



THE UNIVERSITY OF  
NEW SOUTH WALES  
SYDNEY · 2052 · AUSTRALIA

SCHOOL OF SURVEYING & SPATIAL INFORMATION SYSTEMS

## GMAT 2120

# Surveying 2 - Electronic Survey Instruments

### Course Outline – Session 1, 2009

Version: 23/02/2009

*This document, and other material, is available at the Course Website:*  
<http://www.gmat.unsw.edu.au/gmat2120>

(User name and password supplied in class)

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## 1. Staff involved in the Course and their Contact Details

Course convenor: Dr. Craig Roberts

### 1.1 Lecturer(s):

Dr. Craig Roberts      C            EE 408            Ph: 9385 4464      [c.roberts@unsw.edu.au](mailto:c.roberts@unsw.edu.au)

Consulting Hours: see office door

Dr. Jinling Wang      J            EE 405            Ph: 9385 4203      [jinling.wang@unsw.edu.au](mailto:jinling.wang@unsw.edu.au)

Consulting Hours: see office door

Mr. Rod Eckels      R            Part time Lecturer            [r.eckels@unsw.edu.au](mailto:r.eckels@unsw.edu.au)

Consulting Hours: Email to make appointment

### 1.2 Practical Supervisor (for Friday):

Brian Donnelly      B            EE 420            Ph: 9385 4202      [b.donnelly@unsw.edu.au](mailto:b.donnelly@unsw.edu.au)

### 1.3 Staff absences during session:

## 2. Educational Aspects of the Course

### 2.1 How this course relates to others in the program

This course is a part of a three year stream of 'pure' surveying measurement courses. It builds on GMAT1110. You should have already passed or been exempt from that course. If you have attempted but failed GMAT1110 then you should contact the course convenor. This course will run concurrently with GMAT2500 and GMAT2700. Material from these two courses has been structured to run sequentially with material in this course and this will aid in student understanding. Session two will combine all surveying techniques covered in a more practical approach in GMAT2130 and GMAT2550 will extend the concepts from this course. Elective GMAT3100 and GMAT3150 in third year will further extend this course.

Prerequisites: GMAT1110

Corequisite: MATH2089, GMAT2500

### 2.2 Aim of the Course

The aim of the course is to study surveying instrumentation in depth, particularly precise digital levels, electronic theodolites / total stations and electronic distance meters EDM.

### 2.3 Learning Outcomes

By the end of this session you should know in detail about, and be able to use, modern electronic digital levels and electronic total stations (including EDM) to obtain the best possible results with a full understanding of their error sources: magnitude, calibration and correction. Also you should be able to report professionally and thoroughly on results of measurements made with these instruments.

### 2.4 Teaching Strategies

This course will be taught by three lecturers this year due to retirement of previous lecturers. We will make extensive use of material prepared by the previous lecturer, A/Prof J Rüeger and acknowledge his assistance. However we will also incorporate our own material and teaching methods based on our knowledge and experiences. Whilst using this material we will aim to engage you in an understanding of the topics and require you to read the text based material in detail.

We have considered feedback from last year's students in this course and in response will continue to supply electronic teaching materials on the course web site (none had previously existed in this course). We

will endeavour to mark the reports promptly for effective student feedback. We have also made some improvements to the requirements of the pracs so that the level run can be more easily completed in one day.

Due to the restructure of the course in 2006, the practical component of this course has been re-designed to accommodate students with a different level of previous knowledge to past students.

## 2.5 Suggested Learning Methods

Attention at lectures will not be sufficient to learn the topics to the level required. There will be a lot of reading required. You will also need to do the calculations in tutorial problems and practical assignments. There is a significant practical component to this course. It is important that you prepare thoroughly for the practicals by reading the instructions, visiting the site, and familiarising yourself with the equipment prior to the practical classes.

## 2.6 UNSW Graduate Attributes

This course provides an environment that fosters in our students the following attributes listed:

the skills involved in scholarly enquiry	Significant
an in-depth engagement with relevant disciplinary knowledge in its interdisciplinary context	Significant
the capacity for analytical and critical thinking and for creative problem solving	Significant
the ability to engage in independent and reflective learning	Some
the skills to locate, evaluate and use relevant information (Information Literacy)	Some
the capacity for enterprise, initiative and creativity	Some
an appreciation of and respect for, diversity	
a capacity to contribute to, and work within, the international community	
the skills required for collaborative and multidisciplinary work	Significant
an appreciation of, and a responsiveness to, change	Some
a respect for ethical practice and social responsibility	

### 3. Proposed Course Schedule

The supervisors are listed in brackets in the table below. (In case of inclement weather, *some practical classes may need to be rescheduled. Any changes will be notified in the class and at the course website*).

Week No.	Monday 12- 2 pm ASB130	Monday 3 – 4 pm Quad G025	Thursday 9am - 1pm Survey Store EEG16
1	Introduction to Course. Formation of Groups (C). Revision of Levelling. Intro to geodetic levelling types (R)	Tutorial (R)	Collimation Test mini prac & rotating laser levelling of a grid (B/R)
2	Intro to Precise Levelling. Principle of Digital Levels. (How they work) Errors of precision digital levels (R)	Field Demonstration of Digital Level (R)	
3	Booking, recording and reduction of precision levelling data. Error analysis. Specifications and standards. Adjustment and error analysis of double run precision levelling Determination of the precision in levelling networks (R)	Tutorial (R)	PRAC1: Precise level run prac around campus perimeter and on EDM baseline (B/R)
4	L: Theodolite Familiarisation. Precision direction measurement. Arcs of directions booking /recording, error analysis. (C)	Mini Prac: Theodolite familiarisation. Survey Store.	
5	<b>EXAM – Precise Levelling</b>	Tut: Booking / reduction of directions and zenith angles (C)	<i>(Level prac due)</i>
	MID	SESSION	BREAK
6	L: Introduction & Construction of Digital Theodolites: Classification, Axes, Clamps, Levelling Systems, Centring Systems, Circle Reading, Batteries (C)	Tut: Principle of Digital Theodolites 1 (C)	
7	L: Electronic Levels Sensors, Difference from Vertical Circle Compensators, Intro to Electronic Data Recording (C)	Prac Briefing (C)	PRAC2: <i>Angular Meas. Resection, Trig. Hting Obs &amp; means(B)</i>
8	L: Error of Horizontal Collimation – Inclination of Trunnion axis – Circle Eccentricity (C)	Tut: Principle of Digital Theodolites 2 (C)	Mini prac: Tribach calibration (C) Mini prac: Prolonging a line and horizontal collimation error (C)
9	L: Correction of Dir and Zen Angles for the non-vert of VA – Principle of the Index Corr of Vertical Circle / Level Sensor, circle graduation and interpolation errors (C)	Tut: Practice exam and revision of theodolite errors (C)	<i>(Angle prac due)</i>
10	Historical Development of EDM; Physical laws related to EDM; <i>Principles and applications of EDM.</i> (J)	Tut: Basic working principles of EDM. <i>Class discussions.</i> (J)	
11	Propagation of <i>Radiowaves</i> through the atmosphere; Coefficient of refraction; <i>Measurement of atmospheric parameters.</i> (J)	Tut: <i>Demonstration of meteorological instruments;</i> Computation of humidity and PWVP (J)	PRAC3: EDM <i>measurement; Correction for refractive index</i> (J)
12	<i>Geometrical corrections; Miscellaneous Corrections; Numerical examples.</i> (J)	<i>Classification of EDM; EDM reflectors; Legal traceability.</i> (J)	Guest Lecture – Features of latest Total Stations – Leica (C) <i>(Dist prac due)</i>

### 3.1 Allocation of Precise Levelling Runs

The paths of the level runs are defined in the handouts on the field exercises "Precise Levelling with a Digital Level".

Group	10	11	12	13	14	15	16
Run	LR1	LR2	LR3	LR4	LR5	LR6	LR11
Group	20	21	22	23	24	25	26
Run	LR16	LR15	LR14	LR13	LR12	LR11	LR6

## 4. Assessment in the Course

Assessment for the course includes:

- |                                 |     |                             |
|---------------------------------|-----|-----------------------------|
| • Practical reports (Levelling) | 15% | Due 2 weeks after fieldwork |
| • Practical reports (Angle msr) | 15% | Due 2 weeks after fieldwork |
| • Practical reports (EDM)       | 15% | Due 1 weeks after fieldwork |
| • Mini Prac (tribrach/line)     | 5%  | Due on day of prac          |
| • Mid-session test              | 15% | On Wednesday week 5         |
| • Final Exam                    | 35% | In formal exam period       |

### **Practicals:**

Each student will be a member of a group of 2 (or occasionally 3) students. Groups will be established during the first lecture. Students are free to select their partners; however students are advised to select their partners very carefully. Students that do not attend the first lecture, or cannot find a partner, will be put in a group by the lecturer. Get the address, phone number, mobile phone number, fax number, e-mail address, etc. of your group members immediately after the formation of the group. The joint (or individual) submissions for the practicals (require considerable interaction between the students *if applicable!*). Make sure that all field data are copied immediately after the fieldwork, so that all the students in the group have always access to the data.

Further information about the practicals will be distributed during the lectures, and are available on the class web site. Rules for practicals are given in section 6 below.

All practicals (except mini-pracs) require individual reports by the students, even if the fieldwork was shared. The practical reports are to be submitted on or before **2 weeks** from the field day. So if the prac was attempted in week 3, it is due on the Friday of week 5 (in this case Easter Friday so due on the Thursday before. Submissions are to be handed to the lecturer supervising the practical or to the school office.

Reports must follow the instructions given in the handout "Submission of Reports". (A sample report is given on the course web site) Submissions have to include a declaration on the authorship of the work. Each submission is to have a title page (title of assignment, date of submission, course code, course name, student number, name of student) and a summary of results page. Word processed submissions are not required. But spreadsheets may be used for computations as long as they are designed by the student and two outputs are provided (with all columns and rows labelled), namely one with the values in the fields and one with the formulae in the fields.

Each practical has instructions about computations and reporting. It is strongly recommended that student reports are written in the same sequence and with the same headings.

## 5. Course Resources

**5.1 Lecture Material (check the course website):** <http://www.gmat.unsw.edu.au/gmat2120>

Messages and files for this course can be downloaded from the course website. Monitor the site during session because it will be updated regularly. Username and password will be supplied in class. The Powerpoint lecture slides are available for download as PDF files at the course website. The website material is only for use by students enrolled in this course.

The lecture material will be **supplemented** by:

**Hard copies of:**

Rüeger, J. M. 2000. *The Topcon DL-101C Digital Level, Australian Surveyor, Vol. 45, No. 2.*

*Short Instructions for the Topcon DL-101C (Prepared by Bruce Harvey)*

*Short Instructions for the Topcon DL-101C (Topcon Instruction Manual)*

*Short Instructions for the Nikon DTM-821/851 Total Station (Nikon Instruction Manual)*

**On the class website:**

*Reference Notes on Electronic Theodolites Chapters 1 – 8 edited by J. M. Rüeger & C. Roberts*

*Problems on Electronic Theodolites edited by J. M. Rüeger*

*Tutorials on Electronic Theodolites edited by J. M. Rüeger*

The relative importance of class notes and reference books, and purchase details will be discussed in class.

## **5.2 Reference Books**

Some of these books are kept in "OPEN RESERVE" by the University Library.

Rüeger, J. M. 1996. *Electronic Distance Measurement – An Introduction*. 4th ed., Springer-Verlag, Berlin-Heidelberg-New York. Is out of print *but one copy is kept in Open Reserve*.

Bannister, A., Raymond, S. & Baker, R. *Surveying*. 1992. 6th edition, Longman, England

Harvey, B. R. 2006. *Practical Least Squares and Statistics for Surveyors*, 3rd ed., Monograph No. 13, School of Surveying and Spatial Information Systems, University of New South Wales, 319 pages

Rüeger, J. M. 2003. *Electronic Surveying Instruments – A Review of Principles, Problems and Procedures*, Monograph No. 18, School of Surveying & SIS, University of New South Wales, 156 + x pages

Cooper, M. A. R., *Modern Theodolites and Levels*. 2nd ed., Granada, 1982

Deumlich, F. *Surveying Instruments*, Walter de Gruyter, Berlin, 1982

Kahmen, H., Faig, W. *Surveying*. Walter de Gruyter, Berlin, 1988

Muskett, J. *Site Surveying*, 2nd ed., Blackwell Science, Oxford, 1995

Uren, J & Price, WF, *Surveying for Engineers*, 4<sup>th</sup> edition, 2006

## **5.3 Computational Aids**

Pocket calculators are required during lecturing hours, for tutorials and practicals in this course. They have to be hand-held, internally powered and silent. They must be brought to all lectures and practicals.

Computer software relevant to this course and available in the School's computer lab EE401A, includes: FIXIT3, MS Word, MS Excel.

## 6. Administrative Matters

### 6.1 Expected work load

*At UNSW, the normal workload expectations of a student are 24-28 hours per session for each unit of credit, including class contact hours, preparation and time spent on all assessable work.*

To assist students with the organisation of their studies, the expected workloads of the various components of the course are listed below. The listed hours for the field exercises, the preparation of technical reports, and the revision of the course material are *average* values for *average* students, based on handwritten submissions of the reports by previous students. It is strongly suggested that students use the listed hours to plan their work during session.

Lectures and Tutorials	36hr
Field exercises	20hr
Reports on field exercises	58hr
Revision of Lectures, preparation for test and exam (approximately 3hr x 12wk)	36hr
Total	150hr

### 6.2 Rules

Students should read the University Calendar or Student Guide for details of University Rules and special considerations.

Students are reminded that the University regards academic misconduct as a very serious matter. Unauthorised material must not be taken into a test or examination. Any work submitted for assessment must be entirely the student's own work. The penalty for any suspected academic misconduct ranges from zero mark for the assignment or exam involved, through to failure of the course, to expulsion from the University. If absent from an examination, class test or practical, students must submit written documentation to the University, via the Student Centre in the Chancellery.

All assignments or practical reports are compulsory parts of the course and must be handed in by the due date. A mark of zero will be given for any submission which violates this rule. OR **The marks for late submissions will be reduced as follows:** -20% (of the maximum mark) for up to 24 hours after the scheduled submission time, then -10% (of the maximum mark) for each additional 24 hour period late. (For example, a student submitting a report/assignment 4 days late has his/her mark reduced by 4 if the maximum mark of the submission is 10). Any late submission must be made before solutions are issued to the class.

If a student is unable to submit on time due to illness or other legitimate reason, then a brief written explanation (also via email) must be given to the lecturer for consideration as soon as is feasible. In some cases the lecturer may grant an extension to the submission date provided he has been contacted before the due date.

Further assessment may be granted in this course at the lecturer's discretion. If further assessment is granted then performance in tutorials may be considered as well as an oral exam including use of a computer.

If students **attend less than 80%** of their possible classes they may be refused final assessment.

### 6.3 Grievances

In the first instance all grievances should be discussed with the lecturer involved. If the problem cannot be resolved, students should contact the School's Grievance Officer in writing.

## 6.4 Rules for practical / field classes

If there is light rain field work is on, if rain is heavy then the practical might be postponed. Do not assume a class will be cancelled, attend on time and ask the supervisor. Practical classes take place in a variety of weather. Do not forget umbrellas, water proof jackets, hats, sun cream, sturdy footwear (thongs, sandals or ballet style shoes are not acceptable), warm clothes, etc.

There will be a short briefing session at the Survey Store at the start of each practical class. Punctual attendance at the briefing is essential. All group members are expected to attend the briefings.

The practical exercises form an important part of the subject. A good deal of time and care has gone into the organisation of these classes to ensure that you get the maximum benefit from the time that you spend and the equipment which is available. Most practicals will be done in groups of students; however the calculations and reports require individual work. It is important that each student within a group gets experience in each aspect of each practical.

The location of fieldwork will depend on the state of construction on campus. Supervisors will advise you of the site and OHS matters at the briefings. If you have any questions or doubts about an OHS matter discuss it with your supervisor.

Students are required to read the supplied instructions well before the exercise is commenced.

### ISSUING OF EQUIPMENT

During the issue of equipment, a large crowd around the store causes difficulties for everyone, so one group collects their equipment and the remaining groups should stand well back. A group is responsible for all equipment issued to it, with the student signing for the equipment as the representative.

1. *You should first inspect all equipment and make sure that it is in working order, otherwise you will be held responsible.* When returning equipment at the end of the field class, it should be handed back to the Stores Officer, piece by piece, so that he can check it off. Not until all your equipment has been returned and signed off, does your responsibility end.
2. ***It is not sufficient to leave the equipment near the store and depart. Equipment must be returned at least 15 minutes prior to the timetabled time for completion of the class, even if the fieldwork is not complete.***
3. ***Any equipment lost or damaged will have to be paid for by the group.*** In the field, there is less danger of losing items if everything is laid close to an instrument box or in a group where pedestrians can safely bypass it. No equipment is to be left unattended in the field at any time.

### INSTRUMENTS

The equipment used in surveying is usually delicate and often valuable (> \$10,000). Please make sure that you take due care of the equipment and give some thought to the way in which you handle it. The staff member in charge of your class will give detailed instructions about its use. *Theodolites and electronic total stations*, have fragile optical mechanical and electronic components and are delicately adjusted. ***Shut instrument boxes immediately after removing/replacing the instrument.*** Carrying theodolites/ total stations (on tripods) over the shoulder will not be tolerated in this School. Do not force any parts to move, check whether clamps are set, and do not over tighten clamps.

## IN THE PUBLIC EYE

It is hoped that students taking part in surveying practicals on the campus will create a favourable impression on passers-by, **so behave like professionals**. The field classes give you an opportunity to handle interesting equipment and should be a welcome break from lectures. It is hoped you find them enjoyable as well as instructive.

Students should not normally leave the field work location during the practical sessions. However students leaving the field for short periods must ask another student to look after their equipment and must inform the student (and the supervisor, if present) of their time of return. No equipment is to be left unattended in the field at any time.

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## INSTRUCTIONS ON PRACTICALS, FIELD NOTES AND PLANS

**It is essential** that the course number, group number and the student(s) name(s) appear prominently on all field books, field sheets, reports, plans, etc.

**Each student** shall possess and bring along to all practicals:

- writing and drawing materials including good quality pencils (H, 2H, 4H) and a pencil sharpener. The alternative and **preferred option is to use mechanical pencils** (0.5 mm diameter, HB, H). CAR also accepts neat pen.
- Printed field sheets as supplied in the prac instructions or acquire some from the store on the day of the exercise
- charged pocket calculator
- metric scale

Neat **field notes** must be made in pencil of all measurements taken in the field. If no printed forms are distributed by the lecturer, these notes should be tabulated in a field book, and if necessary, referred to a diagram for clarification. Draw neat sketches or diagrams where appropriate. All field notes, diagrams and sketches must be recorded on proper field sheets available from the Survey Store except for measuring tasks where forms are provided.

The **field book** (or form) must also contain the following information on every field work: title, date, site, course number, group number, names of students in group, make, type and serial number of all important instruments (e.g. theodolites, barometers, prisms, thermometers, tapes), observer, booker, staff person, time of observations, general weather, etc. **A locality sketch showing the area of the survey should be prepared at the beginning of each practical.**

**Erasures and overwriting are not permissible.** Errors may be struck out, the correct value neatly written (above) and the correction initialled by the booker whose name must appear at the top of each page. You are advised to use sharp, good quality H or 2H pencils (or a 0.5 mm lead mechanical pencil (HB or H)) to take field notes. Harder pencils are used on dry hot days; softer pencils are used on cold, wet days. CAR also accepts pen.

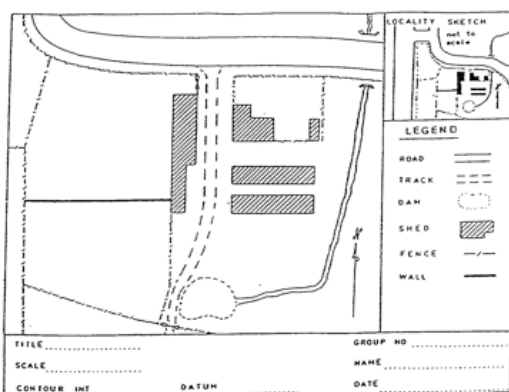
At the end of each exercise, the **field notes must be signed** by your **supervisor**. These original, signed notes must always be submitted with the reports and/or plans.

Whenever possible, plans should be drawn with the North direction towards the upper edge of the paper. Plans should carry the following information in a block in the lower right hand corner:

- a heading, indicating the nature of the plan (e.g. Contour Plan, Detail Plan) and the general locality
- the scale of the plan
- the datum for elevations and contours and for any grids shown on the plan
- the student's name, party number and course number
- the date of the survey

Besides the main drawing, the following items should also be **shown on the plan**:

- the direction of north, indicated by an arrow not less than 50 mm long and labelled "NORTH"
- a small sketch ("locality sketch"), not necessarily to scale, showing the location of the site with respect to adjacent buildings, roads, etc. Names of such buildings should be shown and roads labelled. Annotated Google Earth (or other) digital images are encouraged.



A conventional arrangement of detail on a plan is given above.

PSA, JMR 2001, CAR 2008

# GMAT2120 – Surveying 2 - Electronic Survey Instruments

## INSTRUCTIONS ON REPORTS

All reports must be submitted on **paper of A4 size (297 x 210 mm)** and should be bound in a simple way, e.g. stapled. Reports may be submitted in hand written, typed or word processed form. They should be presentable and readable. Attached plans must be folded to this size. Computer outputs, if not printed on A4 paper, may be cut and pasted on A4 paper or may be reduced to A4. **Reports** should show how the results were obtained from the field data, that the relevant theory has been understood, and that the computation processes have been competently carried out.

The **basic structure** of each report should be as follows:

1. Title Page  
(include course number and name, title of exercise, student's name, group number)
2. List of Contents  
(pages should be numbered consecutively, including those of the appendix)
3. Introduction and Locality sketch  
(Discuss briefly (one sentence each) what was done, where it was done, when it was done, who did what. Confirm that the procedures prescribed by the practical instructions were followed (or list deviations and give reasons). Include a locality sketch and a list of (essential) equipment (make, type, serial number, any instrument correction that might apply). Confirm that all computations on the field forms **and** those in the report have been checked.)
4. Summary of Relevant Results (and Precisions)
5. Body of Report  
(Where applicable this will contain abstracts of field data, calculation of corrections, necessary theory and/or statement of equation used, calculation of 'results', calculation of precisions. The practical instructions give some guidance on what processing and analysis is required. Explain your calculation steps and comment on results. All calculations must be fully documented (**on paper**) and traceable. When using spreadsheets, put the commented paper output with values into the main part and the (commented) output (**on paper**) with the cell equations into the appendix.)
6. Conclusion and Comments  
(This should include a critical appraisal of the methods used and of the results obtained. Discuss successes, failures, problems, defective equipment, how the practical could be made more effective, time spent in the field and the the time spent for computation and the preparation of the report, etc.)
7. References (author, year, title, edition, publisher, city of publication, no of pages)
8. Appendix (field sheets, field sketches, plans, check computations, etc.)

The following notes should be used for guidance in **preparing reports**:

**Equations** used in calculations must be listed in variable form and the source of the equation given (e.g. text book, lecture notes, etc.).

Where calculations are of a **repetitive** nature they should be set out in **tabular form**. Spreadsheets may be used. Note that a **separate output (on paper) showing the formulae** specified for the fields must be provided (in the Appendix) whenever spreadsheets are being used.

Significant **intermediate results** in the computation process should be shown.

Any rejection of field data must be justified and discussed with the supervisor.

A **concise** appraisal or criticism of the methods or techniques involved in the exercise should be included in the conclusion. (Comments based on guesses or intuition are to be avoided.)

It is not necessary to describe, in detail, the methods used unless for some reason they varied from the instructions. (**However**, summarise methods and techniques in "Introduction".)

Compute to one decimal more than the input or measured data.

J. M. Rieger, BRH, CAR

## Some instructions for use of Casio fx-911W Calculator

Setting number of decimal places in display to eg 3 **MODE** **MODE** **MODE** 1 3

Storing and recalling memories eg 123 **STO** **A** **RCL** **A**

**D M S conversion** eg  $14^{\circ}25'36''$  to D.D 14 **°'"** 25 **°'"** 36 **°'"** **=** **°'"** gives 14.427  
Reverse calculation 14.42666667 **=** **SHIFT** **°'"** gives  $14^{\circ}25'36''$ .

To make sure you are working in degrees mode use **MODE** **MODE** **1**

Trig calcs eg  $\cos(63^{\circ}52'41'')$  **cos** 63 **°'"** 52 **°'"** 41 **°'"** **=** gives 0.44...

eg  $\cos^{-1}(0.61)$  **SHIFT** **cos<sup>-1</sup>** 0.61 **=** **SHIFT** **°'"** gives  $52^{\circ}24'37.79''$

**Polar to Rectangular conversion** eg distance = 20.5 and bearing =  $60^{\circ}23'34''$

**SHIFT** **Rec(** 20.5 **,** 60 **°'"** 23 **°'"** 34 **°'"** **)** **=** gives  $\Delta N$  10.128

**RCL** **F** gives  $\Delta E$  17.823

Memory E contains  $\Delta N$  and memory F contains  $\Delta E$

**Rectangular to Polar conversion** eg  $\Delta N = 60.5$  and  $\Delta E = 30.4$

IMPORTANT: If the  $\Delta E$  or  $\Delta N$  is negative, type **(-)** before the number!

**Pol(** 60.5 **,** 30.4 **)** **=** gives distance 67.708

**RCL** **F** gives bearing {if  $<0$  then **RCL F** **=** + 360 **=**} then **°'"** gives bearing in dms  
 $26^{\circ}40'42.9''$

Note the order  $\Delta N$  then  $\Delta E$  and distance then bearing

Memory E contains distance and memory F contains bearing

**Statistics Calculations** eg obs 55 54 51 53

**SHIFT** **Sci** **=** **MODE** **2**

55 **DATA** 54 **DATA** 51 **DATA** 53 **DATA** DATA is the M+ key

**SHIFT**  **$\bar{x}$**  **=** gives mean 53.25 **SHIFT**  **$\sigma_{n-1}$**  **=** gives standard deviation 1.7