from the Victorian Department of Lands. To enable these to be used in Sydney a new graticule was computed using sight reduction tables (pre-computer days) and the New South Wales Department of Lands kindly assisted in their preparation and reproduction. For azimuth observations, students prepare a small planisphere for predicting the altitude and azimuth of σ and B Octantis. The basis for the construction of this planisphere may be found in publications in the Australian Surveyor and the Canadian Surveyor. (Bennett, 1963, 1966)

In the first course in Astronomy no explanation is given for the changes in astronomical coordinates due to precession etc., because it is considered that this would unduly complicate the teaching and defeat the purpose of explaining the principles of field astronomy. However, in the second course the reasons for these changes are given without recourse to involved mathematical derivations and the techniques for finding apparent places from the large catalogues are applied. The Department has at present the whole of the Boss General Catalogue, FK4 and FK4 supplement on computer cards together with a limited number of astronomy programmes. One of these is a programme

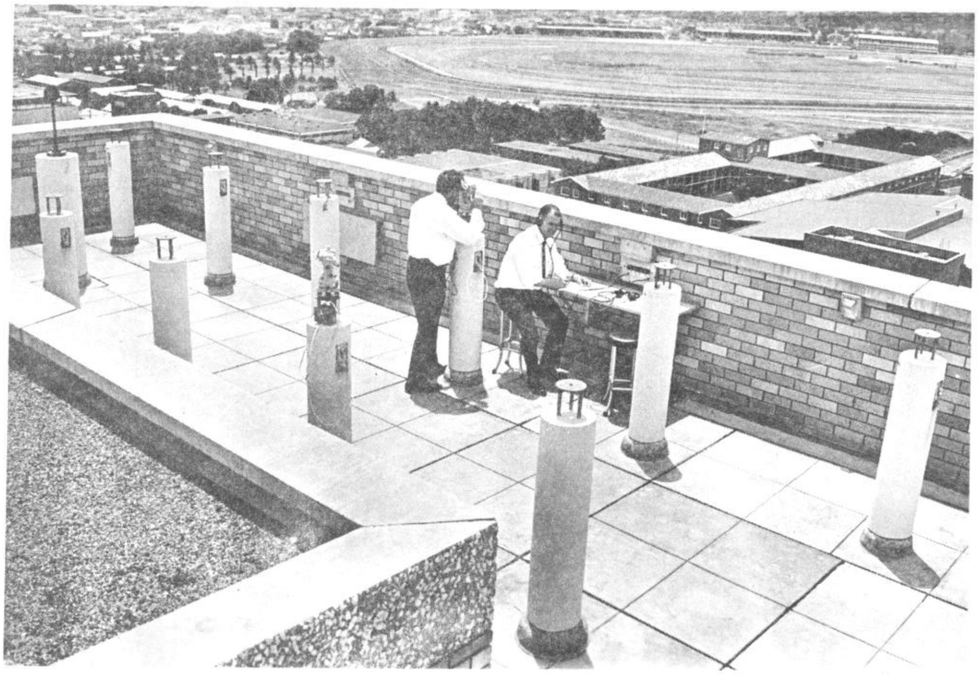

Fig. 4. General Layout of Observing Area on the Roof of the Civil Engineering Building.

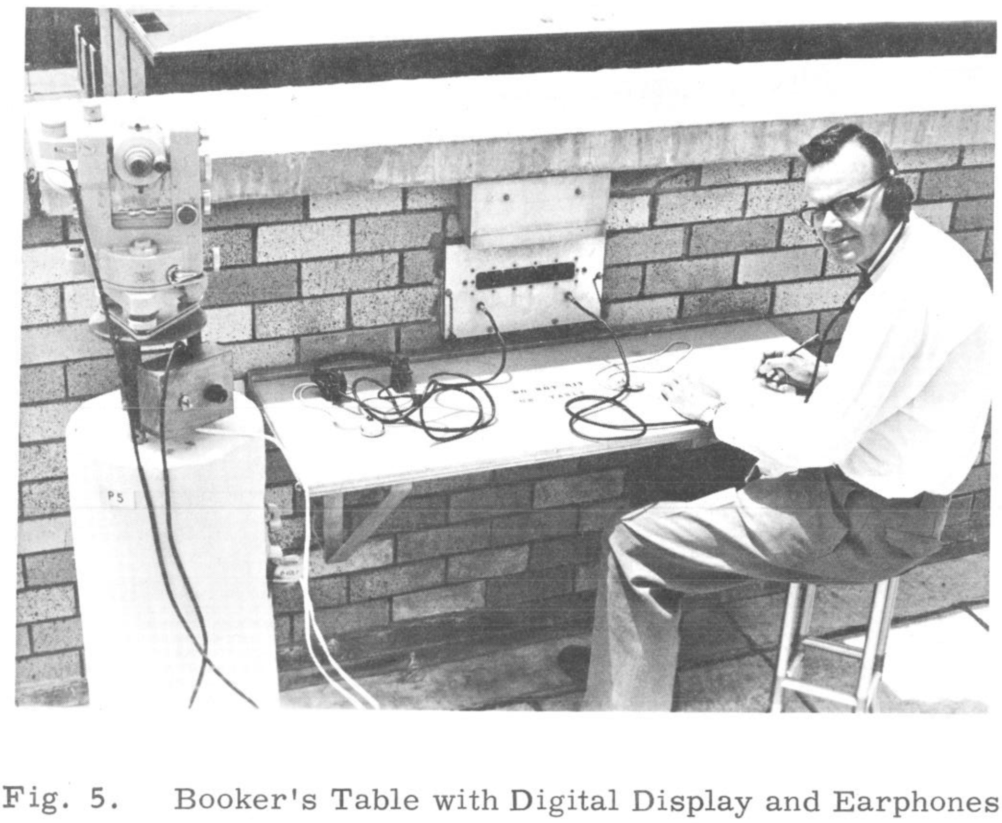

Fig. 5. Booker's Table with Digital Display and Earphones.

for the reduction of mean to apparent place (APLAC) prepared by the Geodetic Survey of Canada. Eventually most of the routine calculations will be done by computer.

A part of the work in which students can achieve a high order of accuracy is in chronometer rating. The Cook - Hänni or Extinction Method is admirably suited for this purpose. A sidereal chronometer with half second contacts is placed in circuit with the loud speaker of the radio and thus for half a second of every second the transmission is inaudible. Because of the difference between, the rates of the mean time radio signal and the chronometer the pip will gradually disappear into, and then reappear from, the "inaudible half second." No difficulty is found in obtaining chronometer corrections correct to one hundredth of a second.

One difficulty which does arise in the teaching of astronomy in the final year, is the provision of suitable practical training in the precise methods of latitude and longitude determination. Now that astronomy is given at the post-graduate level less emphasis is placed on these aspects in the under-graduate course. It is hoped that the University will eventually acquire a universal instrument for this teaching.

As part of his work in the final year of the course each full time student is required to present a thesis. The purpose of the thesis is to provide some training in the preparation of a technical report based upon the student's reading and observations. At the end of the 3rd year, a thesis topic is chosen either from an area of particular interest to the student or from a list prepared by the Department. In the long vacation he is expected to do some reading on his topic so that he may devote his time during the final year to any necessary observations and to the collation of his material. These latter phases are supervised by a member of staff. A number of theses on astronomy have been written, many of which have required extensive observation. Some examples are as follows:-

1. Time recording.
2. Daylight star observations.
3. The longitude story.
4. The astrolabe.
5. A comparison of simultaneous and single determinations of Latitude and Longitude.

5. Layout and Equipment at the University.

When the Civil Engineering building at Kensington was being designed, the opportunity for incorporating suitable features for the teaching of astronomy was seized. The staff of the Department of Surveying occupy offices on the top floor of this building. Above this floor, there is an astronomy laboratory, part of which is divided off for use as a clock room.

Above this room on the open roof, an area surrounded by a parapet has been laid out for astronomical observation. In this area, fourteen pillars have been erected, each of which is equipped with a six volt supply from the mains for lighting the theodolites for night work (see Fig. 4). Adjacent to each pair of pillars is a flap table attached to the parapet wall and used by the booker. Above each table is a shaded neon light and a recess in the wall for a digital time readout actuated by the master clock in the room below (see Fig. 5).

In the clock room two chronometers are housed. One is a mean time, and the other a sidereal time chronometer with electrical contacts. An AWA CR6A communications wireless set is kept in this room for receiving time signals (see Fig. 6). The aerial used for this purpose is a composite one, consisting of five aerials each of a carefully calculated length. The aerial lead is fed through a duct into the clock room through a two-pole switch to the wireless set. When this is not being used, the switch is left open

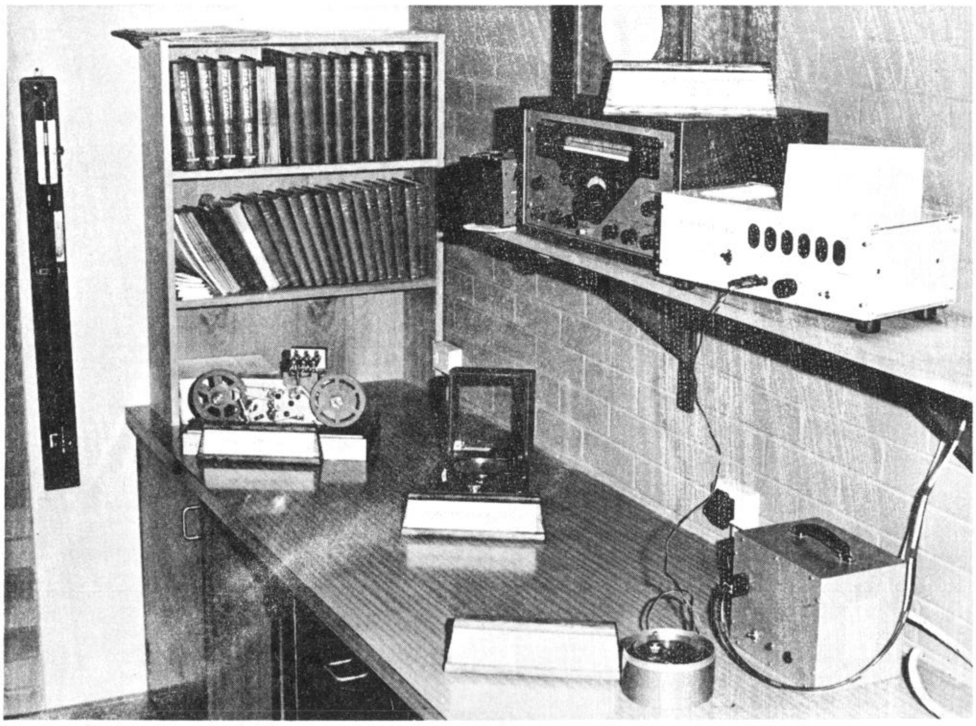

Fig. 6. The Clock Room.

Fig. 7. The Electronic Counter with Digital Display.

to prevent any damage to the set from lightning. In addition, a lead from a Time Standard in the Electrical Engineering building has been brought by means of a land line into the clock room. At present, the time signals from this source are not being used but they will be in the near future.

To accommodate the increasing numbers coming through the course, it was considered that a large number of chronometers would have to be bought. To avoid this an electric counter with a digital display has been developed and constructed by the Miniwatt Electronics Division of Philips Electrical Pty. Ltd. (see Fig. 7). This piece of equipment, when linked to the contacts of the sidereal chronometer, shows the clock time as a display synchronised with the clock reading. It also drives the digital readout display above each of the booker's tables on the roof, so that the readout gives a reading the same as that of the clock in the room below. In addition, this arrangement has the extra advantage of being common to all observers, who therefore should obtain similar values for the clock correction. The output from the wireless receiver is fed to sockets adjacent to the readout displays. Earphones are plugged into these so that, when the receiver is tuned in to the continuous time signals from VNG or WWV, the observer on the roof can compare the clock reading displayed on the readout with the time signals being received.

The instrument used for astronomical observations on the roof are single second glass arc theodolites fitted with lighting equipment for night observation. They are clamped on to stands built into the tops of the pillars. In addition NIFE cells are available for providing the current for lighting the theodolites when they are used out in the field.

The Department of Surveying has, over the years, built up a variety of specialised equipment for use in astronomy. The principle of portability has constantly been kept in mind so that the equipment can be used in the field, where power from batteries must be used and where weight is of importance. For instance, the electronic counter described above is light in weight and can be worked off batteries as well as off the mains.

For timing to fractions of a second, the students use stop watches for interpolating between the whole second values given by the digital readout on the roof. For more refined time observations, other instruments are available.

The Department's chronograph is one using tape whose linear speed is controlled by a vibrating reed. This instrument has been successfully used by two students for theses in which the accuracy of longitude determination was investigated. The main disadvantage of the chronograph is the evaluation of the time record from the tape. This evaluation is time-consuming and investigations are taking place into ways and means of obtaining the clock time of observation without the need for a graphical record.

An instrument, to which the name "Chronostop" (Bennett, 1965) has been given, was designed by a member of staff and built in the school workshops. This device consists of a motor driven circular plate which is checked electromagnetically once per second from the contacts of a chronometer. To record the time of a random event a pointer is dropped from the drive shaft by an external release, the seconds and decimals read from a circular scale and the hours, minutes and tens of seconds from the chronometer. The pointer is automatically picked up after a half revolution of five seconds and then the time of another event may be recorded.

The next step is the use of a printing chronograph for this purpose. At long last, the department is in a position to obtain one of these instruments which will be available early in 1968. This instrument will fulfil a long felt need for a piece of equipment which can be used for precise observing and the testing of lower order instruments as well as for research purposes.

In addition, the department has a "Chronoscope", which is an electronic instrument by means of which the time signal and the clock contact breaks can be displayed on a cathode ray oscilloscope. The relative position of the one with respect to the other gives the time relationship between the clock and the time signal and thus the clock correction to a few hundredths of a second of time can be obtained.

Other pieces of astronomical equipment in the department are a Reeves Astrolabe Attachment, and a Zeiss Ni2 Astrolabe attachment as well as a Cooke, Troughton and Simms 45° Astrolabe on loan from the Royal Australian Navy.

6. Conclusion.

Undoubtedly many other Institutions, which offer a degree or diploma in surveying, follow some of the practices which are described here. It is of interest to note that surveying students at the University of the Witwatersrand, before beginning their studies in field astronomy, complete a descriptive astronomy subject in their first year and a course in spherical trigonometry in their second year. In the final year a short course of celestial mechanics is taken as well. There have been radical changes in our courses since their commencement and further changes no doubt will occur. We in no way offer our methods as an ideal to be emulated but rather as a starting point for discussion.

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BIOGRAPHICAL NOTES.

G.G. BENNETT at present holds the appointment of Senior Lecturer in the Department of Surveying, University of New South Wales, to which he was appointed in 1962. He received a First Class Honours degree in Surveying from the University of Melbourne in 1954. After graduation, Mr. Bennett worked for the Snowy Mountains Hydro-Electric Authority from 1954 to 1959 where he specialised in Geodetic Astronomy. He joined the University of New South Wales in 1959 as a lecturer and completed his Master of Surveying degree at the University of Melbourne in 1962. In 1965 he spent a year as research officer with the Geodetic Surveys Section of the Department of Mines and Technical Surveys, Canada.

Mr. Bennett has published papers on both Geodetic Astronomy and the adjustment of control networks. His current research interests include in addition to the above topics, gyro-theodolites and their applications, as well as all aspects of error theory.

BIOGRAPHICAL NOTES.

J.G. FREISLICH has been Senior Lecturer in the Department of Surveying, University of New South Wales, since 1963. He received a Bachelor of Science (Engineering) in the branch of Mining and Metallurgy at the University of the Witwatersrand, Johannesburg in 1931. After spells of four years as a mine surveyor in the Witwatersrand gold mines and five years with a firm of private surveyors in South Africa, during which time he became a registered Land Surveyor, Mr. Freislich joined the staff of his alma mater, where he held positions both as lecturer and senior lecturer in the Department of Surveying between 1940 and 1963. During this period, he edited the South African Survey Journal from 1952 to 1963.

He is at present co-editor of the Australian Surveyor. Mr. Freislich's interests have long been in the sections of Mine Surveying and Field Astronomy, in which he has published papers. He is currently engaged in research into the characteristics of gyro-theodolites and their applications.

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