AIR NAVIGATION

Instructions for use of the

'UNIQUE' NAVIGATIONAL SLIDE RULE

With Solutions to Typical Practical Problems

Reprint: UK Slide Rule Circle 2010

Including as supplement, a reprint of the 'Half-Hour' Instructions for the use of British made 'Unique' Slide Rules and containing Conversion Tables for Money Calculations

Price Two Shillings nett.

Multiplication and Division are effected by the C and D scales, but since numbers on either edge of the slide cannot be brought into direct coincidence with numbers on the opposite side of the stock, the Cursor must be used in setting the slide in such cases. Otherwise the manipulation of the rule is similar to that of the standard type and any uncertainty in reading the result may be avoided if it is remembered, that **if in setting the rule it is necessary to use the Cursor to cross the slide, it will be necessary to cross the slide again, when reading the result.**

A little practice with simple examples will overcome any initial difficulty.

Squares and Square Roots are obtained easily by projecting from the C and D scales to the scales lying on the edges of the stock.

Logarithms. The mantissa of the logarithm of any number is found by projecting from the C scale to the evenly divided scale lying in the centre of the slide. The figures along the top of this scale are used when the number whose logarithm is required appears in the upper part of the C scale, and the lower figures in the central log scale, refer to logs of numbers in the lower C scale. The vernier may be used to read the fourth figure of the mantissa if desired. To use the vernier, move the slide into its central position, *i.e.*, with the ends of the C and D scale coincident. Place the Cursor line over the number whose logarithm is desired, and read the first three figures of the mantissa directly from the log scale. Move the slide to the right, so that the line in the log scale immediately to the left is brought exactly under the Cursor index, and now read the vernier to obtain the fourth figure of the mantissa.

Example (5-10 Rule).—To find the log of 485. Adjust slide to mid-position. Place cursor line over 485, which lies in the lower parts of the C and D scales, and read the log scale, *viz.*, ·6840. Move slide so that the line immediately to the left of Cursor is brought under the Cursor index and note that the vernier reading is 17. Add ·6840 to ·0017 and so obtain the correct mantissa ·6857. Now add the characteristic 2 and complete the logarithm, 2·6857.

N.B.—The log scale is omitted from the 10-20 rule, which is designed for great accuracy in ordinary calculations.

The 'Unique' Air Navigation Slide Rule

CHAPTER I.

THE "UNIQUE" SLIDE RULE.

MULTIPLICATION, DIVISION, ETC.

THE SLIDE RULE consists of two main parts : the Stock (the body of the Rule) and the Slide, the centre portion which slides to the left and right. The transparent frame carrying the hair line is known as the Cursor (abbreviated Cr.).

The "UNIQUE" Air Navigation Slide Rule is made with eight logarithmic scales, and two linear scales. The latter scales are designed to measure distances on the 1/1000000 and the 1/500000 scale air maps. Their use is apparent.

Referring to the illustration on pp 20-21, the scales have been lettered S1, A, B, S2, T2, C, D, and T1, commencing with the upper scale. The figures of scale S1 represent degrees of the Sine scale. Scales A and B are exactly alike, as also are scales C and D. Scale S2 is exactly the same as scale S1. Scale T2 is a scale of Tangents, and the figures also represent degrees. Scale T1 is exactly the same as scale T2.

The extreme ends of the scales are termed the Left Hand Index and the Right Hand Index (abbreviated L.I. and R.I. respectively), in all cases ; for example : the figure 1 is the L.I. of the scale D, and the figure 10 is the R.I. It will be observed that the divisions of the scales A, B, C, D are similar, except that scales A and B contain two smaller editions of scales C and D. These smaller scales are exactly half the size of scales C and D.

It must be borne in mind always that the figures on the scales A, B, C, D are quite arbitrary, and can represent units, tens, hundreds, thousands, etc. For example, on scale A, if the L.I. is called ten the figure 7 will represent 70, and the figure 40 will represent 400. The R.I., the figure 100 will represent 1,000. If the L.I. is called ·01, the figure 9 will be ·09, 10 will be ·1, and 100 will be 1·0. On scale C the same rules apply.

The scales S1, S2 and T1, T2, are scales of Sines and Tangents respectively. These scales are used to solve all problems in trigonometry that may be met during the navigation of an aircraft. The sine of any angle is read by setting the Cursor over the angle on scale S1, and reading the sine on scale A. To find the cosine of any angle, the same process is employed, but the complement of the angle, whose cosine is to be found, should be used to set on scale S1. Cosecants of angles are found by setting the chosen angle on scale S2, under the left or right index of scale A, and reading the cosecant value on scale A, above the opposite index of scale S2. To find the secant values of angles the same procedure is adopted but the complement of the selected angle is used. To find the tangent of an angle scales T1 and D are used, the angle on scale T1 being selected by the Cursor, and the appropriate tangent read under the Cursor on scale D. For angles greater than 45°, the complement of the angle on scale T2 is set over the Left or Right Index of scale D. The value of the tangent is then read on scale D, under the opposite index of scale T2. Cotangents of angles are found in exactly the same way, using scales T1, D, and T2 except that complementary values of the angles are used. It should be remembered when dealing with tangents of angles greater than 45°, and cotangents of angles less than 45°, that these values are greater than unity. When tangents of angles less than 6° are required, the scales S1 and A should be used, as the discrepancy between sines and tangents of angles less than 6° is negligible.

These various problems may seem a little bewildering at first, but after a little practice with the rule, and by comparing the results obtained with similar results obtained by trigonometrical tables, no difficulty will be found even when very complicated problems are being solved.

MULTIPLICATION.

In the process of multiplication, and division also, scales

E.g.—Tan 27°—30′=·521.

Tangents of angles between 45° and 90° are obtained easily by finding the reciprocal of the tangent of the complementary angles.

$$E.g.\text{—Tan } 72^\circ = \frac{1}{\text{Tan } 18^\circ} = 3{\cdot}078.$$

In this case, 18° in the T scale is projected into the Cr scale, with the slide in its central position.

Cosecants, Secants and Cotangents are found as the reciprocals of sines, cosines and tangents respectively.

When sin or tan terms appear as factors, the cursor is used in conjunction with the appropriate angles in the S or T scales.

Example.—The sides of a triangle are 3·5 and 7·2 feet long. The included angle is 25°. The area is required. Place cursor line over 25 in S. Move slide to bring 20 of B under cursor line. Now move cursor to 35 in B. Bring 10 of B under cursor line and read the result : 5·33 sq. feet in A, opposite 7·2 in B.

UNIVERSAL II. RULE.

This rule has the S and T scales on the slide instead of on the stock. For certain calculations this arrangement of scales is more convenient than that of the universal rule, since it allows of multiplication or division of any series of numbers and functions of angles.

5-10 and 10-20 PRECISION RULES.

It is assumed that users of these Rules are familiar with the Slide Rule in its ordinary form.

Slight modifications of the instructions given above are necessary. The log-log instructions do not apply to the precision type of rule, which has no log-log scale.

The C and D scales which are twice the usual length, are divided into two parts and occupy the positions of the A, B, C and D scales in the standard rule.

3. **Find the cost of 16 tons 3 cwts. 2 quarters of material at £1 2s. 8d. per ton.**

The table gives 3 cwts. 2 qrs. as ·175 tons and 2s. 8d. as £·133.

Multiply 16·175 by 1·133, using scales C and D, and the result will be found to be £18·33, which converts into £18 6s. 7d., which is within one penny of the exact amount.

4. **Find the cost of $15\frac{1}{2}$ yards of material at 8s. $4\frac{1}{2}$d. per yard.**

Using the smaller table, 4d. is seen to be ·333s., and $\frac{1}{2}$d. is ·042s., which, added together, give ·375s. 8s. $4\frac{1}{2}$d. is therefore 8·375s. Use scales C and D to multiply 15·5 by 8·375 and the result will be found to be 129·8s., which is £6 9s. 10d. The exact value is £6 9s. $9\frac{3}{4}$d.

Even when the money amounts must be obtained with absolute correctness the Slide Rule will give a ready means of securing a rapid check on the result, and its value in this connection is obvious.

UNIVERSAL RULES.

In addition to the scales of the Log-Log Rule, universal rules are equipped with **Sine** and **Tangent** scales, denoted by S and T respectively, for trigonometrical calculations.

Sines of angles are found by using the cursor to project from the S scale to the A scale. If the result lies between 1 and 10 of A, the decimal point and a cypher precede the number found in scale A. If the result lies between 10 and 100 in A, the decimal point only should be prefixed.

E.g.—Sin 3°—10′=·0552.
Sin 20°—40′= ·353.

Cosines of angles are obtained by finding the sines of the complementary angles. *E.g.*—Cos 36°=Sin 54°=·809.

Tangents of angles are obtained by projecting from the T scale into the D scale, using the cursor. The tangent scale starts just below 6° and finishes at 45° and all values lie between ·1 and 1.

C and D should preferably be employed, as they are longer and therefore will give more accurate results than the other pair of scales. However, it is sometimes more convenient to use the A and B scales in navigational problems, particularly Time and Ground-Speed problems, but experience will soon show which is the easier pair of scales to employ.

To Multiply 4 by 2.

Scale C	Set L.I.	Under 2
Scale D	Over 4	Read 8

To Multiply 8 by 4.

Scale C	Set R.I.	Under 4
Scale D	Over 8	Read 32

To Multiply 175 by 12·4.

Scale C	Set L.I.	Under 12·4
Scale D	Over 175	Read 2170

Note that either the L.I. or the R.I. may be used at the first setting. If on setting either index the result lies beyond the limits of the adjacent scale, it is only necessary to move the slide and set the other index.

To Multiply 12·3 by 3·25 by ·104.

Scale C	Set L.I.	Set Cr. to 3·25	Set L.I.	Under ·104
Scale D	Over 12·3		to Cr.	Read 4·158

The correct answer is 4·1578, but it is impossible to read the Rule to such a fine degree of accuracy. In such problems as the latter, some question may arise as to the position of the decimal point. Although several Rules have been devised for determining its position, they are not recommended, for it is far easier to calculate mentally the approximate answer; e.g. using the example 12·3×3·25×·104; 12×$3\frac{1}{4}$ is 39, 39×·1 is 3·9. It is thus determined that the answer is of order 4 and not 40 or ·4. Scales A and B are used in exactly the same manner.

DIVISION.

To divide 6 by 3.

Scale C	Set 3	Under L.I.
Scale D	Over 6	Read 2

To divide 12·6 by 23·2.

Scale C	Set 23·2	Under R.I.
Scale D	Over 12·6	Read ·543

To evaluate $\frac{12 \text{ by } 3{\cdot}58.}{22{\cdot}6}$

Scale C	Set 226	Under 358
Scale D	Over 12	Read 1·9

SQUARES AND SQUARE ROOTS.

To find the square of any number, set the Cursor to the chosen number on scale D and read the square underneath the Cursor on scale A. To find the square root the process is reversed, the number being selected on scale A, and the square root being read from scale D. The following rules must be observed when finding the square roots: When the chosen number has an odd number of digits preceding the decimal point or, when less than one, has an odd number of noughts immediately following the decimal point, the left-hand half of the scale A must be used. When the chosen number has an even number of digits before the decimal point, or an even number of noughts after the decimal point, the right-hand half of scale A is used.

CUBES.

To find the cube of 3.

Scale C	Set L.I. (Keep the slide in this position)	Scale A	Read 27
Scale D	Over 3	Scale B	over 3

CUBE ROOTS.

Set the Cr. over the chosen number on scale A. Move the slide until the number on scale B, directly under the Cr., is exactly the same as the number on scale D, under the L.I. or the R.I. of scale C. It will be found that there are three positions of the slide which will give such a result. In most cases the correct position can be ascertained by inspection, or the following rules can be applied. Inspect the number whose cube root is required and count the digits lying before the decimal point,

shillings and pence are not effected easily by Slide Rule, but if the money values are expressed in the decimal system there are no difficulties.

The conversion tables printed below facilitate such calculations by providing a simple and rapid method of converting shillings and pence into the decimal equivalents of the pound, and *vice versa.*

The table may be used also for converting cwts. and quarters into decimals of the ton, and *vice versa.*

The smaller table shews pence as decimals of the shilling.

TABLE FOR CONVERTING SHILLINGS AND PENCE INTO POUNDS AND HUNDREDWEIGHTS AND QUARTERS INTO TONS.

PENCE	QUARTERS	SHILLINGS OR CWTS																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0			·050	·100	·150	·200	·250	·300	·350	·400	·450	·500	·550	·600	·650	·700	·750	·800	·850	·900	·950
1		·004	·054	·104	·154	·204	·254	·304	·354	·404	·454	·504	·554	·604	·654	·704	·754	·804	·854	·904	·954
2		·008	·058	·108	·158	·208	·258	·308	·358	·408	·458	·508	·558	·608	·658	·708	·758	·808	·858	·908	·958
3	1	·012	·062	·112	·162	·212	·262	·312	·362	·412	·462	·512	·562	·612	·662	·712	·762	·812	·862	·912	·962
4		·017	·067	·117	·167	·217	·267	·317	·367	·417	·467	·517	·567	·617	·667	·717	·767	·817	·867	·917	·967
5		·021	·071	·121	·171	·221	·271	·321	·371	·421	·471	·521	·571	·621	·671	·721	·771	·821	·871	·921	·971
6	2	·025	·075	·125	·175	·225	·275	·325	·375	·425	·475	·525	·575	·625	·675	·725	·775	·825	·875	·925	·975
7		·029	·079	·129	·179	·229	·279	·329	·379	·429	·479	·529	·579	·629	·679	·729	·779	·829	·879	·929	·979
8		·033	·083	·133	·183	·233	·283	·333	·383	·433	·483	·533	·583	·633	·683	·733	·783	·833	·883	·933	·983
9	3	·037	·087	·137	·187	·237	·287	·337	·387	·437	·487	·537	·587	·637	·687	·737	·787	·837	·887	·937	·987
10		·042	·092	·142	·192	·242	·292	·342	·392	·442	·492	·542	·592	·642	·692	·742	·792	·842	·892	·942	·992
11		·046	·096	·146	·196	·246	·296	·346	·396	·446	·496	·546	·596	·646	·696	·746	·796	·846	·896	·946	·996

PENCE EXPRESSED AS DECIMALS OF A SHILLING.

½d. is ·042/-	1d. is ·083/-	2d. is ·167/-	3d. is ·250/-	4d is ·333/-	5d. is ·417/-
6d. is ·500/-	7d. is ·583/-	8d. is ·667/-	9d. is ·750/-	10d. is ·833/-	11d. is ·917/-

The following examples are designed to illustrate the value of the Slide Rule in this work.

Example 1. **Calculate the cost of 43 articles at £3 6s. 10d. each.**

In the larger table, in the column headed 6s., and in the line marked 10d., is the number ·342. £3 6s. 10d. is therefore £3·342. To multiply 3·342 by 43, set 10 in scale C opposite 3·342 in scale D, then opposite 43 in C will be found 143·7 in D. The result, therefore, is £143·7 or £143 14s., by the slide rule, and the exact amount is £143 13s. 10d.

2. **Calculate 28% of £61 10s.** To multiply 61·5 by 28, find 61·5 in D and bring 10 of C into coincidence. Opposite 28 in C read 17·22 in D. The result is £17 4s. 5d., which is correct to the nearest penny.

At the end of $6\frac{1}{2}$ years, £1 at 5% compound interest becomes $(1{\cdot}05)^{6\frac{1}{2}}$

Proceeding as at (*k*) above

$$£(1{\cdot}05)^{6\frac{1}{2}} = £\left(\frac{2{\cdot}1}{2}\right)^{6\frac{1}{2}} = \frac{£124}{90{\cdot}5} = £1{\cdot}372$$

Now multiply by 86. $86 \times 1{\cdot}372 = £118$, which is very near the correct amount.

Example (*l*) To evaluate $\sqrt[5]{30}$

Place the cursor line over 30 in LL, move slide so that 5 in C is brought under the cursor line and read the result 1·973 in LU opposite 10 in C, again using the cursor.

If the answer lies outside the range of the log-log scale, *i.e.*, is greater than 40,000 or less than 1·1, it may be found as indicated below.

Example (*m*) Evaluate $2{\cdot}1^{20}$

$(2{\cdot}1)^{20} = (2{\cdot}1^{4})^{5}(19{\cdot}45)^{5}$ *see* (*k*)

$(19{\cdot}45)^{5} = (1{\cdot}945)^{5} \times 10^{5} = 27{\cdot}9 \times 10^{5}$ (*see* (*k*)

$= 2{,}790{,}000$

Alternatively

$$(2{\cdot}1)^{20} = (2{\cdot}1^{10})^{2} = (1670)^{2} \text{ see } (a)$$

$$(1670)^{2} = (1{\cdot}670)^{2} \times (1000)^{2} = 2{\cdot}79 \times (1000)^{2} = 2{,}790{,}000$$

Example (*n*) Evaluate $1{\cdot}2^{\cdot 13}$

$$1{\cdot}2^{\cdot 13} = \left(\frac{12}{10}\right)^{\cdot 13} = \frac{(12)^{\cdot 13}}{(10)^{\cdot 13}} = \frac{1{\cdot}38}{1{\cdot}35} = 1{\cdot}023$$

If the exponent is negative, proceed as with a positive exponent and then find the reciprocal of the result.

SINES, COSINES, TANGENTS. The table on the back of the Log-Log and 5-10 Rules gives values of Sines, Cosines, Tangents and Cotangents, of all angles. Values should be taken from the table and used in computations when necessary.

MONEY CALCULATIONS.

Calculations with sums of money expressed in pounds,

or when less than unity the noughts immediately following the decimal point. Divide by 3. If there is no remainder, use the 1-10 of scale A, with slide to left. If there is a remainder of 1 for integrals, or 2 for decimals, use 1-10 of scale A with slide to the right. If the remainder is 2 for integrals or 1 for decimals, use the 10-100 of scale A with slide to right.

CHAPTER II.

Proportional Problems.

Time and Ground Speed Problems.

These problems are most readily solved by using scales A and B, but if greater accuracy is required, scales C and D should be employed. As most problems of this character involve the use of the factor of 60 minutes, an index mark has been engraved over the figure 6 on scale B. This figure has been chosen rather than 60, because it is in the central part of the scale, and is more convenient to use. It can, of course, still represent 6 or 600 minutes. The following examples will explain the procedure.

1. The ground-speed of an aircraft is 132 m.p.h. Required the time to fly 224 miles.

Scale A	Under 132	Under 224
Scale B	Set 6	Read 101·9

The result is in minutes, thus to the nearest quarter of a minute the time taken is 1 hr. 42 mins.

2. The ground-speed of an aircraft is 102 knots. How far will it travel in 36 minutes?

Scale A	Under 102	Read 61·1
Scale B	Set 6	Over 36

Answer: 61·1 Nautical miles.

3. An aircraft flies 18·4 miles in 12·5 minutes. What will be the ground speed?

Scale A	Under 18·4	Read 88·4
Scale B	Set, 12·5	Over 6

Answer 88·4 m.p.h.

MISCELLANEOUS PROPORTIONAL PROBLEMS.

An aircraft consumes 85 gallons of fuel per hour. A flight of 575 miles is to be made at an estimated ground speed of 178 m.p.h. How much fuel will be required, allowing a 15% safety factor.

To find the time of the flight :

Scale A	Under 178	Under 575
Scale B	Set 6	Read 194

Time of flight : 3 hrs. 14 mins.

To find the amount of fuel required :

Scale A	Under 85	Read 275
Scale B	Set 6	Over 194

To find the amount of fuel to be used as a safety factor :

Scale C	Set L.I.	Under 275
Scale D	Over 15	Read 41·3

Thus the total amount of fuel required for the journey is 275 plus 41, equals 316 gallons.

If the specific gravity of the fuel is ·74, what is the weight of the total required for the flight in question?

As a gallon of water weighs 10 lbs., a gallon of the fuel will weigh 7·4 lbs.

Scale C	Set R.I.	Under 316
Scale D	Over 7·4	Read 2338

The weight of the fuel is 2338 lbs.

The Use of Conversion Factors.

On the back of the " Unique " Navigation Slide Rule will be found several conveniently arranged factors for the speedy conversion of different units of speed, length, and capacity, etc. A few examples will make clear their use.

To convert knots into miles per hour.

Scale C	Set 66	On this scale read Knots
Scale D	Over 76	On this scale read M.P.H.

To convert Litres into Pints.

Scale C	Set 25	On this scale read Litres
Scale D	Over 44	On this scale read Pints

LOG-LOG COMPUTATIONS.

The tenth powers of all numbers in LU lie immediately below in LL, and the tenth roots of numbers in LL lie directly above in LU.

Examples (*a*) $1{\cdot}8^{10}=357$

(*b*) $12^{10}=(1{\cdot}2\times10)^{10}=(1{\cdot}2^{10})\ (10^{10})=6{\cdot}2\times10^{10}$

(*c*) $\sqrt[10]{50}=1{\cdot}48$

(*d*) $\sqrt[10]{2}=\sqrt[10]{\frac{20}{10}}=\frac{1{\cdot}35}{1{\cdot}259}=1{\cdot}072$

NATURAL LOGARITHMS may be obtained by reading opposite the number whose logarithm is desired in LU or LL, the logarithm in D.

Examples (*e*) log e 9=2·2 (*f*) log e 1·5=·405

Powers of e may be obtained by reading opposite the exponent in D, the result in LU or LL.

Examples (*g*) $e^{4}=54{\cdot}6$

(*h*) $e^{\cdot3}=1{\cdot}35$

(*i*) $e^{12}=(e^{4})^{3}=$ from (*g*) above $(54{\cdot}6)^{3}=(5{\cdot}46\times10)^{3}$ $=162000$ see (*k*) below.

Roots of e may be evaluated by using the reciprocal of the exponent in the foregoing rule.

Example (*j*) $\sqrt[8]{e}=e^{\cdot125}=1{\cdot}133$

The most useful purpose which the log-log Scale serves is computing powers and roots when exponents are fractional.

Example (*k*) To evaluate $6{\cdot}4^{3\cdot21}$

Set the cursor line over 6·4 in LL and bring 1 of C into coincidence with it. Read the answer 387 in LL opposite 3·21 in C, again using the cursor.

Find the value of £86 after 6½ years. Compound Interest at 5% per annum being allowed.

First calculate for £1 capital.

£1 at the end of one year becomes (1+·05)=£(1·05), at the end of two years £1 becomes £1·05 (1+·05)=£(1·05)², and so on.

conditions, and care must be taken to select, by inspection, the one giving the correct value.

Squares, square roots, cubes and cube roots may be evaluated with the aid of the log-log scale, sometimes with a higher degree of accuracy than is possible with scales A, B, C and D.

LOGARITHMS. The common log of any number is obtained by finding the number in the LU or LL scale, placing the cursor line over it and moving the slide so that the number 2·303 in C lies under the cursor line. The log will then be found in D opposite either 1 or 10 of C. Suppose the common log of 18·75 is required :—Place the cursor line over 18·75 in LL, and move the slide until 2·303 in C lies under the cursor line. The log 1·273 appears in D opposite 1 in C. By this method the complete logarithm, characteristic and mantissa is obtained. In certain models there is a gauge mark, denoted by U, at 2·303 in C to assist in finding common logs.

RECIPROCAL SCALE.

Certain types of Log-Log Rules are equipped with a reversed C scale (subsequently referred to as the Cr scale) placed along the middle of the Slide. The uses of this scale are indicated in the following examples :—

Reciprocals are obtained by projecting, from C to Cr or vice versa, *e.g.* 4 in C projects into ·25, *i.e.* $\frac{1}{4}$ in Cr.

Multiplication and Division. To compute the value of an expression such as 2·8×3·2×6·5, find 2·8 in scale D, then with the aid of the Cursor, bring 3·2 in Cr into coincidence and read the result, 58·2 in D, opposite 6·5 in C, with one setting of the Slide. The factors may be selected in any order and operations repeated, if necessary, to cover any number of factors.

To find the value of $\frac{82}{3{\cdot}6\times{\cdot}78}$ find 82 in D and bring 36 in C into coincidence. Then opposite 78 in Cr. find the result 29·2 in D, the decimal point being inserted by inspection.

CHAPTER III.

WIND AND DRIFT PROBLEMS.

ONE of the really fascinating characteristics of the Slide Rule is the ease with which it deals with some of the problems in trigonometry which are encountered during the navigation of an aircraft. It is far more accurate, and for many of the problems easier and quicker to use than some of the Course and Ground Speed calculators in use to-day.

To find the Course to Steer and Ground Speed along given Track.

Using scales S2 and A. Under the Air Speed set the angle on the bow or quarter of the Track that the wind is blowing. Under the Wind Speed read the Drift angle. The Drift angle, added or subtracted to the track, will give the course to steer. To find the Ground Speed : if the wind is a head wind, subtract the drift angle from the wind angle on the bow; if a tail wind, add the drift angle to the wind angle on the quarter. Above the resulting angle read the Ground Speed.

Example: Air Speed 126 m.p.h. Track 040°T. Wind velocity 20 m.p.h. from 090°T (50° on the bow).

Scale A	Under 126	Under 20	Read 112 (G/S)
Scale S2	Set 50°	Read 7° (Drift Angle)	Over 43° (50°—7°)

Answer: Course to Steer, 043°T. Ground Speed, 112 m.p.h.

Example: Air Speed 97 Knots. Track 352°T. Wind Velocity 15 Knots from 110°T. (62° on the starbd. quarter.)

Scale A	Under 97	Under 15	Read 103 (G/S)
Scale S2	Set 62°	Read 8° (Drift Angle)	Over 70° (62°+8°)

Answer: Course to Steer, 360°T. Ground Speed, 103 Knots

Note that when the Drift is less than 1 degree, the Ground Speed should be found by adding or subtracting the Wind Speed and the Air Speed.

To find the Wind Velocity, knowing the Track and Ground Speed, Course and Air Speed.

On scale A mark the Air Speed and Ground Speed with the Cursor and a light pencil mark. Adjust the slide until the number of degrees read between the Air Speed and the Ground Speed markings equals the Drift Angle, i.e. the difference between the Course and the Track. Above the Drift Angle on scale S2 read the Wind Speed on scale A. Under the Air Speed read the Wind Direction as an angle on the bow or quarter of the Track, or under the Ground Speed as an angle on the bow or quarter of the Course. Note that if the G/S is less than the A/S, the angle is on the bow, and if the A/S is less than the G/S, an angle on the quarter.

Example: Course 137°T. Air Speed 150 m.p.h.
Track 142°T. Ground Speed 130 m.p.h.

Mark the scale A at 130 and 150. Adjust the slide until a difference of reading of 5 degrees on scale S2 is obtained between the above markings. In this example 29° and 34° will be found to correspond. On scale A above 5° read 23·4 m.p.h. (Wind Speed). The Wind Direction is 34° on the bow of the Track, and is therefore 108°T as the Drift is to Starboard.

To find the Wind Speed and Ground Speed, knowing the Course and Air Speed, Drift Angle, and Wind Direction.

This method is particularly useful when a flight is being made over the sea, and it is desired to know the Ground Speed. In such cases the Drift Angle can nearly always be found by a Drift-Sight or back-bearings of an object dropped from the aircraft, but it is not such a simple matter to determine the Ground Speed. It is a known fact, in a steadily moving air mass, the difference between the Wind Direction at the surface and the Wind Direction at a reasonable height remains nearly constant with the changes of surface wind direction.

This difference can be ascertained at the departure point, from meteorological information available, and applied to the direction of the surface wind, obtained during the flight by bearings of the wind lanes on the sea surface. It has also been found that in practice a reasonably accurate forecast of the direction of the upper winds can be given by a meteorologist, whereas difficulty is sometimes experienced in forecasting the speed. The wind direction can also be ascertained by noting the direction of movement of cloud shadows, on the surface. With these various sources at the navigator's disposal little

of the dividend, but if the answer is found opposite 10 in C the number of digits preceding its decimal point is the same as the difference between the numbers of digits appearing before the decimal points of dividend and divisor respectively. When the numbers to be multiplied together or divided are of values less than unity, the number of ciphers immediately following the decimal points must be taken into account and reckoned as negative in the application of the rules for fixing the position of decimal point in the answer.

SQUARES. Numbers may be squared by multiplication direct, but results are more readily obtained by reading in scale A the squares of numbers directly opposite in scale D, the cursor or, preferably the slide, being used to project from one scale to the other.

The calculation of the area of a circle from the diameter is a computation often desired. Find the number representing diameter on D and bring the 1 or 10 of scale C into coincidence with it. The answer appears in A opposite the line at 785 in B.

SQUARE ROOTS. The square roots of all numbers in scale A appear directly below in scale D. Since, however, any number appears twice in scale A, care is necessary in selecting the one to be used. The rule is :—If the original number has an odd number of digits preceding its decimal point, or, when less than unity, has an odd number of ciphers immediately following its decimal point, the left-hand half of scale A must be used. When the number of digits preceding, or the ciphers immediately following the decimal point in the original number is even, the right-hand half of scale A must be used.

CUBES of numbers may be found by repeated multiplication, or more quickly by moving the 1 or 10 of scale C into coincidence with the number to be cubed in D, and reading the answer in A directly opposite the original number in B.

CUBE ROOTS. Find the number whose cube root is required in scale A and place the cursor line over it. Move the slide until the number in scale B, directly under the cursor line, is exactly the same as that in D opposite 1 or 10 in C. There will be three positions of the slide satisfying these

17 in C. Approximate cancellation of the numbers will fix the position of decimal point in the answer. 22·5 divides 86·2 approximately 4, and the 4 thus obtained divides 11·45 nearly 3, which leaves 6 in the numerator when divided into 18 ; ·8 into 1·7 gives roughly 2, and the result is approximately $6 \times 2 \times \cdot 05 = 12 \times \cdot 05 = \cdot 6$. The answer, therefore, is ·627.

Frequently the position of decimal point may be determined without resorting to the approximation indicated above, *e.g.*, suppose the fraction $\frac{51 \cdot 9}{69 \cdot 7}$ is desired as a percentage. Using the Slide Rule to divide 519 by 697, the result, 745 obtained, is obviously 74·5 per cent.

Those using the Slide Rule for the first time are advised to master the operations of multiplication and division, as explained above, before reading any further. Practice with simple numbers giving results easily checked is recommended, e.g., *using scales C and D evaluate* $\frac{2 \times 12 \times 6}{4 \times 9}$ *and see if the answer is 4. Now repeat, taking the numbers in a different order, and see if the result is the same. Take note of the time saved by dividing and multiplying alternately, as described in the example given earlier. Half-an-hour spent on similar simple examples will suffice to teach the use of the rule for the fundamental operations of multiplication and division.*

The following rules, based upon the manipulation of the Slide Rule, are sometimes used to fix the decimal point, but their use is not recommended. In multiplication, when the 1 of scale C is used in the setting of the slide, the number of digits occurring before the decimal point of the answer is one less than the sum of the numbers of digits appearing before the decimal points of the original numbers. When the 10 of scale C is used in setting, the number of digits before the decimal point of the answer is the same as the sum of the numbers of digits preceding the decimal points of the original numbers. When dividing, if the answer appears opposite 1 in C the number of digits preceding the decimal point of the answer is one greater than the difference obtained by subtracting the number of digits lying before the decimal point of the divisor from the number of digits appearing before the decimal point

difficulty is usually encountered in finding the wind direction.

Example: Air Speed 110 Knots. Course 136°T. Track 142°T. Drift 6 degrees to Starbd. Wind direction 348°T.

The difference between the Track and Wind direction is 206 degrees. The Wind angle is therefore 26° on the quarter, a tail wind. Therefore 26 degrees added to 6° (the Drift) will give the angle to use to find the Ground Speed.

Scale A	Under 110	Read 26·2 (Wind Speed)	Read 133 (G/S)
Scale S2	Set 26°	Over 6°	Over 32°

Answer: Wind Speed 26·2 Knots. Ground Speed 133 Knots.

To find the New Track and Ground Speed after an alteration of Course.

This method is not mathematically correct, but is sufficiently accurate when it is desired to know the Track and Ground Speed immediately after an alteration of course. In practice, Drift should be checked by observation as soon as possible after any alteration of course, so it should never be really necessary to calculate the D.R. Track.

Example: Before alteration of Course the Track was 045°T. Wind Velocity 20 m.p.h. from 095°T, True Air Speed 140 m.p.h. Drift 6¼° Course steered 051°T. Course is altered to 120°.
The wind is now 25° on the Port bow of the air-craft, previously it was 44° on the Starbd. bow.

Scale A	Under 6·25	Read 3·8
Scale S2	Set 44°	Over 25°

The New Drift is 3° 48′, and the New Track is therefore 124° to the nearest whole degree.

To find the New Ground Speed :

Scale A	Under 20 (Wind Speed)	Set Cr. to 140 (Air Speed)
Scale S2	Set 3° 48′	

If the Angle under the Cursor is not an even degree or half degree, adjust the slide accordingly, to bring the half or whole degree under the Cursor. Then move the Cursor 3° 48′ to the left (as the wind is ahead) and read on scale A the New Ground Speed, 122½ m.p.h.

If course is being altered frequently, as it would be if a search of some kind were being carried out, it would be far easier and decidedly more accurate to keep a plot of Air Courses on the chart. When it is desired to know the D.R. position, the total windage affecting the aircraft during the search can be applied to the air position. This can most effectively be accomplished by plotting a wind scale, sub-divided into intervals of, say, five minutes. The distance that the aircraft has been blown downwind can them be conveniently stepped off with dividers from the air position.

Thus if the air courses flown have totalled 55 minutes from the last fix, then 55 minutes of wind is used. The wind scale is, of course, constructed to the same scale as the distance scale of the chart or map.

It should always be borne in mind that the errors of D.R. Navigation are accumulative ; therefore the more observations of Drift, Ground Speed, or position that can be made, the more accurate will be the final result.

It will be seen in all these problems that the Drift Angle is always subtracted from the Wind Angle to the Track for Head Winds, and added for Tail Winds. Little difficulty will be found in remembering this, for it will always be readily reen when using the Slide Rule, for a Head Wind will always seduce the Ground Speed, and a Tail Wind will increase it.

INTERCEPTION PROBLEMS.

In theory, the most accurate method of determining the Course to steer to intercept a moving surface vessel is by plotting, and for examination purposes this is the safest method to adopt. In practice, however, this very seldom works out, because changes of wind or weather *en route* often necessitate an alteration of Course, and consequently the time and labour spent in solving the original problem is wasted. Again, the problem often arises—when the ground speed during the flight is not what it was estimated to be—how much has Course to be altered? Theoretically, a new interception problem should be worked out, but this is a rather lengthy procedure. The following method, using the Slide Rule, gives a simple solution to this type of problem.

be used instead of the 1. For example, if 25×45 is to be computed, the procedure is :—Set the 10 of C opposite 25 in D and coincident with 45 in C, the result, 1125, will be found in D. Scales A and B may be used for multiplication if desired, the result will always be on the scale, and the slight delay occasioned by the double setting avoided. It is for this reason that the upper pair of scales is sometimes employed in multiplication, but greater accuracy will always be obtained when scales C and D are used, and their use in multiplication and division generally is strongly recommended.

In this example the answer is 1125, but the manipulation of the slide rule would be exactly the same in the multiplication of any two numbers in which two five, and four five are the only significant figures, for example, $25\times45=1125$; $2{\cdot}5\times45=112{\cdot}5$; $\cdot25\times4{\cdot}5=1{\cdot}125$; $\cdot025\times\cdot45=\cdot01125$. The position of the decimal point in the answer is easily determined by inspection. When three or more numbers are to be multiplied together, the computation is effected by a series of operations, the cursor line being used to mark the intermediate answers until the final result is reached.

DIVISION. Set the slide so that the divisor on scale C is coincident with the dividend on scale D, the result will be found in D opposite 1 or 10 in C.

For example, suppose it is desired to divide 13·9 by 5·65. Adjust the slide so that 565 in scale C is coincident with 139 in scale D. Opposite 10 in C will be found the result in D, viz., 246. Inserting the decimal point, the result 2·46 is obtained.

In computing the value of an expression such as the following : $\frac{86{\cdot}2\times\cdot049\times18\times1{\cdot}7}{22{\cdot}5\times11{\cdot}45\times\cdot8}$ it is evident that repeated multiplication of the four numbers of the numerator, followed by division separately, by the three numbers of the denominator will give the result, but time is saved by dividing and multiplying alternately. Using scales C and D, find 862 on D, and bring 225 on C into coincidence ; adjust cursor line to 18 in C, then move slide to bring 8 on C under cursor line ; move cursor line into position above 49 in C and adjust slide so that 1145 in C lies under cursor line ; read the answer, 627, in D opposite

Reprint of Instructions for other types or 'UNIQUE' Slide Rules

'UNIQUE' SLIDE RULES

SINCE the operations of multiplication and division occur so frequently in the computation of numerical results, any mechanical means of performing them rapidly is valuable. Various forms of Slide Rules are obtainable, with the aid of which, results, sufficiently accurate for most purposes, may be readily obtained. Compared with ordinary, or contracted methods, or the use of logarithms, computation by the Slide Rule is less laborious, less liable to error, and very much more expeditious.

An illustration of the 10in. " Unique " Log-Log Slide Rule is given on pp. 20 and 21 and an inspection of the rule itself shows that the essential parts consist of four scales, denoted for reference in the illustration by the letters A, B, C and D, and a log-log scale running along the top and bottom edges, denoted by LU and LL. A transparent cursor with a fine line drawn across it is supplied to assist in certain operations.

The scales are in all cases divided in decimals, and practice in reading them may be necessary. It is obviously quite impossible to number every division, and in reading a position in any scale the nearest number to the left, or to the right, must be carefully observed, and the divisions of the scale followed until the exact position is reached. For example, in the illustration of the rule, the cursor line is standing at 1·748 in LU, at 31·2 in A, at 37·8 in B, at 6·15 in C, at 5·6 in D, and at 270 in LL.

(The comprehensive numbering of the scales is a distinctive feature of the Unique Slide Rule, and in this respect it is superior to the more expensive instruments, most of which are numbered in an inadequate and misleading manner.)

MULTIPLICATION is effected by using scale C in conjunction with scale D. Supposing multiplication of 15 and 45 is desired, the procedure is :—Move the slide so that the 1 on C is brought opposite 15 on D, and read the answer 675 in scale D, opposite 45 in scale C. In some cases when the 1 of scale C is used, the answer is off the scale, and the 10 on scale C must

Example: Bearing and distance of ship 012°.282′. Ship's Course and speed 125° 17 Kts. Air Speed 120 Kts. Wind Velocity 22 Kts., from 247°.

Find the angular difference between the relative bearing and the ship's course, i.e. 125°—12°=113° or 67° on the " quarter " of the relative bearing. Estimate the Ground Speed of the aircraft. This can be done quite roughly, as a few knots either side of the correct Ground Speed is negligible. Ground Speed is therefore estimated to be 125 Kts.

Scale A	Under 125 (G/S)	Under 17 (Ship's speed)
Scale S2	Set 67°	Read 7° 11′

This will give the angle the Track Out makes with the relative bearing. The Track is therefore 019°T.

Find now the angular difference between the Wind direction and the Track. 019°+180°=199°~247°=48° on the quarter.

Scale A	Under 120	Under 22	Read 133½
Scale S2	Set 48°	Read 7° 50′	Over 55° 50′

As the wind is a Tail Wind, 7° 50′ and 48° are added, and the true Ground Speed out is 133½ Kts. If the first part of the problem is rechecked, using the correct G/S of 133½ Kts., it will be seen that the angle between the relative bearing and the Track is still approximately 7 degrees.

The Drift has been found to be 7° 50′ Starboard. The Course to steer is therefore 011°.

If, after the Course has been set, an alteration in the estimated ground speed is discovered, the amount which Course has to be altered (to maintain the relative bearing of approach) can be found by carrying out the procedure adopted in the first part of this example, using the new ground speed, and thus finding the new Track to intercept. This Track can then be maintained by Drift observations and slight alterations to Course. During the latter stages of the flight, if large changes of Drift or Ground Speed are found, a new relative bearing should be measured between the calculated D.R. positions of the ship and the aircraft, at the same instant of time. If this is done for a few minutes ahead, and a change of relative bearing is discovered, the new Course to steer can be determined by using the new angle between the new relative bearing and the ship's Course.

The estimated time of interception should be calculated by measuring the distance along the Track, and applying the measured ground speed. If the speed of closing is used along the line of relative bearing, some difficulty will be encountered in the calculation of a new E.T.I. when it is found that the G/S is not what it was estimated to be.

CHAPTER IV.

THE CALCULATION OF TRUE TRACK AND DISTANCE.

The True Track and Distance by the Middle Latitude Formula.

Formulæ:

Departure	=	D. Long × Cos. Mid. Lat.
Tan. Track	=	Dep. ÷ D. Lat.
Distance	=	Dep. × Cosec. Track.
		D. Lat. × Sec. Track.

To find the Rhumb Line Track and Distance from Calais to Heligoland.

Calais	Lat.	50° 58′ N	Long	1° 51′ E
Heligoland		54° 11′ N		7° 53′ E
	D.Lat.	3° 13′ N	D.Long.	6° 02′ E
		193′		362′
	Mid.Lat.	52° 34′5		

To find the Departure.

Scale S1	Under R.I.	Under 37° 25′5 (Complement of Mid)
Scale B	Set 362	Read 220 Lat..
Departure 220′		

To find the True Track.

RULE : Always set the larger value of D.Lat. and Dep. on scale C, and the smaller value on scale D.

H=Height of observer in feet above the object.
θ=Angle of depression in minutes.

For distances over ten miles or for greater accuracy.

Formula: $\frac{\cdot 565\ H}{\theta - \cdot 4D_1} = D_2$

D_1 and D_2=Distances in Nautical miles.

D_1 should be found, using the first formula, and then when $\cdot 4D_1$ is obtained the second formula can be used to calculate the final result.

To find D_1

Scale C	Set θ	Under H
Scale D	Over 565	Read D_1

Evaluate $\theta - \cdot 4D_1$

To find D

Scale C	Set $\theta - \cdot 4D_1$	Under H
Scale D	Over 565	Read D

should invariably be taken first, as it will not then be necessary to transfer this position line for the " run " between it and the next observation. It will be found sufficiently accurate in practice to extend the position line until it cuts the line resulting from the second sight, thus giving a fix, and saving one the labour of transferring the observation for the time interval between sights.

Correction of Refraction.

Altitudes above 8°. Multiply the Cotangent of the Altitude by ·96.

Altitude 36°, required the correction for refraction.

Scale C	Set ·96	Read 1·3
Scale T1	Over 36°	Over L.I.

Correction is 1·3 minutes minus to the apparent altitude.

Correction for Dip of the Sea Horizon.

Formula: $\sqrt{\text{Height}} \times \cdot 98$

Example: An observer flying at 840 ft. above sea level requires the dip correction.

Scale A	Set Cr. to 840	
Scale C	Set R.I. to Cr.	Under ·98
Scale D		Read 28·4

Dip Correction is 28·4 minutes minus to the observed altitude.

To find the distance to the Sea Horizon.

Formula: $\sqrt{\text{Height}} \times 1 \cdot 15$. The resulting distance is given in Nautical miles.

To find the distance of an object from the Angle of Depression.

For distances up to ten miles.

Formula: $\dfrac{\cdot 565\ H}{\theta}$ = distance in Nautical miles = D_1

Scale C	Set 220	Set Cr. to R.I.	
Scale D	Over 193		
Scale T1		Under Cr.	Read 41° 15′

As the Dep. is greater than the D.Lat. the Track is obviously greater than 45 degrees. Therefore the complement of the angle 41° 15′ is used. The Track is always named the same as the D.Lat. and the D.Long.

True Track=N48° 45′E or 049°T to the nearest half degree.

To find the Rhumb Line Distance.

Scale S1	Set Cr. to 48° 45′	Under R.I.
Scale B	Set 220 to Cr.	Read 293

Rhumb line distance 293 Nautical miles.

A check on the answer can be obtained by setting the Cr. to 41° 15′ (Complement Track) and reading 293′ (D.Lat.) on scale B.

To find the Rhumb Line Track and Distance from Calais to Gibraltar.

Calais	Lat. 50° 58′ N	Long. 1° 51′ E
Gibraltar	36° 04′ N	5° 26′ W
	D.Lat. 14° 54′ S	D.Long. 7° 17′ W
	894′	437′
	Mid.Lat. 43° 31′	

To find the Departure.

Scale S1	Under R.I.	Under 46° 29′
Scale B	Set 437	Read 317

Departure 317′

To find the True Track.

Scale C	Set 894	Set Cr. to R.I.
Scale D	Over 317	
Scale T1		Under Cr. read 19° 30′

True Track S19½W or 199½° True.

To find the Rhumb Line Distance.

Scale S1	Set Cr. to 19° 30′	Under R.I.
Scale B	Set 317 to Cr.	Read 951

Rhumb Line Distance 951 Nautical miles.

Distances of over 200 miles should always be calculated in preference to measuring the distance by dividers on the map or chart. Again, it is always easier and more accurate to calculate the Track and distance between places which are not on the same map or chart sheet. A little practice with the Slide Rule will enable this problem to be solved more accurately, and in a shorter time, than it would be if Traverse Tables were employed.

The Great Circle Track and Distance, etc.

In Air Navigation, the Great Circle Track has other uses than the saving in distance during a long flight. It can be used to avoid ranges of high mountains or prohibited areas, without increasing the distance flown, and in flights, when it is desired to bring the track of the aircraft within visibility distance of some landmark, to assist navigation, when by flying the Rhumb Line Track the landmark would have been missed altogether. It is, of course, not always possible to utilise the Great Circle Track in this manner, but these advantages should not be forgotten when planning a flight of even moderate distance.

To calculate the problems involved, by spherical trigonometry, is a very tedious procedure. When, in order to shorten the work, short tables are employed, an added disadvantage is encountered, namely the necessity of having to choose two points near the departure point and destination to obtain angles to fit the tables.

By using the Slide Rule all these difficulties are overcome, for the solution is both rapid and accurate, and the actual positions of the chosen places can be used.

To Calculate the Great Circle Distance.

Formulæ:

Tan Lat. A × Tan Lat. B ÷ Cos D. Long.
(If Lat. A and B are in the same Hemisphere.)

220 m.p.h. is the G/S Out against the head wind, and 239 m.p.h. the G/S Home.

220 + 239 = 459.

Scale C	Set L.I.	Set Cr. to 239	Set 459 to Cr.	Under 3·5
Scale D	Over 220			Read 401

Radius of Action is therefore 401 miles.

The time to turn is found from the time required to fly the 401 miles at the Outward G/S.

To find the Error in Track from a Position Line Parallel to the D.R. Track.

When navigating by astronomical observations, every advantage should be taken to observe heavenly bodies abeam of the aircraft, as the resulting position lines will give a good indication of the true track of the plane.

If no terrestrial observations have been possible since the departure, it will be desired to know the error in the course being steered. This can be easily found as follows.

Example: After flying 186 miles an observer obtained a position line placing the aircraft 38 miles to starboard of the D.R. Track. Find the error in the track.

Scale C	Set 186	Under L.I.
Scale D	Over 38	
Scale T1		Read 11½°

The Track error is 11½°.

This method can also be employed when navigating over land, or when D/F W/T bearings are being used. It can also be used to give the alteration of course required to reach a certain destination, when of course the distance of the aircraft from the destination should be used instead of the distance run since departure.

It might be noted here that when sights are being taken to make a running fix, a sight of a heavenly body on the beam

Although a fix by this method is not very practicable when airborne, it is invaluable when a survey of an advanced landing ground or anchorage is being carried out.

To find Conversion Angle.

Formula: $\frac{1}{2}$ D.Long.×Sin.Mid.Lat.=Conversion Angle.

D.Long 6° 40′ Mid.Lat. 62°

Scale S1	Under 6° 40′		Read 2° 56′
Scale B			Over ·5
Scale S2	Set R.I.	Set Cr. to 62° Set R.I. to Cr.	

Conversion Angle=2° 56′

Numerous rules have been proposed which are purported to aid the navigator in remembering how Conversion Angle should be applied. If it is remembered that no matter whether the Latitude is North or South, or whether the bearing is from a shore station or from the aircraft, the conversion angle correction is always applied towards the Equator, no difficulty will be encountered.

Radius of Action.

The problem of finding the radius of action of an aircraft along a given track for a known endurance is a very simple matter if the Slide Rule is always employed.

Formula:

$$\frac{\text{G/S Out} \times \text{G/S Home}}{\text{G/S Out} + \text{G/S Home}} \times \text{Petrol Hours} = \text{Radius of Action}$$

Example: Air Speed 230 m.p.h. Track out 040°T. Wind Velocity 20 m.p.h. from 102°T. Petrol Hours 3·5.

Note the wind is 62° on the bow.

Scale A	Under 230	Under 20	Read 220	Read 239
Scale S2	Set 62°	Read 4½°(Drift)	Over 57½°	Over 66½°

Tan Lat. A×Tan Lat. B—Cos D.Long.
(If Lats. A and B are in different hemispheres.)

The result is called C.
C×Cos Lat. A×Cos Lat. B=Cos distance

N.B.—The rules regarding the Plus and Minus to D.Long. are reversed if the D.Long, exceeds 90 degrees.

Example: Position A. Lat. 38° 45′ N Long. 9° 30′ W
Position B Lat. 40° 25′ N Long. 73° 15′ W
Difference of Longtitude is 63° 45′ W

Scale T2	Set R.I.	Under 40° 25′	
Scale D		Read ·683	
Scale T1	over 38° 45′		

i.e. Tan Lat. A×Tan Lat. B=·683

Scale S1	Under 26° 15′	(Comp. 63° 45′)
Scale A	Read ·442	

i.e. Cos D.Long.=·442
·683+·442=1·125 (as A and B are in the same Hemisphere).

Scale S1	Under 51° 15′ (Comp. Lat. A)		Read 48° 03′
Scale B		Set L.I. to Cr.	Over 1·125
Scale S2	Set R.I.	Set Cr. to 49° 35′ (Comp. Lat. B)	

The angle 48° 03′ is read as a complementary angle to that indicated on scale S1, as the answer is the cosine of the distance.

Great Circle Distance 48° 03′ or 2883 Naut. miles.

In the latter process the formula is 1·125×cos Lat. A× cos Lat. B=cos distance.

Note that the scales S1 and S2 are sine scales, and to use these scales for cosines the complementary angles must be used. After becoming acquainted with the use of the trigonometrical scales, the beginner will be able to select the complements of angles quite easily from the sine scale by counting the degrees from the right-hand index, or from an easily recognised complement, e.g. 60°, 45°, or 30°.

The Initial Track.

Formula:

Sec. Lat. A×cosec Lat. B = A (opposite name to Lat. A)
Tan Lat. A×cot dist. = B (same name as Lat. B)

The algebraic sum of A and B is the cosine of the Initial Track.

Latitude A 38° 45′ N. Latitude B 40° 25′ N. Distance 48° 03′

To find A.

Scale S1	Under 51° 15′	(Compl. 38° 45′)	Under R.I.
Scale B			Read 1·12
Scale S2	Set 40° 25′	Set Cr. to 48° 03′	Set R.I. to Cr.

Note that 1·12 can be read under the L.I. or R.I. of scale S1.

To find B.

Scale T2	Set R.I.	Under 41° 57′ (Compl. dist.)
Scale D		Read ·721
Scale T1	Over 38° 45′	

1·12—·721=·399 (see rules above)
(A is South, B is North)

·399 is the cosine of 66°30′. This is read from the scales A and S1 by setting the Cursor over the required figures.

Initial Track N 66½°W or 293½°T.

To find the Latitude of the Vertex.

Formula:
Sin Initial Track×cos Lat. Dep.=cos Lat. Vertex.
Initial Co. 66° 30′. Latitude Departure 38° 45′ N.

Scale S1	Under 66° 30′	Read 44° 20′ (as a Cosine)
Scale S2	Set R.I.	Over 51° 15′

Latitude of Vertex 44° 20′ N.

To find the Longtitude of the Vertex.

Formula: Cosec. Lat. Dep.×cot Init. Track=Tan difference of Longtitude between point of departure and Longtitude of Vertex.

Lat. of Departure 38° 45′ N. Initial Tr. 66° 30′.

Scale S1	Under 38° 45′	Under L.I.
Scale B	Set R.I.	Read 1·6
Scale T2	Set L.I.	Under 23° 30′ (compl. of 66°30′)
Scale D	Over 1·6	
Scale T1		Read 34° 50′

As the Hour Angle is westerly, the body is decreasing in altitude. The correction is therefore subtracted and the calculated altitude to use is 36° 39′ and the intercept will be 16 miles away.

The Fix by Horizontal Angles.

The horizontal angle between two points results in a circle of position, the radius of which is obtained by the formula :

$$\frac{\cdot 5d}{\text{Sin } \theta}$$

where d=the distance between the points and θ=the horizontal angle.

The intersection of two circles of position will give the position of the observer.

Although this problem can be solved by using a station pointer or a protracter, these instruments are not always convenient to use on all charts. By using the Slide Rule to solve the problem of finding the radii of the circles of position, and determining the centres of these circles by construction, an accurate and simple method is always at hand.

Example: A and B are two objects 6 miles apart, and C a third object 8·6 miles from B. The horizontal angle between A and B is 68° and between B and C 56°. Required the radii of the two circles of position.

Scale S1	Under 68°	
Scale A		Under ·5
Scale B	Set 6	Read 3·23
Scale S1	Under 56°	
Scale A		Under ·5
Scale B	Set 8·6	Read 5·19

The respective radii are 3·23 and 5·19 miles respectively. Arcs made, using each pair of objects and the radius applicable will determine the centres of the required circles of position, and the intersection of arcs from these centres will give the position of the observer.

of the wind (downwind), and the distance will be the distance the aircraft has been blown downwind, during the time of flight at the given wind speed.

CHAPTER V.

MISCELLANEOUS PROBLEMS.

The use of Pre-Computed Lines of Position.

When a long flight is being carried out above a layer of clouds, or over the high seas, and astronomical navigation is being employed, it is very convenient sometimes to compute the calculated altitude before the observed altitude is taken. This saves time if course has to be altered as a result of the observation made, and it enables most of the work to be done when the navigator is fresh and not flurried.

Knowledge of the estimated track and ground speed of the aircraft will enable its D.R. position to be plotted for every hour or half-hour of the flight. Using these positions and the G.M.T. of each E.T.A. calculate the individual altitudes of the chosen heavenly body.

When in flight, and the time approaches for the first observation, take the series of sights as near as possible to the G.M.T. which was used for the calculated altitudes. The Pre-computed altitude can be corrected for any slight difference of time by the following formula :

$$\text{Correction} = \text{Cos Lat.} \times \text{Sin. Az.} \times \frac{\text{Diff. in Secs.}}{4}$$

Example: Pre-Calculated Altitude 36° 47′, Azimuth S47W
G.M.T. 15 hrs. 06 mins. 00 secs. D.R. Lat. 48°N.
G.M.T. of observation 15 hrs. 07 mins. 06 secs.
Obs. Alt. 36° 23′. Difference 66 secs.

Scale S1	Under 42° (Compl. 48°)				
Scale A					Read 8·1
Scale B			Set Cr. to 66	Set 4 to Cr.	Over R.I.
Scale S2	Set R.I.	Set Cr. to 47°	Set R.I. to Cr.		

The correction to Pre-Computed Altitude is 8·1 minutes.

The Longtitude of the Vertex will be 34° 50′ West of the point of departure, and will therefore be in Longtitude 44° 20′W.

To find the Latitudes in which the Great Circle Track will cut given Meridians.

Formula: Tan. Lat.=Tan. Lat. Vertex × cos. D.Long. between the Longtitude of the Vertex and the given Meridian.

Meridian 19° 30′W. Lat. vertex 44° 20′N. D.Long is 10 degrees.

From scales A and S1 find cos D.Long. (10°) equals ·985.

Scale T2	Set R.I.	Under 44° 20′
Scale D	Over ·985	Read 43° 54′

Latitude of Track in Meridian 19° 30′W=43° 54′N.

To find the Track in any Latitude.

Formula: Sin. Track=sec. Lat. × cos Lat. Vertex.
Chosen Latitude 40°. Latitude of Vertex 44° 20′N.

Scale S1	Under R.I.	Read 69°
Scale S2	Set 50° (compl. of 40°)	Over 45° 40′ (compl. 44° 20′)

Track in Latitude 40°N. is N.69°W or 291°T.

For Calculation of a D.R. or Air Position.

Formula: Dep. = Dist. × Sin. Track.
D.Lat. = Dist. × Cos. Track.
D.Long. = Dep. × Sec. Mid. Lat.

To find the D.R. position after a run of 3 hours along a Track of 242°T at a G/S of 138 Kts., from a position Latitude 50° 30′N. Longtitude 9° 20′W.

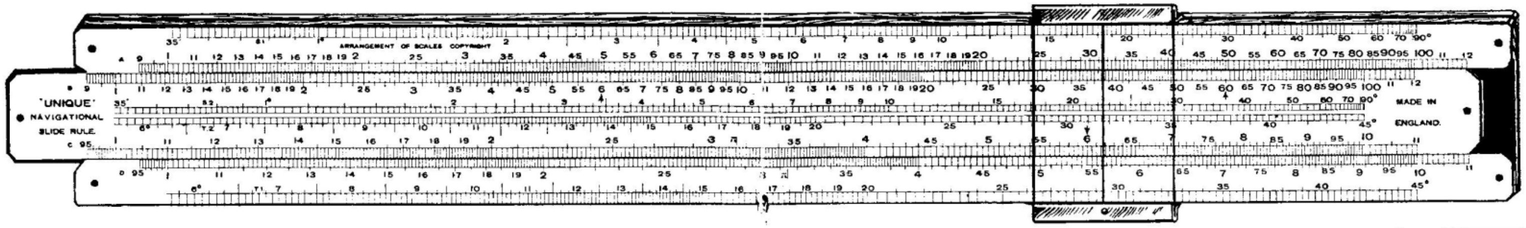
242°T is a bearing of S 62°W. 3 hours at 138 Kts. represents a run of 414 Nautical miles.

To find the Departure.

Scale A	Under 414	Read 365·5
Scale S2	Set R.I.	Over 62°

Departure=365′·5

The 'Unique' Navigational Slide Rule



To find the difference of Latitude.

Scale A Under 414 Read 194·5
Scale S2 Set R.I. Over 28° (compl. of 62°)

D.Lat. 194′·5 or 3° 14′·5S (named S because the Tr. is S)

Note that both these problems can be solved together with one setting of the Slide by moving the Cursor from the Course on scale S2 to the complement of the Course, thus multiplying by the sine in the first case, and by the cosine in the second.

To find the difference of Longtitude.

The Middle Latitude is obtained by applying half the D.Lat. found, to the Latitude of the departure position. Thus the Mid.Lat. is 48° 53′.

Scale A Under 365·5 Read 556
Scale S2 Set 41° 07′ (compl. Mid.Lat.) Over R.I.

D.Long. 556′ or 9° 16′W (named W because the Tr. is W)
The D.R. position is therefore Lat. 47° 15′·5N. Long. 18° 36′ W.

This process of calculating the D.R. position is very useful when changing from one chart to another, especially if the charts are of a different scale, or when greater accuracy is required than can be obtained by measuring a long distance run, on a chart with a varying scale of Latitude.

If it is desired, the Course and Air Speed of the aircraft can be used to calculate an Air position. When the Geographical position is required the wind velocity is applied as an additional track and distance. This " track " will represent the direction

The 'Unique' Log-Log Slide Rule