AIR NAVIGATION FOR FLIGHT OFFICERS

LIEUT. COMMANDER
A. E. DIXIE R.N.

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BY

LIEUT.-COMMANDER A. E. DIXIE, R.N.

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PREFACE

THIS work has been undertaken in the hope that it may prove of assistance to officers in the Royal Naval Air Service, as it condenses into a small compass all the subjects in navigation they are required to know.

A. E. DIXIE.

NAVIGATION SCHOOL, PORTSMOUTH.
March, 1917.

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ILLUSTRATIONS AND DIAGRAMS

NOTE

In the diagrams throughout the book, solid black indicates the red or north seeking end, and broken lines the blue or south seeking end of the magnet.

Attention is directed to the Catalogue of Standard Naval Publications at the end of this book.

AIR NAVIGATION

FOR

FLIGHT OFFICERS

CHAPTER I

MAGNETISM

A KNOWLEDGE of magnetism is absolutely essential in order to understand the action of the iron and steel used in construction on a compass. Also to know what causes the error, and why this error is introduced.

Magnetism is a force existent all over the world, whose nature is that it exerts its influence on iron and steel, causing them to become magnetic. It was first discovered in a substance called 'Lodestone,' and afterwards in certain other iron ores found in various parts of the world.

These iron ores are known as 'natural

magnets,' which are never used in compass adjustment, one reason being that they vary greatly in strength.

Artificial Magnets.—These are pieces of iron or steel to which magnetic properties have been imparted by various methods.

They have the same magnetic properties as natural magnets, but with increased power, depending on the amount of magnetism they receive.

Any part of a magnet contains more or less magnetism, but its greatest power is concentrated at two points near each extremity, these positions being known as the 'Poles' of the magnet. The earth itself possesses the properties of a huge magnet, following the same laws that an ordinary magnet does. Its poles do not coincide with the geographical poles of the earth, but are some distance from either; one being situated north-west of Hudson Bay, and the other in South Victoria Land.

They are not points like the geographical poles, but are areas of considerable extent.

The earth being a magnet has certain lines of force (see Fig. 1) passing through it, and if any iron or steel is placed in these lines of force they will be affected by it and become magnetic themselves.

The magnetism in any magnet is of equal and opposite character at either pole, and it has been found by experiment that if the same like named poles of two magnets be brought

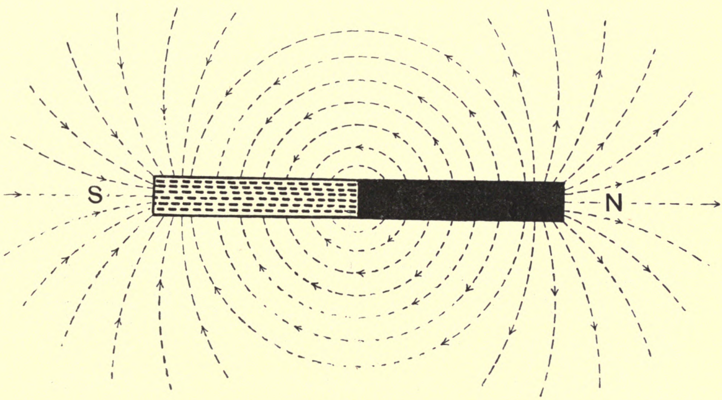


Fig. 1.

into each other's field, that they will repel one another, but that unlike poles will attract each other. Hence the following rule holds good, which is known as 'The First Law of Magnetism':

Like poles repel. Unlike poles attract.

This rule should be carefully memorised; by doing so, compass adjustment with regard to the placing of the adjusting magnet will be quite easy to understand.

Fig. 1 shows an ordinary bar magnet with the lines of force emanating from it. It has been found convenient to imagine the lines of force as issuing from the north-seeking end, and entering the south-seeking end.

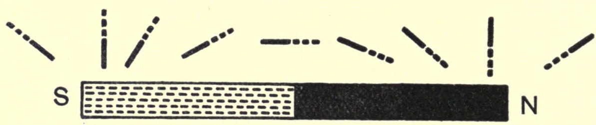


FIG. 2.

Fig. 2 will show what would happen to a small freely suspended magnet if passed along an ordinary bar magnet.

As the earth is a large magnet the following figure (Fig. 3) shows what would happen to a freely suspended magnetised needle if carried from one pole to another.

The portions of the magnetic poles visible are indicated by two white semicircles.

From Fig. 3 it will be seen that on the line joining the red and blue magnetism of the earth the small magnet will assume a horizontal position, whilst at the magnetic poles it will be vertical, so that in any intermediate place it will tend to set at different angles to the horizontal.

This angle is known as the 'Dip,' and an explanation will be given later.

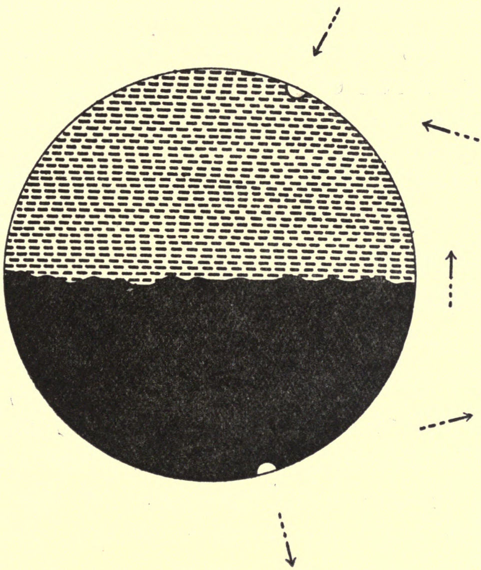


Fig. 3.

A magnet cannot exist without having two consequent poles, one at each end, consequently if it be divided into two or any number of pieces, each of these pieces becomes a complete magnet in itself, as shown in Fig. 4.

In connection with the foregoing figures it will be noticed that the magnets are represented as red and blue: red for the north-seeking end, and blue for the south-seeking end.

This is the conventional way that magnets are painted, and from now onwards the north-seeking or red end of a magnet or compass

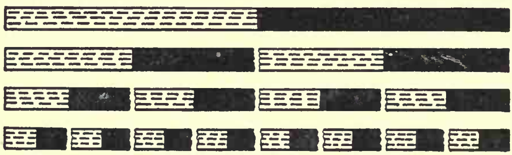


FIG. 4.

needle will be called the north pole, and the south-seeking or blue end the south pole.

Hence the northern part of the earth must be coloured blue, and the southern half red, to conform with the law given before.

As the geographical and magnetic poles do not coincide, the compass needle cannot, except in certain positions, point to the true north, but at an angle to it, according to the needle's position on the earth's surface. This angle, which may have any value up to 180°, is the angle between the true and magnetic meridians, and is known as the 'Variation.'

It is called easterly if the north end of the needle is drawn to the right of the true meridian, and westerly if drawn to the left.

At those places where the true and magnetic meridians do coincide the variation is nothing.

The value of the variation has been found for practically all over the world, and if required it can be taken from the Admiralty Variation Chart or Compass Manual.

The continuous lines on the chart denote that the variation is westerly; the pecked lines, that the variation is easterly; and the two side by side show the lines of no variation.

This variation undergoes an annual change, probably due to the magnetic poles shifting.

This change is given on the variation chart and also on Admiralty charts, but for ordnance maps it must be taken from the former if no Admiralty chart is available.

The magnetic poles are not points like the geographical poles; that is to say, they are areas of considerable extent.

The following definitions will be found useful, and should be committed to memory and thoroughly understood.

Line of Total Force.—Is the direction that freely suspended magnetic needle will take up when under the influence of the earth's forces.

Magnetic Poles.—Are the two places on the earth's surface where the total force is vertical, and to which the needle points in all adjoining regions.

Magnetic Equator.—Is the line separating the red and blue magnetism of the earth, and along which the line of total force is horizontal.

It does not coincide with the geographical equator, and only intersects it in two places.

Magnetic Meridian.—Is the vertical plane passing through the longitudinal axis of a freely suspended magnetic needle when resting in a line of total force and free from local attraction.

Variation.—Is the horizontal angle between the true and magnetic meridians.

Deviation.—Is the horizontal angle between the magnetic meridian and the vertical plane passing through the longitudinal axis of a magnetised needle when under the influence of local attraction.

It is called easterly or + when the north end of the needle is drawn to the right of the magnetic meridian, westerly or — if drawn to the left of the magnetic meridian.

Compass Error.—Is the algebraical sum of the variation and deviation.

Dip.—Is the vertical angle between the direction of a freely suspended magnetic needle resting in a line of total force and the horizontal plane passing through the centre of the needle.

Poles of a Magnet.—Are the two points of maximum intensity situated about one-twelfth of the total length of the magnet from either extremity.

Magnetic Latitude.—Is measured north or south from the magnetic equator, and is somewhat similar to terrestrial latitude.

Lines of equal dip correspond to magnetic latitude.

Horizontal Force.—Is the horizontal component of the earth's magnetism.

Vertical Force.—Is the vertical component of the earth's magnetism.

N.B.—The size of the angle of dip depends on the value of these two.

The following figure shows the connection between horizontal force, vertical force, total force, and dip.

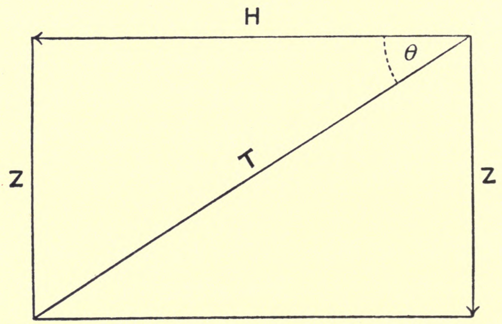


FIG. 5.

H represents the horizontal force.
Z represents the vertical force.
T represents the total force.
θ represents the angle of dip.

$$\text{Then} \qquad \frac{Z}{H} = \text{Tangent Dip.}$$

$$\text{i.e.} \ \frac{\text{Vert. Force}}{\text{Hor. Force}} = \text{Tangent Dip.}$$

$$H^2 + Z^2 = T^2$$

i.e. $(\text{Hor. Force})^2 + (\text{Vert. Force})^2 = (\text{Total Force})^2$.

$$Z = H \operatorname{Tan} \theta$$

i.e. Vert. Force = Hor. Force × Tangent Dip.

$$H = Z \operatorname{Cot} \theta$$

i.e. Hor. Force = Vert. Force × Cotangent Dip.

$$Z = T \operatorname{Sin} \theta$$

i.e. Vert. Force = Total Force × Sine Dip.

$$H = T \operatorname{Cos} \theta$$

i.e. Hor. Force = Total Force × Cosine Dip.

The Methods of Making Magnets.—There are four different ways of making magnets, as follows :

(1) By Percussion.

The bar to be magnetised is placed in the direction of the lines of force of the earth, and one end is smartly tapped with a hammer. This induces magnetism in it, the amount received depending on the number and force of the blows and the coercive force of the metal to be magnetised.

The pole of the magnet which is lowest will be of opposite polarity to the hemisphere where it was manufactured.

(2) By Single Touch.

The bar to be magnetised is placed on a flat surface, and one end of a magnet placed on one extremity of the bar and drawn smartly along the length of the latter, being lifted off

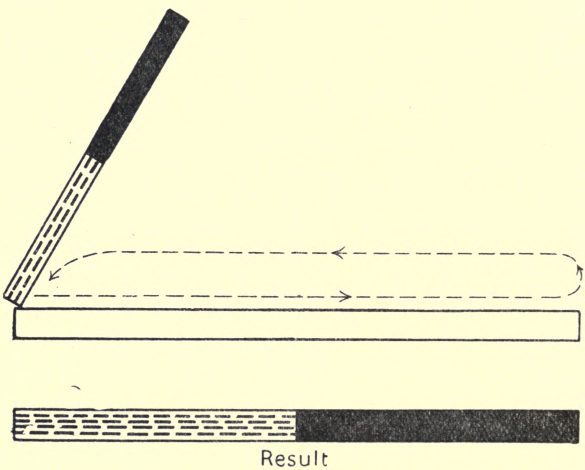


FIG. 6.

at the end of the stroke and replaced on the starting-point.

This operation may be repeated as often as necessary.

The end of the bar last touched by the magnet will be of opposite polarity to the end of the inducing magnet touching it.

(3) By Divided Touch.

The bar to be magnetised is placed on a flat surface, and the opposite ends of two magnets placed on its centre and drawn smartly outwards towards their respective ends. This operation is repeated as often as

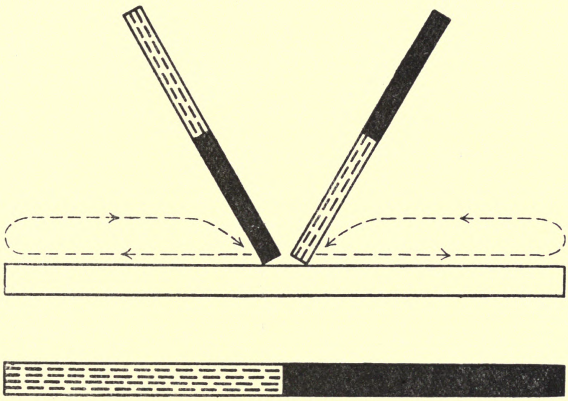


FIG. 7.

necessary. The ends of the bar last touched by the magnets will have opposite polarity to the ends of the respective magnets used.

(4) By Electro Magnet.

The bar to be magnetised is placed across the poles of an electric magnet and kept there as long as necessary. The ends of the bar will acquire opposite polarity to the poles of the electro magnet.

This method is always employed in the manufacture of magnets used in compass work, as by its means they can be made stronger and more uniform in power.

Alloy Used in Making Magnets.—Magnets

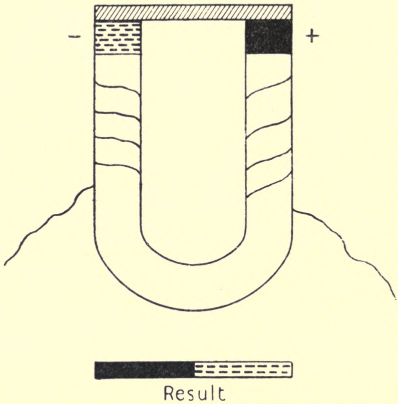


FIG. 8.

are made of hard steel with a mixture of 5 per cent. of tungsten.

This has been found to increase its coercive force. By 'coercive force' is meant the property by which iron or steel not only retains its magnetism after it has been imparted to it, but also the resistance it puts up against being magnetised.

Compass magnets, if properly stowed, i.e. (unlike poles together) and well looked after retain their magnetism without appreciable loss for years.

Effect of Temperature on Magnets.—Ordinary atmospheric changes of temperature have practically no effect on a permanent magnet, such as those used for compass adjustments.

If, however, it be placed in a very strong magnetic field of opposite power, or if heated to a dull red heat, i.e. between 1300° and 1500° Fahrenheit, it becomes de-magnetised.

On the other hand, soft iron increases its capacity for receiving magnetism on being heated, this increases up to a temperature of 1427° Fahr., but after this there is a rapid decrease, and at 1445° the iron becomes non-magnetic.

Effect of Magnetism on Hard and Soft Iron.—The iron or steel used in construction varies in its magnetic character.

This necessitates a little explanation.

Iron or steel may be classed under two headings: 'Hard' and 'Soft.'

Hard iron, on account of its coercive force, does not pick up or part with its magnetism freely.

It acquires magnetic properties during its manufacture on account of the hammering and violence it has been subjected to. After manufacture it loses some of this magnetism, but soon settles down, and the residue may be regarded as permanent.

Soft iron has little or no coercive force, and picks up and loses its magnetism freely, so that for every direction of the machine's head a different amount of magnetism is induced.

Soft iron is seldom absolutely pure, consequently it nearly always retains a certain amount of magnetism, not due to the lines of force of the earth.

The deviations caused by hard iron are called semicircular, because they only change their sign once in the whole circle.

They are corrected by horizontal magnets placed longitudinally and transversely.

Those caused by soft iron are termed 'quadrantal,' because they change their sign in each quadrant.

They are corrected by soft iron balls or spheres placed on each side of the compass.

Sub-Permanent Magnetism, its Cause and Effect.—This is caused by iron which does not come under the category of hard or soft, but lying between the two. After being on one course for some time it acquires a mag-

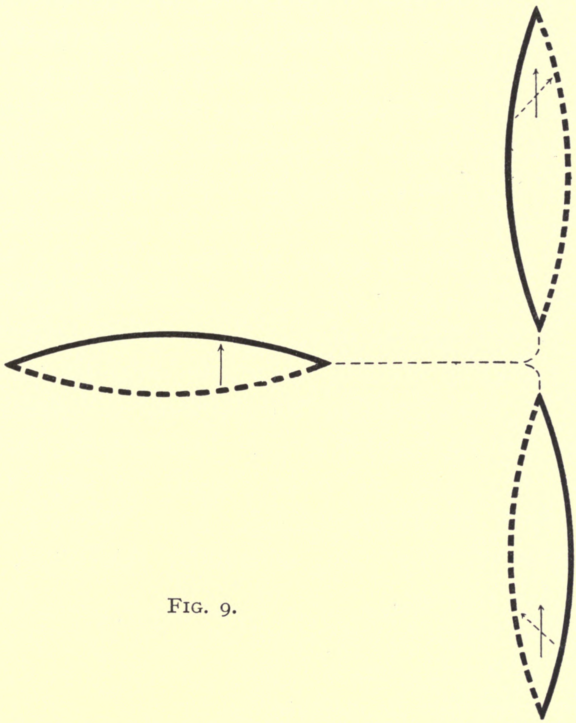


FIG. 9.

netic character due to the lines of force of the earth, and this is accentuated by vibration of engines, gunfire, etc.

On alteration of course this magnetism does not immediately disappear as in the case of soft iron, but only does so gradually, the time taken depending on the length of time on the course and the coercive force of the metal. It cannot be corrected, and its amount can only be ascertained by actual observation.

Its effect, if not allowed for, is always to place the machine's head towards the direction of the old course, as shown in sketch (p. 17).

The variation, dip, horizontal and vertical force are all given in Admiralty publications.

Reference to these will show that in the south of England the dip is approximately 67°.

It will also be noticed that as the latitude gets higher the dip increases, and therefore the vertical force in big latitudes is greater than the horizontal force. Hence it is necessary that the compass should be kept the greatest distance possible from vertical or nearly vertical iron, especially the ends, in these latitudes.

The effect of a magnet ' end on ' to a single pole of a compass is much greater than that of a magnet ' broadside on.'

The proof is here given for anyone who may be interested in it.

Proof.—AB is a magnet and N is an isolated north pole of strengths M and m respectively.

First consider the ' end-on ' position, where *d* is the distance from the centre of the magnet to the isolated pole, and L is the length of the magnet.

Then the force acting on N due to the south pole of the magnet is :

$$\frac{Mm}{\left(d - \frac{L}{2}\right)^2}$$

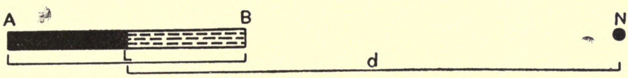


Fig. 10.

And the force acting on N due to the north pole of the magnet is :

$$\frac{Mm}{\left(d + \frac{L}{2}\right)^2}$$

As these two forces act always along the same straight line their total is :

$$\frac{Mm}{\left(d - \frac{L}{2}\right)^2} - \frac{Mm}{\left(d + \frac{L}{2}\right)^2} =$$

$$\frac{Mmd^2 + MmdL + Mm\frac{L^2}{4} - Mmd^2 + Mmdl - Mm\frac{L^2}{4}}{\left(d^2 - \frac{L^2}{4}\right)^2}$$

$$= 2\frac{MmdL}{\left(d^2 - \frac{L^2}{4}\right)^2}$$

Now in the 'broadside on' position :
Force due to south pole of magnet on N :

$$\frac{Mm}{\left(\sqrt{d^2+\frac{L^2}{4}}\right)^2}$$

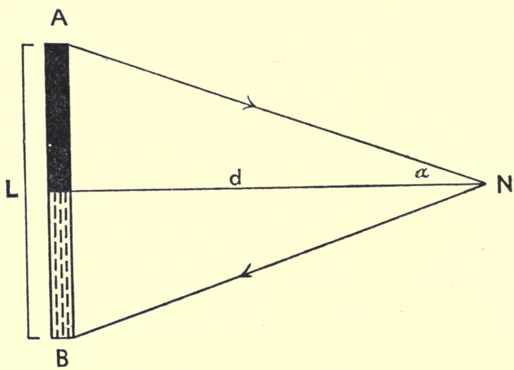


FIG. 11.

And force due to north pole of magnet on N :

$$\frac{Mm}{\left(\sqrt{d^2+\frac{L^2}{4}}\right)^2}$$

And their resultant is evidently equal to the line CN, as in sketch following, and which equals 2 Sine a.

Hence the total force acting on N due to the magnet broadside on is:

$$\frac{Mm}{d^2 - \frac{L^2}{4}} \times 2 \text{ Sine } \alpha$$

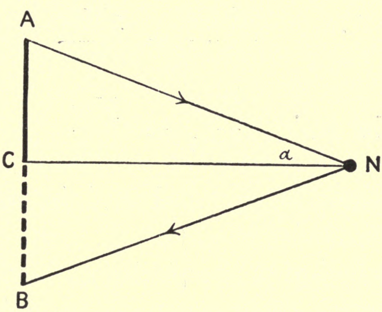


FIG. 12.

That is:

$$\frac{Mm}{d^2 + \frac{L^2}{4}} \times \frac{L}{\sqrt{d^2 - \frac{L^2}{4}}} = \frac{MmL}{\left(d^2 + \frac{L^2}{4}\right)^{\frac{3}{2}}}$$

Analysing these results we find that 'end on':

$$\text{Total force} = \frac{2\ MmL}{\left(d^2 - \frac{L^2}{4}\right)^2}$$

And for ‘ broadside on ’ :

$$\text{Total force} = \frac{\mathrm{M}m\mathrm{L}}{\left(d^2 - \frac{\mathrm{L}^2}{4}\right)^{\frac{3}{2}}}$$

If d is large compared with L we can neglect L, and the equations become :

$$\text{‘ End on ’} \quad \frac{2\mathrm{M}md}{d^4} = \frac{2\mathrm{M}m}{d^3}$$

$$\text{‘ Broadside on ’} \quad \frac{\mathrm{M}m}{(d^2)^{\frac{3}{2}}} = \frac{\mathrm{M}m}{d^3}$$

Showing that force ‘ end on ’ is twice that ‘ broadside on.’

In conclusion it should be understood that the magnetic effect exerted by any object cannot be screened off from any object liable to be influenced by magnetism, if the latter falls within the magnetic field of the former.

CHAPTER II

THE MAGNETIC COMPASS

This is an instrument constructed to give the direction of the magnetic north, and by means of a graduated card fixed to it to give any other direction with relation to it.

A freely suspended magnetic needle would of course point to the magnetic north, and if a card were attached to it it might seem at first sight that this would fulfil all requirements; but it must be remembered that this form of suspension would be affected by the varying angle of dip, and would therefore only be actually horizontal when on the magnetic equator. In any other place it would have a varying angle of tilt which would make reading awkward, whilst in high latitudes the card would come up against the glass cover of the compass bowl and prevent the card from working.

Various methods, including the lowering of the centre of gravity, have been devised to overcome this, and the compass card as now constructed will remain horizontal in any part of the world.

As the card remains horizontal, the only force we need consider as acting on the compass card is the horizontal component of the earth's magnetism.

The general system of pivoting a compass card is as follows.

The magnets and card are fixed together, and are fitted with a cap in their centre which is inverted and fitted with a ruby or other hard stone to take the wear and also to reduce friction to as little as possible. This is then placed on to a metal spike which is given an iridium point, the latter being an extremely hard metal. (Sapphire or ruby points will probably be used in future, owing to the deterioration in quality of the iridium now being mined.)

In all the later patterns of aero compasses the above arrangement is reversed, the pivot being fixed to the card.

Owing to a sticky deposit which is liable to form in the cap this would at first sight seem to be a disadvantage, but the fact that it gives greater steadiness, coupled with the greater angle of clearance between card and covering glass, negatives this disadvantage.

The card, cap and pivot are enclosed in a non-magnetic bowl and covered with a glass cover.

In the earlier pattern compasses the card used to work in air, but owing to the great vibration encountered in aeroplanes, this kind of compass was found to be totally unsuitable, so the liquid type had to be introduced instead.

Its advantages over the compass card working in air are as follows:

The card is steadier, it takes less time to settle down if disturbed, and a heavier card may be used, as the total weight resting on the pivot may be made to any amount required by varying the size of the float.

The size of the bowl is such, that a clearance of about one quarter of its diameter is allowed for between its inner edge and the edge of the card, otherwise when turning rapidly a rotary motion is set up in the liquid which is communicated to the card. This makes it liable to become unsteady or to lag behind.

The Liquid used in a Compass.—This is a mixture of two parts of distilled water to one part of pure alcohol, the object of the alcohol being to prevent freezing.

This mixture is quite efficient up to $-2°$

Fahrenheit. It has been found that a slightly higher percentage of alcohol gives better results in very low temperatures, and all the later pattern compasses are now filled with a mixture of three parts of distilled water to two parts of alcohol.

Distilled water only must be used, otherwise the impurities in ordinary water would clog up the cap and render the compass sluggish.

To Remove a Bubble from a Compass.—The fact of an air bubble having formed in a compass can always be seen. It should never be allowed to remain, as it makes steering difficult and also tends to make the compass sluggish.

The following procedure should be carried out.

The bowl should be removed from its outer containing case and laid on its side with the filling screw uppermost. Remove the screw plug and drop in distilled water with a pipette or clean fountain-pen filler.

Rock the bowl gently from side to side to make sure the bubble is underneath the filling plug.

As soon as the water overflows replace the screw plug and take care that the leather washer is in place. If on examination it is found that all the air is not yet out the operation must be repeated.

The bowl should be as cool as possible so as to enable the maximum amount of water to be introduced.

Remarks on Placing a Compass.—The placing of a compass in a good position is of great importance, as should a bad position be chosen, even the best of compasses will be unsatisfactory in their behaviour. The points to be attended to are as follows:

(1) It should be placed in a position where the pilot has a clear view of it, and if possible in the centre of the longitudinal axis of the machine. This tends to make the errors more symmetrical and therefore more easily adjusted.

The pilot should also be directly behind the compass, to avoid errors in reading due to parallax.

(2) The maximum distance possible from magneto, engine, or anything magnetic liable to occasional movement.

(3) If possible, all metal within at least 2 feet from the compass should be made of some non-magnetic material.

(4) The greatest distance possible from the *ends* of vertical iron rods, struts, etc.

Essential Features in an Aeroplane Compass.

(1) Steadiness under all conditions.

(2) Good expansion arrangements.

(3) Satisfactory system of lighting.

(4) Sufficient allowance between card and covering glass to prevent their touching each other in the event of the machine climbing, planing, or banking.

(5) Good marking of the card and reduction of eye strain to a minimum.

These requirements have been attained as follows.

(1) *Steadiness.*—After numerous experiments it was found that the most efficient way to damp the existent vibrations was to place the compass bowl in a bed of horse-hair. This effectually deadened shocks.

The horse-hair is placed in light outer containing case, and the bowl rests lightly on it.

This method was found generally to be much more preferable to the old gimballed type of suspension.

This applies to the earlier pattern compasses; for Pattern 255 and later types the reader should refer to the book 'Magnetic Compass in Aircraft,' by Captain F. Creagh Osborne, R.N.

(2) *Expansion and Contraction.*—Due provision has been made for this by fitting what is known as an 'expansion chamber' in the bowl.

(3) *Lighting.*—In the earlier types this was arranged for by a small dry cell battery and electric lamp fitted on the front side of the bowl.

In the later types this method is of secondary importance, as the card markings are treated with a radium compound enabling it to be easily read in the dark.

(4) *Allowance for Heeling.*—This is arranged for by the method of pivoting, which allows of a heel of 15° in the earlier types; and by altering the pivoting in the later types this has been increased to about 30°. These are the angles that the machine has to heel over to before the card touches the covering glass.

(5) *Making of the Card.*—This has been

done in what is known as the 'New Style,' i.e. the card is graduated from 0° to 360°, running with the hands of a watch.

North is thus represented by 0° or 360°, North-east by 45°, East by 90°, South-east by 135°, South by 180°, South-west by 225°, West by 270°, North-west by 315°.

North, South, East, and West are called the 'Cardinal Points.' North-east, South-east, South-west, and North-west are called the 'Quadrantal Points.' Small aeroplane compasses are only marked every 5° to prevent overcrowding, owing to the small size of the card. The number is given opposite every tenth degree.

Airship compasses are graduated to every degree, and large compasses for big aeroplanes every two degrees.

Prisms and Reflectors.—These are introduced to do away with eye strain as much as possible, the card being so small.

Broken Pivots.—This causes the card to work jerkily, and the compass should be taken apart and the pivot examined to see whether it is bent or damaged. If it cannot be repaired the compass should be returned to store, and a new one drawn in lieu.

Magnet Block.—These are supplied for holding the adjusting magnets. They should be placed so that their centre is directly under the centre of the compass, and care should be taken that the magnet holes, of which there are two sets at right angles to each other, should be set so that they are in line respectively with the longitudinal and transverse axes of the machine. These blocks will not be met with in Pattern 255 and later types.

Effect of Banking.—The effect after a heavy bank is to make the compass unsteady for a short time. It has been found by experiment that if on a fast machine steering anywhere within 20° of the north point, a quick alteration of course will cause the north pole of the compass to follow the machine's head round. On steadying the machine, the north pole of the compass swings back to its correct position.

For a description of the various types of compasses used in aircraft, reference should be made to the pamphlet entitled 'Compasses for Use in Aircraft,' by Captain F. Creagh Osborne, R.N.

CHAPTER III

THE ANALYSIS AND ADJUSTMENT OF DEVIATION

THE effect of the magnetic qualities in hard and soft iron is to deflect the compass needle from the magnetic meridian. This deflection, or local attraction, as it is otherwise called, is known as 'deviation.'

For purposes of analysis and adjustment, this deviation can be split up into five 'coefficients,' as they are called, viz. A, B, C, D, and E.

These coefficients, with the exception of A, may be assumed to be acting immediately over or under the centre of the compass, longitudinally, transversely, or diagonally. Coefficients A, D, and E are caused by soft iron, and B and C by hard iron.

Coefficient A.—Is due to iron being unsymmetrically distributed around the compass, or is due to the latter being out of the middle longitudinal line of the machine.

It is extremely rare in a well-placed compass.

An '*apparent*' A may be caused by an error in the magnetic bearing of an object which is being used for swinging. In practice it will be found that nearly every aeroplane compass has an 'A.'

It cannot be corrected but can only be allowed for. It is called a 'constant' deviation, because it is the same in amount and sign for all directions of the machine's head.

It is found by taking the mean of the deviations on a number of equidistant points, calling all easterly deviations + and all westerly deviations –. In practice, it is usual to take the deviations on the cardinal and quadrantal points.

Coefficient B.—Is caused by the horizontal component of the permanent magnetism of the machine acting longitudinally.

It is called + if the north end of the needle is drawn towards the nose of the machine, and – if drawn towards the tail.

It is maximum on east and west, diminishing to zero on north and south.

It is found by taking the mean of the deviations on east and west, changing the sign on west.

It is corrected by horizontal magnets, placed red end to the front for a + B, and red end to the rear if B is –. It causes a semi-circular deviation, so called because its sign changes once only.

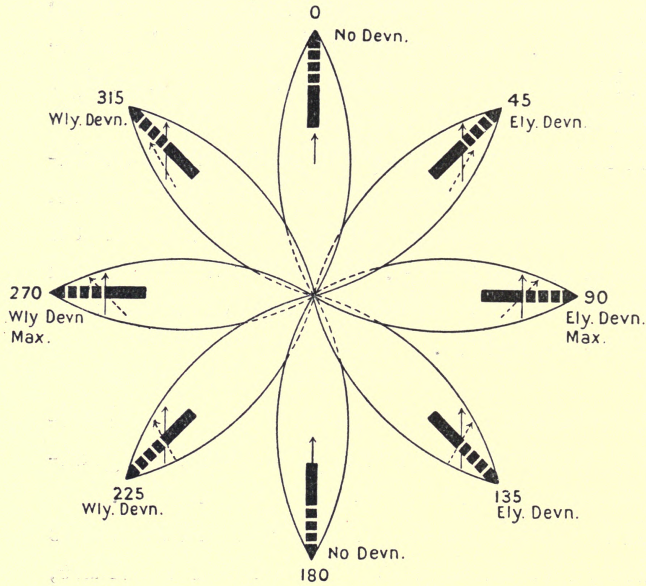
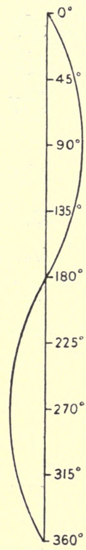


FIG. 13.—Diagram for + B.



Curve for + B.

It varies inversely as the horizontal force,

e.g. Hor. Force 1. B = 10° + say

Then with Hor. Force 2. B $= \frac{1}{2} \times 10^\circ$

$= 5^\circ +$.

Diagram for + B. (Fig. 13.)

The shaded rod denotes the permanent magnetism acting longitudinally. The pecked arrow denotes the direction in which the needle is deflected.

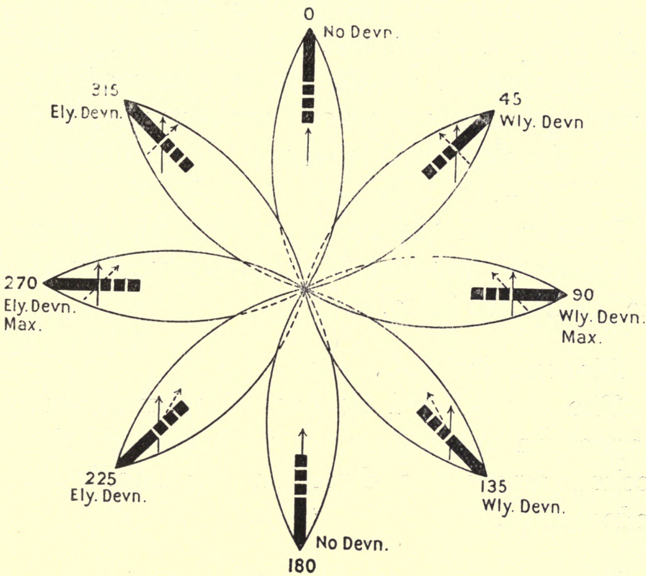
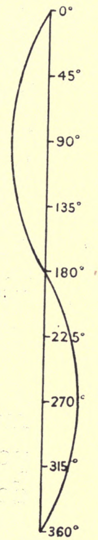


Fig. 14.—Diagram for — B.



Curve for — B.

Diagram for – B. (Fig. 14.)

The above remarks apply here as well.

Coefficient C.—Is caused by the horizontal component of the machine's permanent magnetism acting transversely.

It is called + if the north end of the needle is drawn to the right-hand side of the machine and – if drawn to the left-hand side.

It is maximum on north and south, diminishing to zero on east and west.

It is found by taking the mean of the deviations on north and south, changing the sign on that of south. It is corrected by horizontal magnets placed transversely, red end to the right if C is + and red end to the left if C is –.

It is called 'semicircular' for the same reason as B, and like B changes inversely as the horizontal force.

Diagram for + C. (Fig. 15.)

The shaded rod denotes the permanent magnetism acting tıansversely, and the pecked arrow the direction the needle is deflected to.

Diagram for – C. (Fig. 16.)

See remarks above.

Coefficient D.—Is the effect of induction in horizontal soft iron acting longitudinally or transversely.

If the effect of the transverse iron is greater than that of the longitudinal it causes a + D, and if the effect of the longitudinal is greater it causes a – D.

D is maximum on the quadrantal points (i.e. 45°, 135°, 225°, 315°), diminishing to zero on the cardinal points.

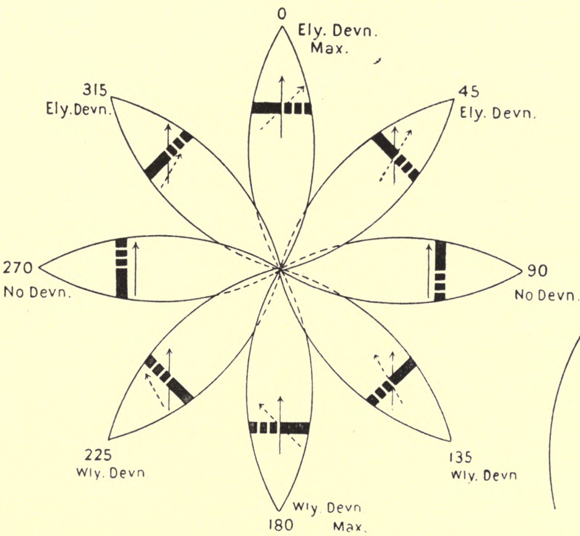
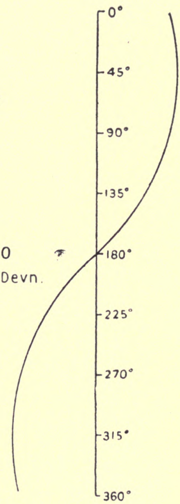


FIG. 15.—Diagram for + C.



Curve for + C.

It is found by taking the mean of the deviations on the semicardinal points, changing the signs on south-east and north-west. That is on 135° and 315°.

It is corrected by soft iron spheres placed transversely if D is + and longitudinally if D is –.

The size of the spheres and the distance of

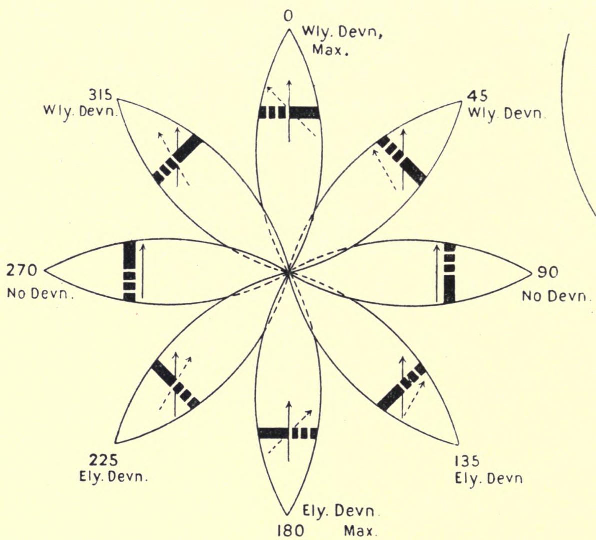
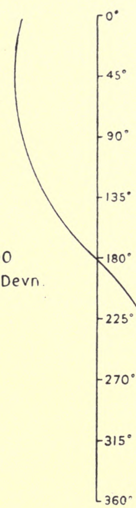


FIG. 16.—Diagram for — C.



Curve for — C.

their centre from the centre of the compass is given in tables to be found in the 'Admiralty Compass Manual.'

D is called 'quadrantal' because it changes its sign in each quadrant. It does not change on change of position because the force acting on the iron is the same as that acting on the compass needle, and the two are therefore always in proportion, as shown below.

FIG. 17.

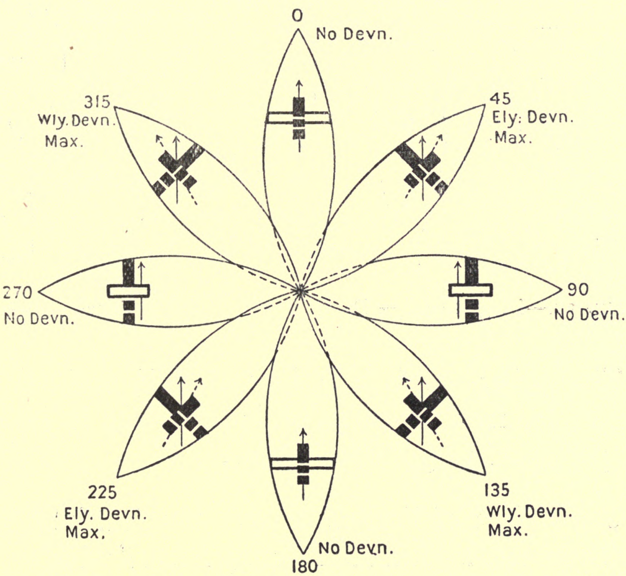


FIG. 18.—Diagram for + D.

Curve for + D.

Diagram for + D. (Fig. 18.)

The white rods denote that the iron is non-magnetic.

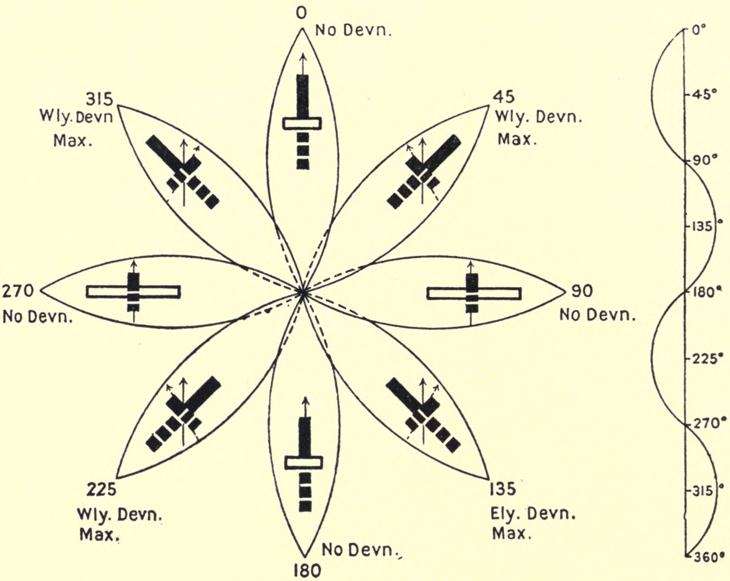


FIG. 19.—Diagram for — D. Curve for — D.

The other coefficient is called E and is caused by iron running obliquely, but it is not proposed to go into it here.

The Effect of Vertical Iron.—Vertical iron causes what is known as 'Heeling Error,' which comes into action on the machine banking.

This is maximum on north and south, and zero on east and west.

Analysis of a Table of Deviations.—By this is meant the splitting up of a table of deviations into the various coefficients, which is done by following the rules given in the explanation of the various coefficients.

A worked example is here given.

Analyse the following table of deviations:

Machine's Head.	Deviation.	Machine's Head.	Deviation.
0°	3.W —	180°	5.E. +
45°	4.E. +	225°	3.W. —
90°	7.E. +	270°	8.W.
135°	10.E. +	315°	6.W.

Coefficient A.

+	
4	3
7	3
10	8
5	6
—	—
26	20

$$\begin{array}{r|l} & +\ 26 \\ & -\ 20 \\ \hline 8 & +\ 6 \\ \hline & +\ 0^\circ\ 45' \end{array}$$

Coefficient B.

$+7$
$+8$ Original sign
$2 \mid +15$ changed.
$+7^\circ\ 30'$.

Coefficient C.

-3
-5 Original sign
$2 \mid -8$ changed.
$-4^\circ\ 00'$

Coefficient D.

+	−	
4	10 Sign changed.	-13
6 Sign changed.	3	$+10$
10	13	$4 \mid -3$
		$-0^\circ\ 45'$

Coefficient E.

+	−	
5	3	$4 \mid +3$
8	7	$+0^\circ\ 45'$
13	10	

Correctors would then be placed as follows:

B would be corrected by magnets placed longitudinally, red end in front.

C would be corrected by transverse magnets, red end to left.

D would be corrected by spheres placed longitudinally, the size, etc., being taken from the tables.

But in this case, D being so small, it would be best to ignore it altogether.

CHAPTER IV

THE PRACTICAL CORRECTION OF A COMPASS; METHODS OF SWINGING, ETC.

Before going into the practical correction of a compass, it is proposed to give a description of the various methods of swinging.

This swinging should always be carefully carried out, as a well-placed compass whose behaviour is good, and whose errors are known and can be trusted, is a great relief to a pilot making a flight, when objects below are hidden by cloud, fog, etc.

There are five methods of swinging, as follows:

(*a*) By Sun or Star.

(*b*) By ' Reciprocal Bearings.'

(*c*) By Distant Object.

(*d*) By two objects in line or ' in transit,' as it is usually called.

(*e*) By using a marked-out flying ground.

In connection with this, the last-mentioned one is the only one possible for the later pattern compasses, owing to their construction.

(*a*) **By Sun or Star.**—The requirements for these are a watch whose error on Greenwich mean time is known, a shade for use if the sun is observed, notebook and tables for giving the true bearing of the body at various intervals of time.

The body observed should be fairly low in altitude.

Place the machine's head in the required direction by compass, and observe bearing of the body, noting the time of doing so by the watch. Transfer this watch time into apparent time at place (this will be explained in the chapter on Astronomy), and look up the body's declination.

With these data, and knowing your latitude, the true bearing can be looked out from the tables.

Apply the variation to this to get the magnetic bearing. The difference between the true and magnetic bearings will be the deviation for that particular direction in which the machine is heading.

This operation should be repeated for all required directions. In practice it is customary to work out a table of times and magnetic bearings in advance, as it much facilitates operations.

This method is always used at sea when out of sight of land, but is not of much practical value on a flying ground.

(*b*) **By 'Reciprocal Bearings.'**—For this purpose a compass known as the 'Landing Compass,' or 'Shore Compass,' is set up in some place on the flying ground where it will be free from all local attraction in the shape of sheds, adjacent machines, etc.

This ensures it being free from deviation.

The machine to be swung is wheeled out and also placed in a position similar to the other compass, and heading in any required direction.

Simultaneous bearings are taken of the shore compass by the machine's compass, and of the machine's compass by the shore compass.

Either of these bearings should now be reversed and the difference between this reversed bearing and the other one will be the deviation for that particular direction of the machine's head.

This operation can be repeated on any other direction of the machine's head.

Examples:

(1)	Bearing of shore compass . .	227°
	Bearing of machine's compass .	40°
	Reversed bearing by shore compass	47°
	Bearing by machine's compass .	40°
	Deviation	7° E.
(2)	Bearing by shore compass . .	62°
	Bearing by machine's compass .	247°
	Reversed bearing by shore compass	242°
	Bearing by machine's compass .	247°
	Deviation .	5° W.

The shore compass should be set up some little distance from the machine, not less than fifteen or twenty yards.

(*c*) **By Distant Object.**—This is a very easy method, as it entails the use of no instruments, and only one observer is needed.

The magnetic bearing of some distant object having been found beforehand, from a particular spot, the machine is wheeled out and placed so that the compass is over this spot, and heading in the required direction. All that has to be done now is to take the bearing of the distant object by the compass, and repeat it on any other direction.

The difference between the compass bearing of the distant object and the magnetic bearing already found, will be the deviation for that particular direction of the machine's head.

Examples :

Machine's Head.	Magnetic Bearing.	Compass Bearing.	Deviation.
0°	309°	314°	5° W.
45°	309°	311°	2° W.
90°	309°	306°	3° E.

(*d*) **By Two Objects in Line.**—This is the same as Case (*c*). But in place of one object there are two in line, the magnetic bearing of one, and therefore of both, being known.

This case is valuable for checking deviation, as the magnetic bearing can be obtained from the chart ; and when flying, as soon as the objects come into line, the bearing can be taken. This will show at once whether or not the deviation has altered.

(*e*) **By a Marked-out Flying Ground.**—This is the simplest method of all, requiring no instruments and no objects, and a machine's compass can be adjusted at any hour of the day or night, and also in thick weather when all distant objects and marks are obscured.

The spot having been chosen, permanent lines are marked out running north, south, east, and west. The north-east, south-east, south-west, and north-west lines may also be drawn in if required. Permanent marks should be placed at the ends of these lines and also at the central spot.

All that has to be done is to place the machine's head along the desired line and note the compass reading.

The difference between this and the lubber point of the compass will be the deviation.

An explanation of the methods of marking out a flying ground will now be given.

In the working of the following example, the explanation of the various terms used will be found in the chapter on Astronomy.

The marking out of a flying ground can be done in two ways.

(*a*) By means of the shore compass, set up in any convenient spot free from local attraction.

The lines can be got straight away by direct observation, and marked in.

(*b*) An alternative method, which involves a little more trouble, but once done holds good as long as the first case. It consists of finding the magnetic bearing of one or more conspicuous objects visible from the swinging ground, and from this bearing to get the magnetic directions required. The magnetic bearing of one of the objects is obtained by simply taking a horizontal angle between the sun's limb and the object required. The sun's bearing can now be worked out and this angle applied to it.

The result will be the true bearing of the object, so, to get the magnetic bearing, the variation must be applied. It is just as well to have the bearings of two or three objects in case one is done away with, so if angles between the first object and one or two others be taken, they can be applied to the bearing of the first.

An example of this follows.

On April 14, 1916, at a certain flying ground in Latitude 51° North, Longitude 3° West, it was desired to lay out magnetic lines for compass adjustment.

The following observations were made.

Rough time about 5.45 A.M.

The watch, which was slow on Greenwich mean time 0 hrs. 2 min. 15 sec., showed 5 hrs. 55 min. 33 sec. At the same time the observed horizontal angle between an object A to the right of the sun and the sun's near limb, was 97° 50′.

The following angles were also observed.

	Right of A.		Left of A.
Object B	64° 40′	Object C	37° 50′

Variation 16° W. Required the magnetic bearings of A, B, and C.

N.B.—In this example the working is not rigorously exact, but is near enough for practical purposes.

	h. m. s.
Time by watch .	5 55 33
Slow on G.M.T. .	2 15
G.M.T.	5 57 48
Long. in time .	12 00
Mean time at place .	5 45 48
Equation of time from Nautical Almanac . .	+ 20
Apparent time at place . .	5 46 08

True bearing sun's limb from table	81° 17′
Sun's semidiameter from Nautical Almanac .	+ 16′
True bearing sun's centre . .	81° 33′
Angle to A right of sun . .	97° 50′
True bearing of A	179° 23′
Variation . .	16° 00′ W.
Magnetic bearing of A . .	195° 23′

Right of A.

Magnetic bearing of A . . .	195° 23′
Angle to B . .	64° 40′
Magnetic bearing of B . . .	260° 03′

Left of A.

Magnetic bearing of A . . .	195° 23′
Angle to C .	37° 50′
Magnetic bearing of C . . .	157° 33

To get the sun's true bearing from the tables, we require to know three things: the latitude, the sun's declination, and the sun's hour angle.

The latitude we know already, the hour angle will be the apparent time, since we keep our time from the sun, and the declination can be taken out of the Nautical Almanac for that day at sight. The declination is given for noon each day, but as its total change for twenty-four hours is comparatively small, this can be neglected, as it is near enough for compass work.

The bearing given in the tables is that of the sun's centre, so to get the bearing of the sun's limb, the semidiameter must be applied. Whether to add or subtract it can easily be ascertained from a figure; the one on p. 52 is the one for the example given.

NOA is the angle given in the tables, and NOB is the angle required. As A is to the right of the sun, the angle AOB is additive to the angle NOA.

It should be remembered that the observer is at O facing the sun.

Therefore, in this case, the semidiameter must be added to the bearing from the tables.

The semidiameter, in the case of compass work, may be taken as a constant of 16′.

Having found the magnetic bearing of A

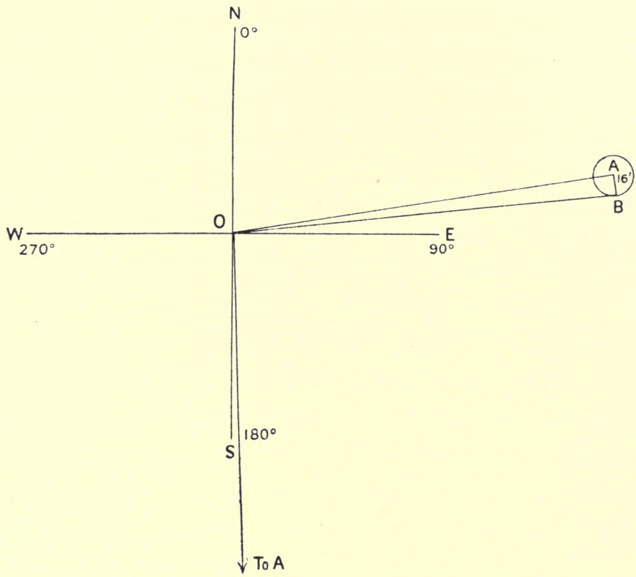


FIG. 20.

to be 195° 23′, it follows that the magnetic north must lie either 195° 23′ to the left of A, or 360° 00′ – 195° 23′, i.e. 164° 37′ to the right of A as shown in the following sketch.

To lay out the ground, the following procedure should be adopted.

Set the vernier of the verge plate to zero, and having placed the landing compass over the central position on the swinging ground, turn the whole bowl of the compass round until the object A is seen in the prism slit in line with the sight wire.

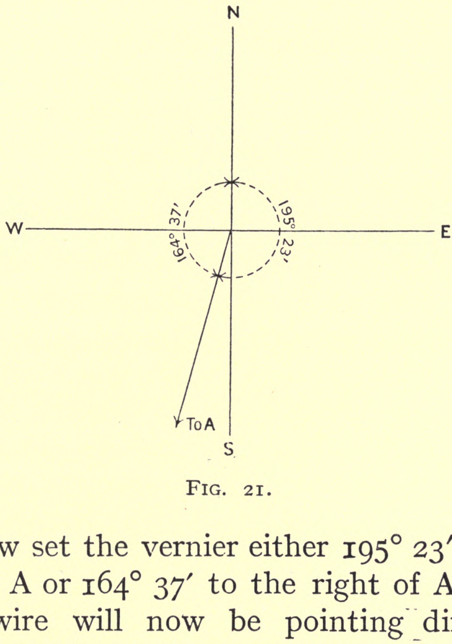


FIG. 21.

Now set the vernier either 195° 23′ to the left of A or 164° 37′ to the right of A. The sight wire will now be pointing direct to the magnetic north.

Get someone to walk slowly across your line of sight with a peg, and stop him when he comes in line with the sight wire. Drive this peg into the ground, this will represent the north point from the position of the compass. Taking this north point as the starting point, the remaining points of the compass can now be pegged out in turn and the lines painted in if required, the pegs being left standing or replaced by small base plates flush with the ground.

The advantage of having two or more marks whose bearing is known, lies in the fact that some of them may be destroyed in course of time, in which case bearings to new marks would have to be found.

If it is desired to lay out more than one swinging ground, the bearing may be found from one position and calculated for the others from the chart or map on the largest scale possible.

When taking the horizontal angle between the sun and an object, always have the sun as low in altitude as possible.

The Practical Correction of a Compass.—By this is meant the actual placing of the adjusting magnets to neutralise the effect of the iron surrounding the compass.

If the machine is a new one, it should be swung for its natural deviations on the eight principal points of the compass by one of the methods already described.

By 'natural' deviations is meant the deviations of the compass before any of the correctors are applied.

These deviations having been ascertained, the coefficients can be worked out and the various correctors placed in position roughly.

Coefficient D should always be corrected first, if intended to correct it, its amount and requisite size of spheres being obtained from the published tables.

This can be done with the machine heading in any direction, and when once done, holds good for any place the machine may be in.

Now place the nose of the machine north or south, or east or west; and correct the coefficients C and B by adjusting the transverse and longitudinal magnets respectively as necessary.

This is done, in the case of taking a distant object, by so adjusting the magnets as to make the compass bearing of the object agree as nearly as possible with the magnetic bearing previously found.

If, however, the machine is being swung on a marked-out flying ground, it is only necessary to place the machine heading along the lines on the ground, and make the compass point accurately by altering the position of the magnets as requisite.

Having done this, all that remains to be done is to again swing the machine and tabulate the remaining deviations, which will be the deviations to be used when flying.

If the compass has been swung before, it will only be necessary to readjust the magnets, if required, by placing the nose of the machine in the requisite directions and making the compass bearing agree as nearly as possible with the magnetic bearing.

The machine should then be swung as before, to get the remaining deviations.

CHAPTER V

CORRECTING COURSES. NAMING DEVIATION RULES FOR GETTING THE CORRECT ANGLE FROM THE BEARING TABLES. FINAL NOTES

On the Correction of Courses.—A knowledge of how to apply the variation and deviation to different courses in a correct manner is of great importance, as by doing so wrongly in the case of the variation only, the pilot may find himself flying on a course about 30° from his right direction if the variation is 15°.

If, however, the following rules be learnt and attended to, he need never get into that position.

Rules.—The following rules apply to variation and deviation alike.

(*a*) Given compass course or magnetic course to find true course.

Add easterly. Subtract westerly.

Examples:

Compass course 228°. Variation 17° E. Deviation 4° W. Find true course.

Compass Course . . .	228°
Variation	+17°
	245°
Deviation	−4°
True Course . . .	241°

Magnetic course 163°. Variation 14° W. Find true course.

Magnetic Course . . .	163°
Variation	−14°
True Course. . . .	149°

(*b*) Given true course to find magnetic or compass course.

Add westerly. Subtract easterly.

True course 117°. Variation 14° W. Deviation 6° E. Find magnetic and compass courses.

True Course. . . .	117°
Variation	+14° W.
Magnetic Course . . .	131°

True Course	117°
Variation	+14°
	131°
Deviation	−6°
Compass Course . . .	125°

Should the result, after correction, be found to exceed 360°, the latter amount must be subtracted from the total.

Example :

Compass course 355°. Variation 15° E Deviation 5° E. Find true course.

Compass Course . . .	355°
Variation	+15°
	370°
Deviation	+5°
True Course . . .	375°
	−360°
True Course . . .	15°

Notes on How to Name Deviation.—Naming deviation is, to a novice, at first a little difficult, but if Figs. 22 and 23 be studied, it

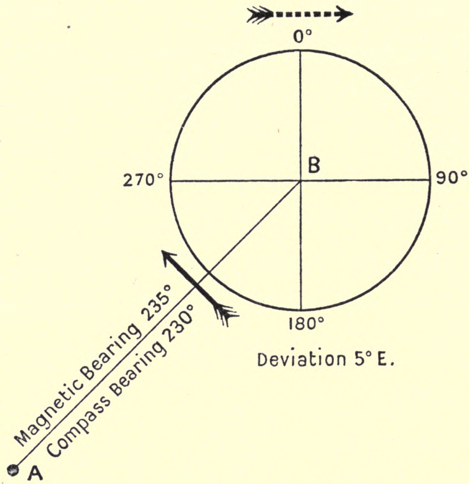


FIG. 22.—Showing easterly deviation.

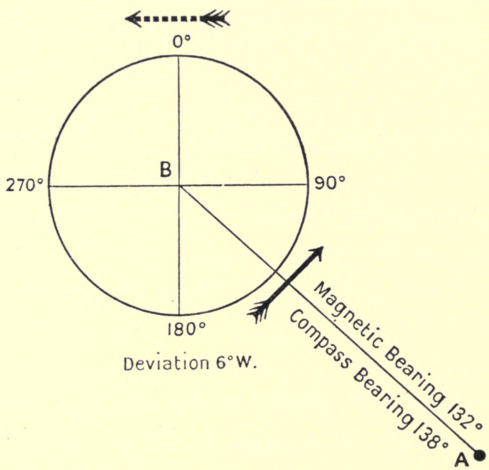


FIG. 23.—Showing westerly deviation.

will at once become apparent, and after a little practice it can be done without any writing down.

In either figure the circle is supposed to represent the compass card, and AB the line joining the distant object to the centre of the card.

This line AB should be considered as absolutely fixed, and in Fig. 22 suppose it to run in the direction of, say, 235° magnetic.

The compass card is free to revolve about its centre, at B, and in this case the degree 230° is found by observation to be lying under the line AB.

Therefore the 235th degree must have moved in the direction shown by the black arrow.

Now, if one part of the card moves, the whole must move in the same direction ; hence, if we follow the card round to the north point, the latter must clearly move in the direction shown by the pecked arrow.

As the direction of the pecked arrow is eastward, the deviation must be easterly.

In Fig. 23, suppose the line AB to run, say, 132°. From observation we find the degree 138° to be under this line. The card's motion must have been in the direction of the black arrow, and following its motion round, we see the north point of the card must move in the direction of the pecked arrow. Hence the deviation must be westerly. Therefore, for any card graduated according to the new style, i.e. from 0° to 360°, the rule is as follows:

If the compass bearing is less than the magnetic bearing, the deviation is easterly; if greater than the magnetic bearing, the deviation is westerly.

Notes on the True Bearings taken from the Tables.—With reference to the bearings taken from the tables, it must be remembered that these tables were made out for the old pattern graduation of the card, and therefore require some manipulation before the bearing by the new style of card can be written down.

The following rules should be well learnt:

(*a*) In north latitude.

If the time is A.M., the bearing may be taken straight out of the tables and written down.

If the time is P.M., the bearing given in the tables must be subtracted from 360° and the result written down as the bearing to be used.

(*b*) In south latitude.

If the time is A.M., subtract the bearing given in the tables from 180°, and use the result.

If the time is P.M., add 180° to the bearing given in the tables, and use the result.

N.B.—The bearings in the tables are always given from the pole of the observer's hemisphere.

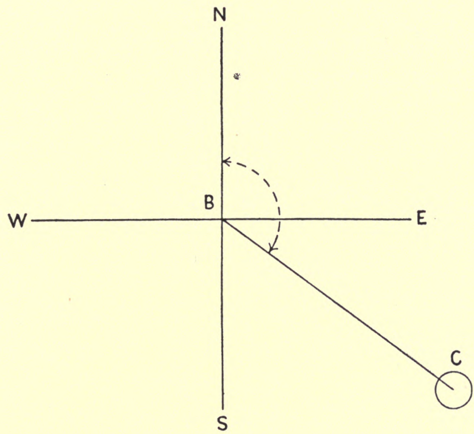


FIG. 24.

These rules will now be illustrated graphically by figures.

Fig. 24. NORTH LATITUDE. A.M. Time.

NBC is the angle given in the tables and is the one required.

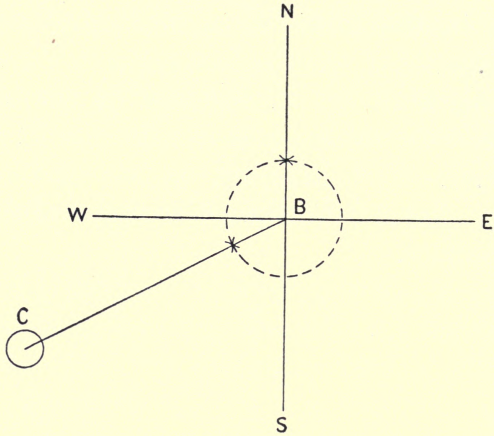


FIG. 25.

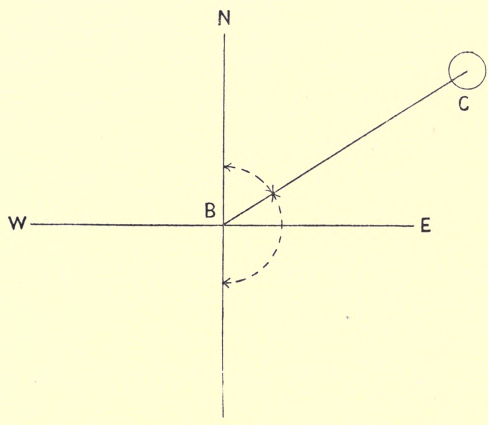


FIG. 26.

Fig. 25. North Latitude. p.m. Time.

NBC is the angle given in the tables, but the angle NESC is the one required, i.e. 360° - NBC.

Fig. 26. South Latitude. a.m. Time.

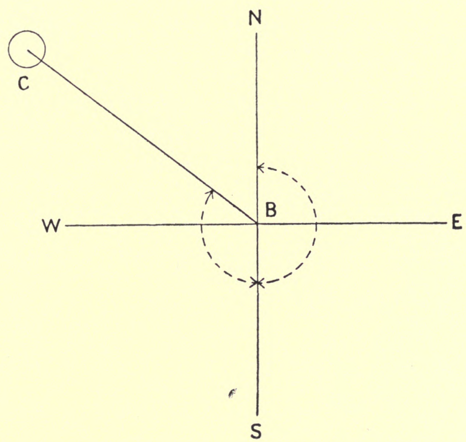


Fig. 27.

SBC is the angle given in the tables, and NBC the angle required, so 180° - SBC = NBC.

Fig. 27. South Latitude. p.m. Time.

SBC is the angle given in the tables, and

NESC the angle required, so that 180° + SBC = NESC.

To Test a Compass.—This should be done now and again to see if the cap and pivot are in good working order, as they are liable to damage from shocks in landing, etc.

This can be done in two different ways.

(1) By comparing it with another compass which is known to be accurate.

The two compasses should be placed as near to one another as possible without interfering with each other's field. Bearings of a distant object as far away as possible should be taken by both compasses on various directions of the aeroplane's head.

The bearings taken by the machine's compass corrected for the known deviation should be practically the same as the bearing shown by the other compass.

Should they differ by any moderate amount, the cap and pivot should be examined.

(2) By deflecting the card about a point from its normal position of rest, and noting if it returns to its old position. If not, it is probable that something is wrong.

CHAPTER VI

METEOROLOGY

In this chapter a few notes will be given of the relation of wind and weather, and from a study of these it is hoped that the pilot may be able to deduce, from his own observations, the type of weather he is likely to encounter.

He must remember, however, that even the best observatories, equipped as they are with every improved type of instrument and with all their telegraphic facilities, are sometimes very much out in their forecasts, so that he need not wonder at the very frequent apparent failures of his attempts.

Wind, which is simply the atmosphere in motion, is of two kinds, called cyclonic and anti-cyclonic.

The following remarks on cyclones and anti-cyclones are written for the Northern Hemisphere, and to apply them to the Southern Hemisphere, all directions of the wind round its centre should be reversed.

A cyclonic wind is one that either brings rain or is associated with bad weather.

It blows spirally round a centre or core of low pressure in a direction contrary to the hands of a watch in the Northern Hemisphere. The sequence of wind and weather in a cyclone are everywhere the same, and they differ in *intensity* only according to the steepness and closeness together of the isobars.

The following definitions should be learnt :

Path of a Storm.—Is the direction that the whole storm is travelling in.

Trough of a Storm.—Is the line more or less at right angles to the path where the barometer has reached its lowest and has just turned to the rise.

Right and Left Hand Semicircles.—Are the two halves of the storm situated on the right and left hand respectively of the observer, when he is standing in the centre of the storm facing the direction it is travelling in.

Centre of a Storm.—Is the area of lowest pressure. Here the wind often drops to a flat calm.

Isobar.—Is a line of equal barometric height or pressure.

Isotherm.—Is a line of equal temperature.

The wind in a cyclonic disturbance does not blow tangentially to the isobars, but spirally inwards at an angle of about 10°–15° to them, being more incurved in the rear part of the storm.

In the Temperate Zones these depressions almost invariably travel eastwards, but their paths may be deflected by land or by an area of high pressure.

The centre of a storm can always be found by the following rule, known as Buys-Ballot's Law.

Rule.—Face the wind, and the centre will be found to bear about 135° on the right hand until the barometer has fallen three-tenths of an inch, about 112° between three-tenths and six-tenths, and about 90° after six-tenths.

N.B.—In the Southern Hemisphere it will be as above, but on the observer's left hand.

The sketch on p. 70 shows the relation of the wind to the isobars, in a cyclonic depression, the egg-shaped lines representing lines of equal pressure.

It must be clearly understood that this sketch is purely arbitrary, and that a cyclonic depression may take any shape or form of isobar.

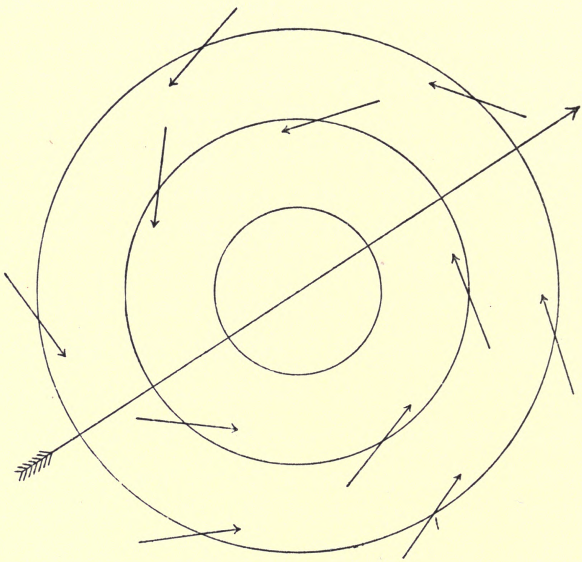


FIG. 28.

With reference to the statement made before, that the weather sequence in a cyclonic depression was always the same but differing in intensity only, it must be understood that by intensity is meant that whereas in one case with a slight and gradual fall, which means that the isobars are spaced wide apart, only a mild type of wind, rain, and cloud are experienced, yet, on the other hand, when the isobars are close together, the above mentioned are met with in a much greater and stronger form.

As a general rule, the steeper the fall of the barometer the stronger the wind and coming weather.

Sometimes it will be noticed that a big fall of the barometer is not attended by any drastic change in the weather, but that, after a time, the former recovers itself. This is due to what is known as 'Surge.'

The best explanation of this is to consider a general lowering of pressure over a large area, which takes some time to fill up again, the area being so large that it only fills up comparatively slowly.

The sketch on p. 72 shows the weather sequence in a cyclonic depression.

The rate at which a storm, as a whole, travels is very uncertain, depending on the areas of high pressure round it and the amount of land about.

Anti-cyclone.—This is a region of high pressure associated with fine and mild weather, in which the wind blows more or less tangentially to the isobars with the hands of a watch in the Northern Hemisphere.

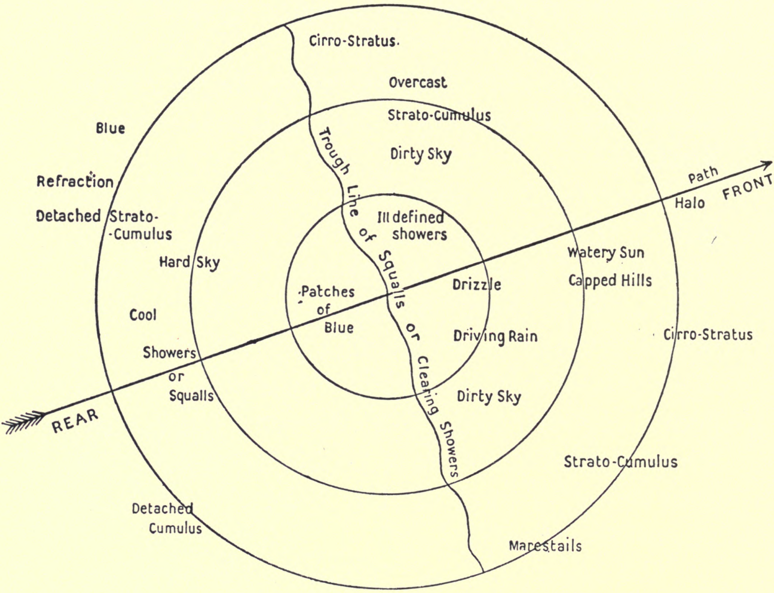


FIG. 29.

Its force scarcely ever rises above a pleasant breeze. Unlike a cyclonic depression, an anti-cyclone may remain stationary for days on end.

One great feature of an anti-cyclone is the radiation weather in it.

The sketch below gives the sequence of weather usually experienced in an anti-cyclone.

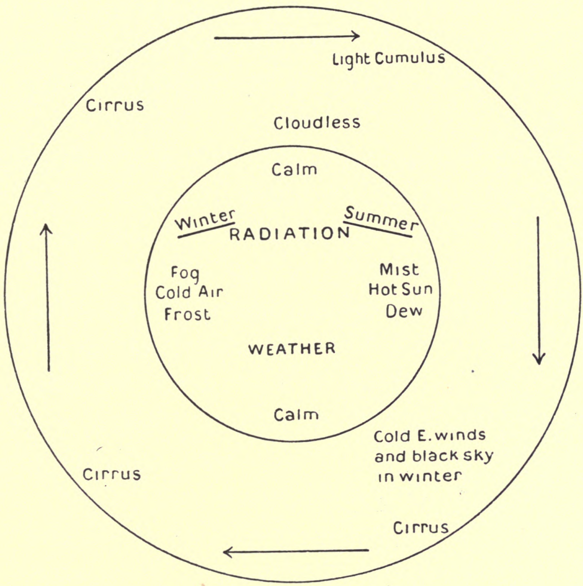


FIG. 30.

Formation of Cloud, Fog, and Dew.—If the barometric pressure at any place falls, a current of air rises, carrying with it a large amount of water vapour, more especially if the low pressure should happen to be situated over the sea.

As this air rises, it expands owing to the diminished pressure ; this causes a loss of heat, which is further accentuated by the low temperature in the upper regions. This loss of heat results in the condensation of the water vapour, which also mixes with the small particles of dust and other matter floating in the air.

The result of this is to cause the familiar appearance which we know as cloud.

There are two theories that have been put forward as to the formation of cloud.

(1) Is known as condensation by cooling. This method has been described above.

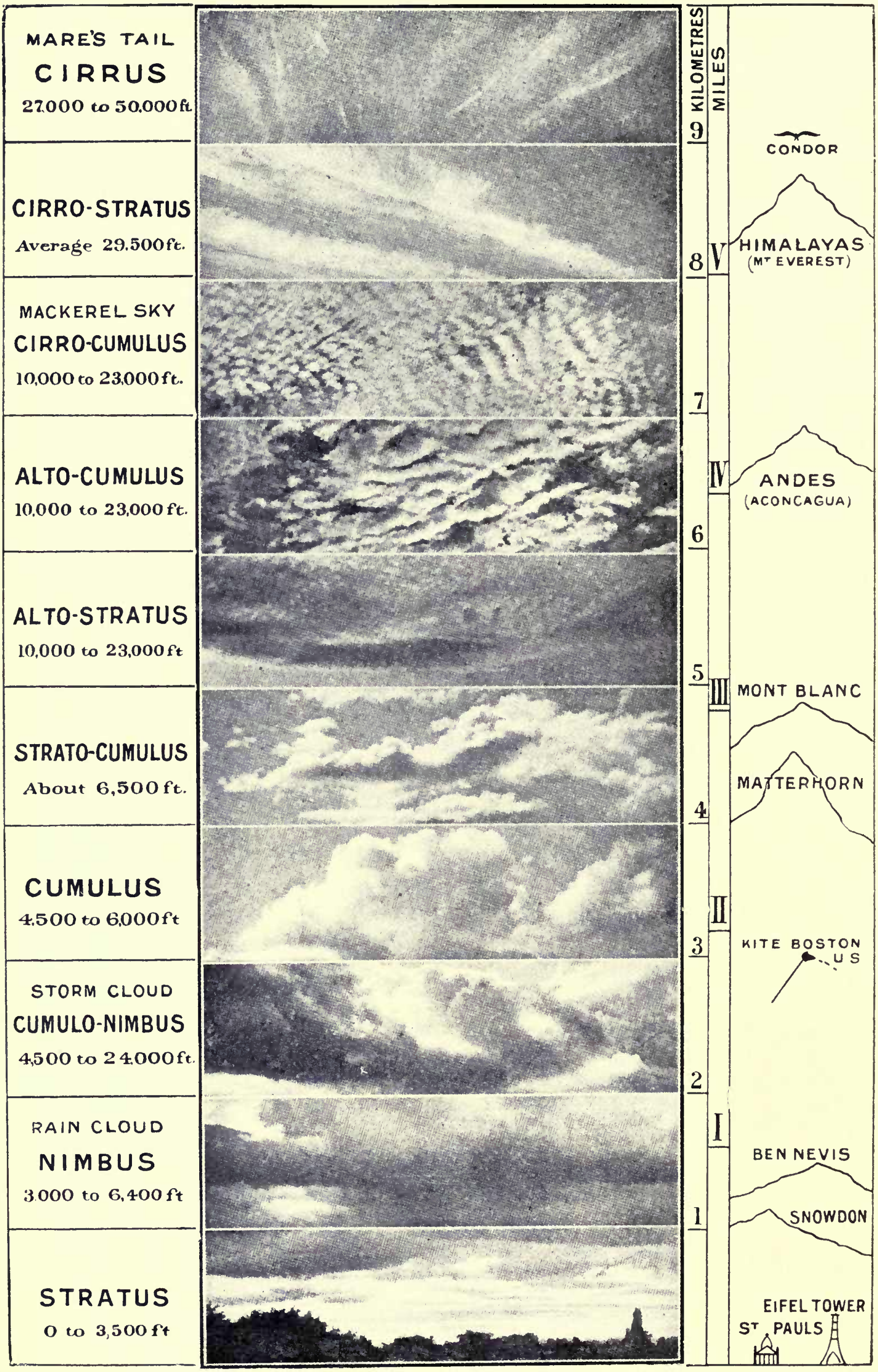
(2) Is known as condensation by mixing. This is supposed to take place when a mass of damp air, on rising, meets another mass of damp air at a different temperature.

There are ten different classes of clouds, four of which are known as 'Fundamental Clouds,' whilst the other six are made up of mixtures of the other four.

The following tables give the names and average heights of these clouds.

(*a*) 'Fundamental Clouds.'

(1) Stratus	0 to 3,500 feet.
(2) Nimbus, or Rain Cloud .	3,000 ,, 6,400 ,,



THE TEN DIFFERENT KINDS OF CLOUDS.

(3)	Cumulus . . .	4,500 to 6,000 feet.
(4)	Cirrus, or Mare's Tail .	27,000 ,, 50,000 ,,

(*b*) 'Composite Clouds.'

(1)	Cumulo Nimbus, or Storm Cloud . . .	4,500 to 24,000 feet.
(2)	Strato Cumulus .	Average 6,500 ,,
(3)	Alto Stratus . .	10,000 to 23,000 ,,
(4)	Alto Cumulus . .	10,000 ,, 23,000 ,,
(5)	Cirro Cumulus, or Mackerel Sky . .	10,000 ,, 23,000 ,,
(6)	Cirro Stratus . .	Average 29,500 ,,

The accompanying illustration has been published through the courtesy of Mr. Elliott Stock, 7 Paternoster Row, E.C., whose permission has been obtained.

Cause of Fog.—This may be caused in two different ways.

(1) Warm air saturated with moisture passing over a cold surface of water, the vapour in the air is chill and condensed, forming a white cloud called fog.

(2) Cold air blowing over warm water chills the water vapour rising from the latter, with the same result as in the first case.

A fog bank may be driven a good distance from the place where it started, provided that the air temperatures are nearly the same;

but such fogs do not last long, and soon disappear.

It sometimes happens that during a fog very large and heavy raindrops come down. this is a sure sign that the fog will disappear very shortly.

General Forecasting of Weather.—The general forecasting of the weather of the British Islands is done by two methods:

(1) By a Synoptic Analysis.

(2) By Lord Dunboyne's method.

Taking the two in the sequence mentioned above.

(1) **By Synoptic Analysis.**—At 7 A.M. every morning certain information is telegraphed to the headquarters of the Meteorological Office from all stations connected with it, and also wireless reports are received from ships.

The information thus received is collated and placed on the weather chart for the day, ready for issue. The information telegraphed to the central office is as follows:

Force and direction of wind.

Height of barometer, and whether rising or falling.

Temperature of air and sea, the latter only at those stations bordering the coast.

State of weather prevailing at the time at each station.

State of sea.

These observations are placed on the chart as necessary ready for issue to the general public, though this has been modified during the war by issue only to official bodies.

The symbols in use on the synoptic chart are given below.

Isobars.—Are denoted by continuous lines.

Isotherms.—Are denoted by pecked lines.

Wind force is denoted as shown below; the direction of the wind goes *with* the arrows, and is named according to where it comes *from*.

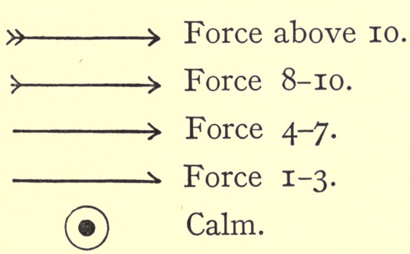


FIG. 31.

The general state of the weather is shown below.

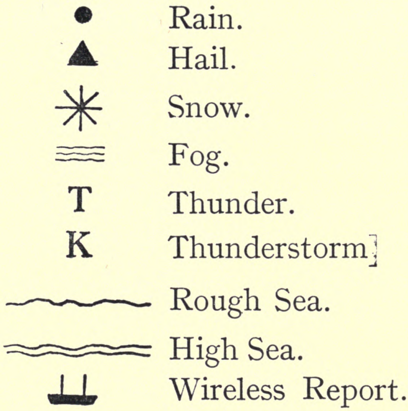


FIG. 32.

(2) **Dunboyne's Weather Report.**—This report is issued by the Admiralty daily at 10.30 A.M. It is liable to revision as time goes on, and actual observation shows the need for it.

The weather report is for the British Islands in general and London in particular.

It divides the British Islands into three parts as follows:

(1) North of the latitude of the Wash.

(2) The English Channel and north coast of France.

(3) The southern halves of England

and Ireland south of the latitude mentioned in (1).

On the daily sheet is printed an explana- of the terms used, as follows :

The day referred to is a twenty-four hour day.

Fine.—The wind moderate in force or less, no appreciable rainfall, probably some hours of sunshine.

Fair.—The wind fresh in force or less, little or no rain, probably cloudy.

Changeable.—Sometimes fair or fine, sometimes unsettled.

Unsettled.—A high wind alone or heavy rain alone, or both wind and rain combined in moderation.

Disturbed.—High wind or gale with rain more or less. On some occasions the term 'Very Disturbed' may be used.

N.B.—Intervals of fog may occur during the periods of fair or fine.

Period.—Four days or more.

Interval.—Twelve hours or less.

Spell.—More than twelve hours, less than four days.

CHAPTER VII

GENERAL WEATHER IN THE BRITISH ISLANDS

THE prevailing wind in the British Islands is from some westerly point.

Two of the principal reasons are as follows :

(1) The British Islands, situated as they are in a high northern latitude, are in the region of the ' Anti-trades ' or Westerlies.

(2) There is usually a low pressure round about Iceland, and a high pressure about the Azores, and, bearing in mind the direction of the wind circulation round a high and low pressure respectively, the result is as shown in the sketch on p. 81.

Much could be said about the cause of wind due to the earth's rotation, but it is not proposed to touch on this in these notes. (*See* Appendix.)

Should the reader require to go further into this matter, he should consult the Admiralty ' Manual of Navigation.'

Westerly gales are very prevalent in the winter months, i.e. from October to March inclusive; they are rare from May to July, also inclusive, and seldom last long.

In the English Channel, winds from N.N.E. to E. cause the land to become covered with a thick white fog resembling smoke.

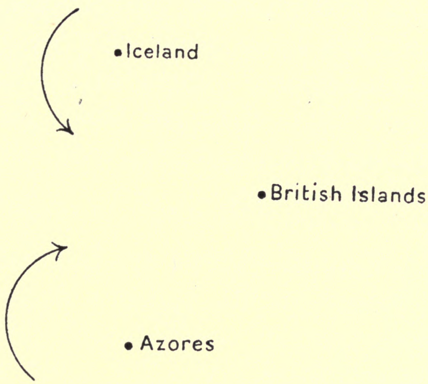


FIG. 33.

Easterly winds are very common in the spring months. A south-easterly wind with a falling barometer is an almost infallible sign of a coming gale.

Land and sea breezes may occur during a long spell of fine weather, the land breeze by night and the sea breeze by day.

Long-drawn-out calms are suspicious, and are generally the advance guard of a spell of bad weather.

The paths of storms passing over the British Islands are rather erratic, owing to their being deflected by the land. They may also be deflected by coming up against a high-pressure system.

Storms passing over the British Islands almost always have their centres north of the English Channel; from this, reference to Fig. 28 will show that the usual dangerous wind will be south-easterly, with, of course, the barometer falling.

Storm Signals.—These are hoisted by the various storm signal stations according to orders received from the Meteorological Office, from the warnings given by their synoptic charts. The new system is known as the International Code, but its introduction has been delayed by the war.

It consists of a display of either one or two cones hoisted as follows:

One Cone, point upwards.—Gale commencing with wind in the north-west quadrant.

One Cone, point downwards.—Gale commencing with wind in the south-west quadrant.

Two Cones, one above the other, both points *upwards.*—Gale commencing with the wind in the north-east quadrant.

Two Cones, one above the other, both points downwards.—Gale commencing with the wind in the south-east quadrant.

Two Cones, bases together.—Hurricane. Wind force, 12 Beaufort Scale.

Beaufort's System of Weather Notation.—The following tables have been copied from the Admiralty 'Manual of Navigation,' permission to do so having been given by the Controller of H.M. Stationery Office.

Beaufort's System of Wind Notation

No.	General Description	For Coast Use.	Miles per Hour.	Metres per Second.
0	Calm	Calm: smoke rises vertically	Less than 1	Less than 0·3
1	Light air	Direction of wind shown by smoke drift but not by wind vane	1–3	0·3–1·5
2	Slight breeze	Wind felt on face, leaves begin to rustle, ordinary vane moved by wind	4–7	1·6–3·3
3	Gentle breeze	Leaves and twigs in constant motion, wind extends a light flag	8–12	3·4–5·4
4	Moderate breeze	Raises dust and loose paper, small branches are moved	13–18	5·5–8·0
5	Fresh breeze	Small trees in leaf begin to sway, crested wavelets form on inland waters	19–24	8·1–10·7

No.	General Description.	For Coast Use.	Miles per Hour.	Metres per Second.
6	Strong breeze	Large branches in motion, whistling heard in telegraph wires	25–31	10·8–13·8
7	High wind	Whole trees in motion, inconvenience felt when walking against wind	32–38	13·9–17·1
8	Gale	Breaks twigs off trees, generally impedes progress	39–46	17·2–20·7
9	Strong gale	Slight structural damage occurs, chimney-pots and slates removed	47–54	20·8–24·4
10	Whole gale	Seldom experienced inland, trees uprooted, considerable structural damage occurs	55–63	24·5–28·4
11	Storm	Very rarely experienced, causes widespread damage	64–75	28·5–33·5
12	Hurricane	. . . .	Above 75	33·6 and above

Beaufort's System of Weather Notation

b Blue sky, i.e. sky not more than ¼ clouded.
bc Sky ¼ to ½ clouded.
c Sky ½ to ¾ clouded.
o Sky overcast, i.e. more than ¾ clouded.
g Gloomy.
m Mist.
f Fog.

r	Rain.
d	Drizzling rain.
e	Wet air without rain falling.
p	Passing showers.
h	Hail.
s	Snow.
t	Thunder.
l	Lightning.
tl	Thunderstorm.
tlr	Thunderstorm accompanied by rain.
q	Squalls.
u	Ugly threatening sky.
v	More than ordinary visibility.
w	Unusually heavy dew.
x	Hoar frost.
z	Dust haze or smoke.

Beaufort's Scale for Sea Disturbance

No.	Description.
0	Calm.
1	Very smooth.
2	Smooth.
3	Slight.
4	Moderate.
5	Rather rough.
6	Rough.
7	High.
8	Very high.
9	Phenomenal.

CHAPTER VIII

FORECASTING BY SOLITARY OBSERVER

In connection with this, the solitary observer has the following information at his disposal.

(1) The ordinary Daily Weather Notice, from which he can obtain the positions of the high pressures. This gives him the probable path of any low pressure.

(2) His knowledge from personal observation of the *present* state of the weather.

(3) The movements of the barometer from his record, or from the trace shown by his barograph.

(4) The wireless reports received from stations or ships to the westward of him, bearing in mind that nearly all depressions, with their attendant bad weather, are travelling to the eastward.

With reference to the trace shown by the barograph, it should be remembered that, should the fall of the barometer be at a uniform rate, the trace on the paper will be a descending straight line; if the rate of fall is increasing, the trace becomes convex, and if the rate is decreasing, the trace is concave to the top of the recording sheet.

If the rise of the barometer is at a uniform rate, the trace is shown by an ascending straight line; if the rate is increasing, the trace is concave; whilst if it is decreasing, the trace is convex to the top of the recording sheet.

Thus all we can tell from the movements of the barograph is that, with a falling glass, a convex trace means that the wind and weather will get worse much more rapidly than with a concave trace, and with a rising glass, a concave trace will indicate that the weather will improve more rapidly than with a convex trace.

On the other hand, the quicker the rise or fall, the steeper the isobars, and therefore the stronger the wind.

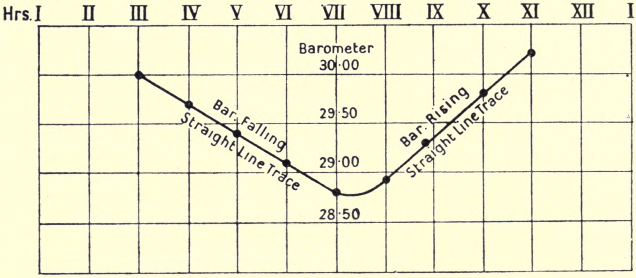
The above is shown by the diagrams on p. 88.

Bad weather, which takes a long time to develop, is also long in showing improvement, and vice versa.

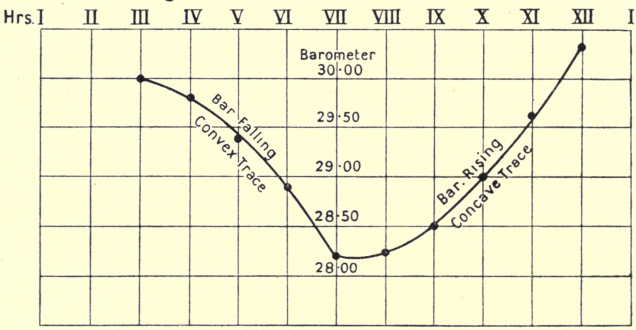
This can easily be remembered by the old-time jingle:

Long foretold, long last,
Short notice, soon past.

I. Steady Rate of Fall or Rise.



II. Increasing Rate of Fall or Rise.



III. Decreasing Rate of Fall or Rise.

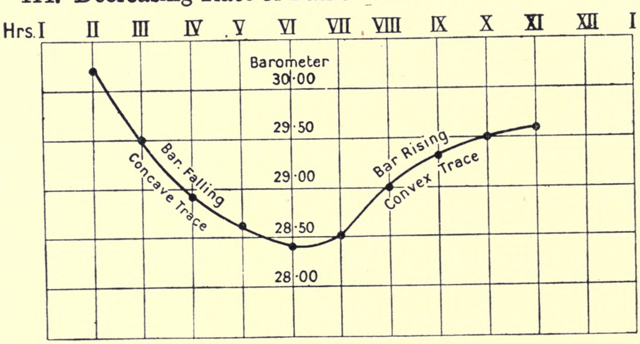


FIG. 34.

In connection with the forecasting of the coming weather, the rules given by the late Admiral Fitzroy are well worth committing to memory.

Taken in conjunction with other instrumental aids, they are of the greatest use in foretelling weather.

These rules are given below.

Admiral Fitzroy's Weather Rules.—Whether clear or otherwise, a rosy sky at sunset indicates fine weather ; a sickly greenish hue, wind and rain ; tawny or coppery clouds, wind ; a dark or Indian red, rain ; a red sky in the morning, bad weather, or much wind, perhaps also rain ; a grey sky in the morning, fine weather ; a high dawn, wind ; a low dawn, fine weather.

The darker or angrier the colour of the red in the morning, the worse the coming bad weather will prove to be. Also an opal-tinted sky in the morning is a sign of coming bad weather.

A high dawn is when the first indications of daylight are seen above a bank of clouds.

A low dawn is when the day breaks on or near the horizon, the first streaks of light being very low down.

Soft-looking or delicate clouds foretell fine weather, with moderate or light winds; hard-edged oily looking clouds show wind. A dark, gloomy blue sky is windy; but a light, bright blue sky indicates fine weather.

Generally, the *softer* clouds look, the less wind but perhaps more rain may be expected; and the harder, more greasy, rolled, tufted or ragged, the stronger the coming wind will prove to be.

A bright yellow sky at sunset foretells wind; a pale yellow, rain; orange or copper-coloured, wind and rain; and thus, by the prevalence of the various tints in the sky, the coming weather may be foretold fairly accurately, and, if aided with the usual instruments, almost exactly. Light delicate quiet tints or colours, with soft indefinite forms of clouds, indicate and accompany fine weather, but gaudy or unusual hues, with hard definitely outlined clouds, foretell rain and probably strong wind.

Small inky-looking clouds foretell rain; light scud clouds driving across heavy masses, show wind and rain; but if alone, may indicate wind only, the latter proportionate to their motion.

High upper clouds crossing in a direction different from that of the lower clouds, or from the surface wind felt below, foretell a change toward *their* direction.

After fine clear weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of distant cloud, which increase and are followed by a general overcasting of vapour that grows into cloudiness.

This appearance, more or less oily or watery, as rain or wind will predominate, is a certain sign.

Usually, the higher and more distant such clouds seem to be, the more gradual but more general the coming change of weather will prove to be.

Misty clouds forming or hanging on heights show wind and rain approaching; if they remain, increase or descend. If they rise or disperse, the weather will get better or become fine.

Dew is an indication of fine weather, its formation never begins under an overcast sky or when there is much wind. Great clearness of the air, especially near the horizon, distant objects very well defined or raised by refraction, also what is called a good hearing day, are signs of rain or wind coming.

A great deal of refraction is a sign of easterly wind.

More than usual twinkling or apparent size of the stars, haloes, etc., are more or less indications of approaching wind, with or without rain.

CHAPTER IX

ASTRONOMY

In olden days the sky and its stars were divided into twelve constellations.

These constellations were supposed to represent human beings and different animals.

After telescopes were invented, and as the power of the latter grew, more and more stars became visible, and the original twelve constellations outgrew themselves.

In modern star maps, this number twelve has been greatly increased, and in those drawn by the late Mr. R. A. Procter, no less than eighty-four constellations are given.

Some of the latter are very small and do not contain any stars which would be of practical value to the pilot, and in the following star maps, twenty-two in number, only those constellations are given which might be of use to a Flight Officer.

These drawings only give the principal stars in each of the constellations; of course there are many more, but it would serve no good purpose by putting them in, and would only lead to confusion.

If any more stars are required by the pilot, he cannot do better than consult Procter's Star Atlas.

The stars in the following drawings are not put in exactly correct as regards their declinations and right ascensions, but they are near enough for all practical purposes.

As the stars in the constellations are lettered according to the Greek alphabet, the latter is here appended for the benefit of those who may not know it.

α Alpha.	ν Nu.
β Beta.	ξ Xi.
γ Gamma.	o Omicron.
δ Delta.	π Pi.
ϵ Epsilon.	ρ Rho.
ζ Zeta.	σ Sigma.
η Eta.	τ Tau.
θ Theta.	υ Upsilon.
ι Iota.	ϕ Phi.
κ Kappa.	χ Chi.
λ Lambda	ψ Psi
μ Mu.	ω Omega.

These Greek letters are given against each star in the sketches, and also the old Arabic names in the case of the more important ones in each constellation.

In these drawings the true north should be taken as the top of the page.

Owing to their immense distance away, the *relative* position of the stars to one another as seen from the earth seems to be always the same, but as a matter of fact they all undergo a slight change every year in the same direction, known as 'Precession.' This does not, of course, alter their relative positions to one another. So that, having once picked up a star with reference to its relative position to another constellation, it will always be found in that same place.

On account of the diurnal motion of the earth, the *Compass* Bearing of any star is always changing from the time it rises to the time it sets.

When looking for stars at night, it often happens that the constellations they are in may be upside down.

This is due to the apparent rotation of the Stellar Sphere, which appears to revolve from east to west round the axis of the earth.

Several of these constellations are what is known as 'Circumpolar,' that is to say, they never set in these latitudes.

The Great and Little Bears and Cassiopeia are examples of this.

A sketch is given to illustrate this paragraph.

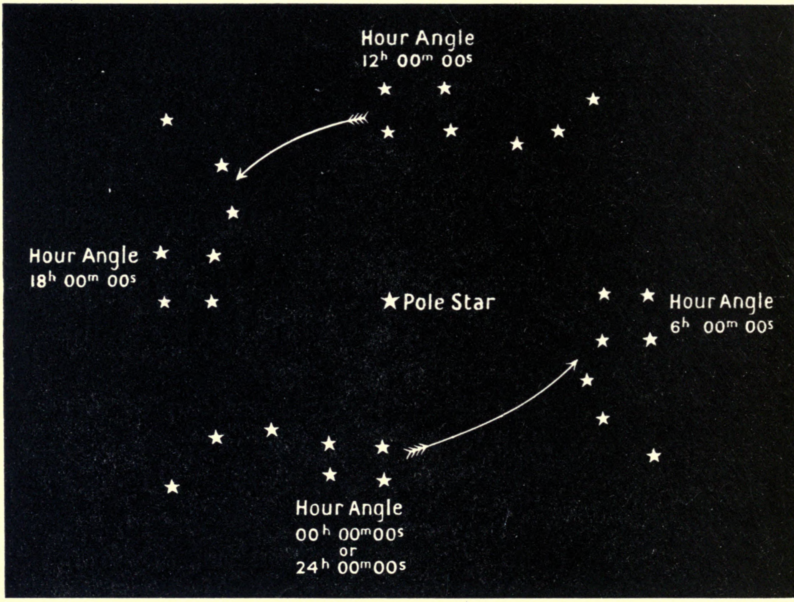


FIG. 35.

Note.—The hour angle referred to is the hour angle of α (Dubhe) Ursa Majoris.

The pole star or ' Polaris ' is situated very nearly at the north pole of the celestial concave, revolving round it about $1\frac{1}{4}$ degrees from it. It can be found by drawing a line from α and β Ursa Majoris, and continuing it towards the pole.

When looking for a star, it should be remembered that if the declination of the star is less than (or south of) the observer's

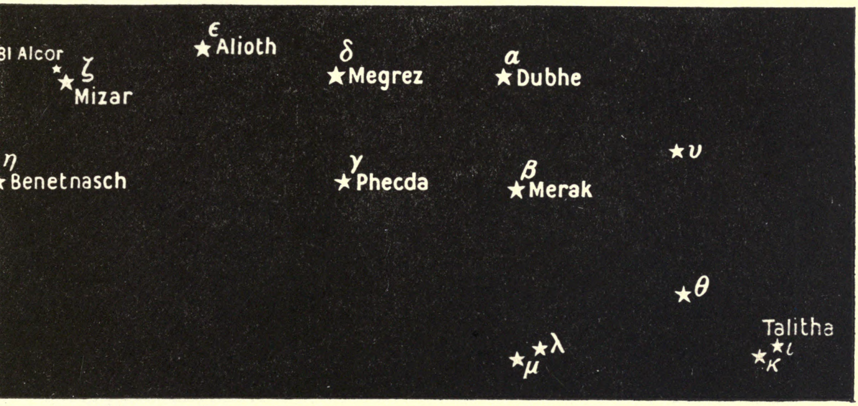


Fig. 36.—Ursa Majoris. (The Great Bear.)

latitude, it will cross the meridian south of him; if equal to the latitude, it will rise due east, pass directly overhead, and set due west; if greater than (or north of) the observer's latitude, it will always be north of him.

For a beginner, the best constellations to learn in order to connect up the other big stars, are the Great Bear and Orion.

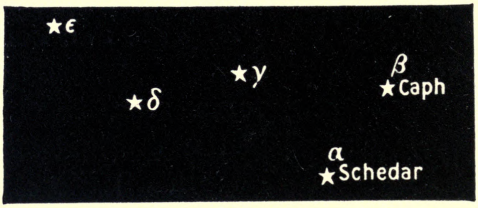


FIG. 37.—Cassiopeia. (The Chair.)

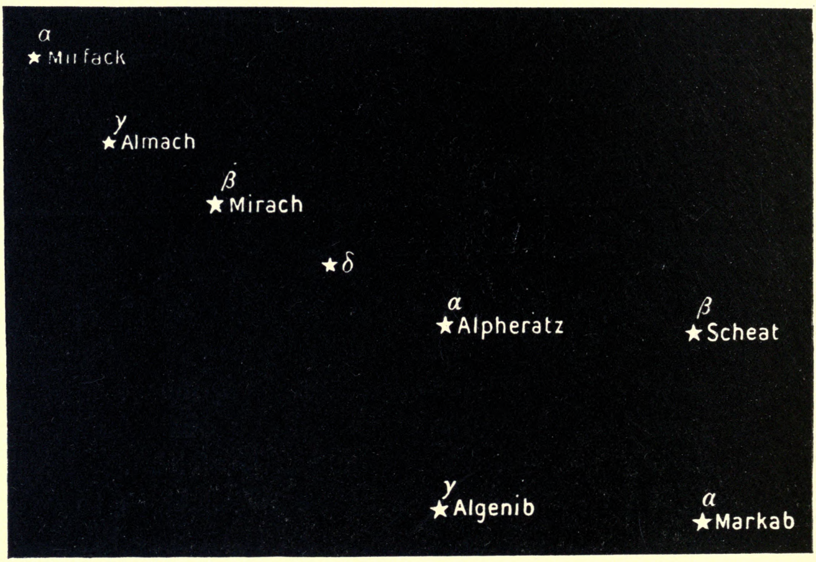


FIG. 38.—Square of Pegasus.

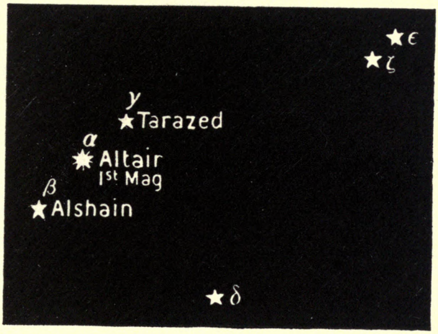


FIG. 39.—Aquila. (The Eagle.)

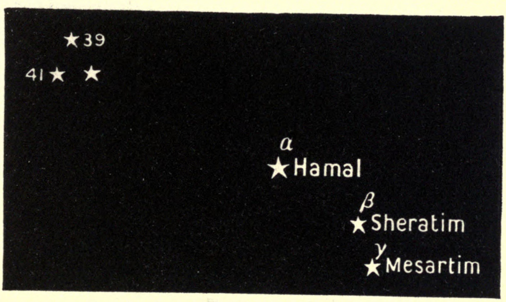


FIG. 40.—Aries. (The Ram.)

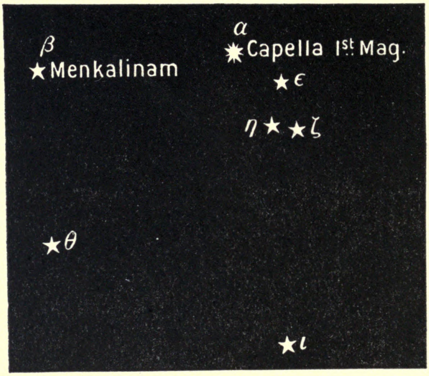


FIG. 41.—Auriga. (The Charioteer.)

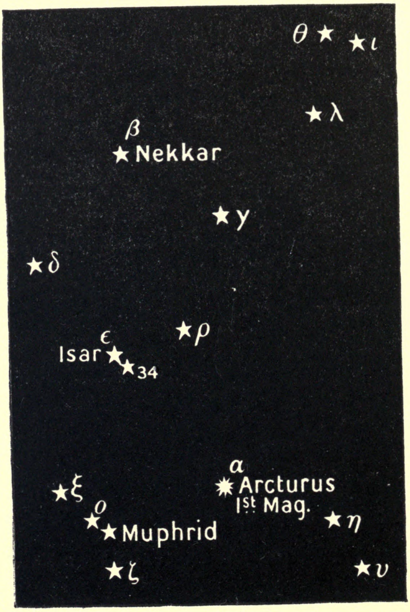


FIG. 42.—Bootes. (The Herdsman.)

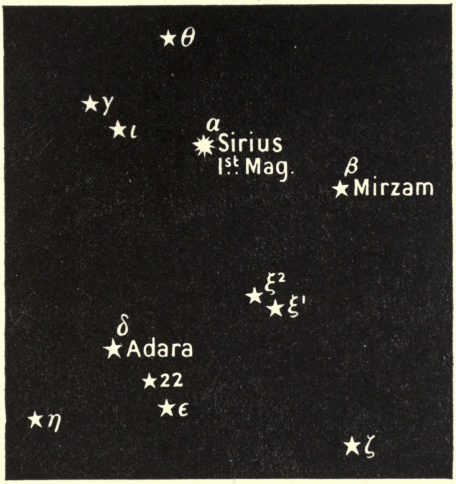


FIG. 43.—Canis Major. (The Greater Dog.)

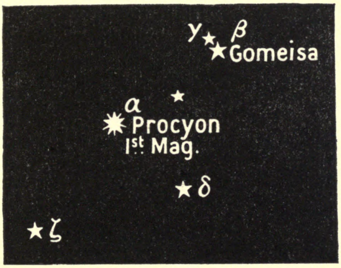


FIG. 44.—Canis Minor. (The Lesser Dog.)

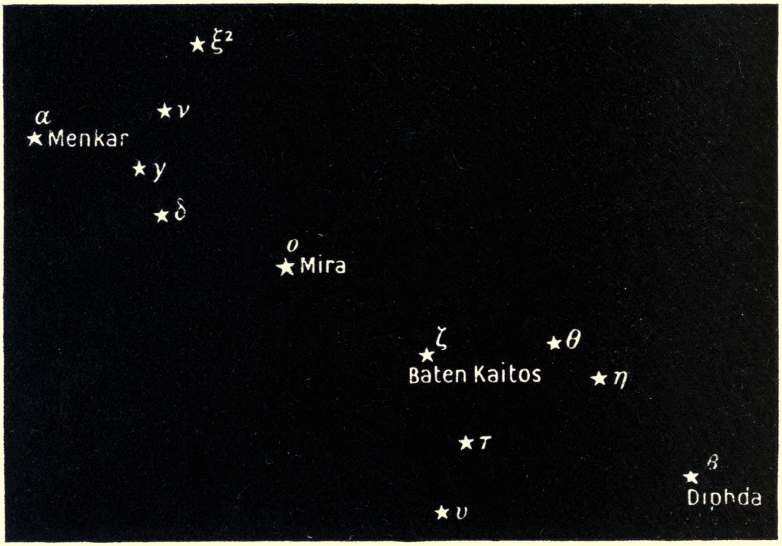


FIG. 45.—Catus. (The Whale.)

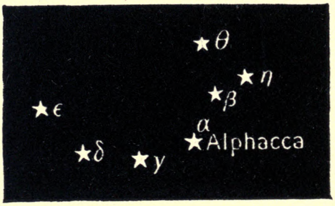


FIG. 46.—Corona Borealis. (The Northern Crown.

FIG. 47.—Crux. (The Southern Cross.)

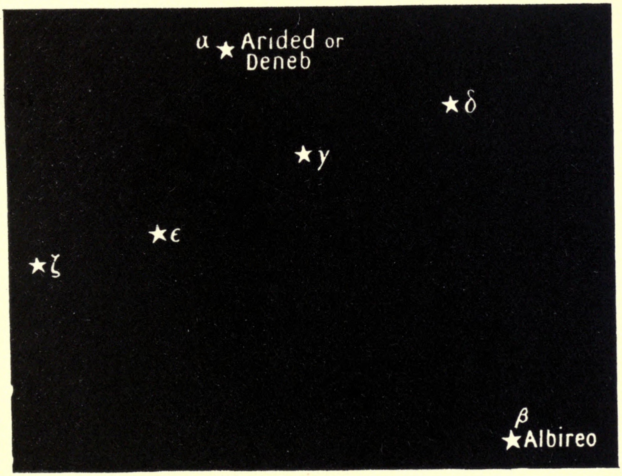


FIG. 48.—Cygnus. (The Swan.)

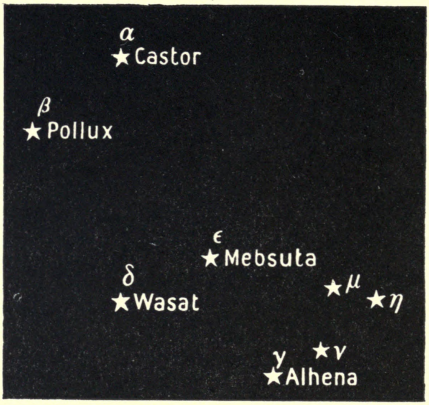


FIG. 49.—Gemini. (The Twins.)

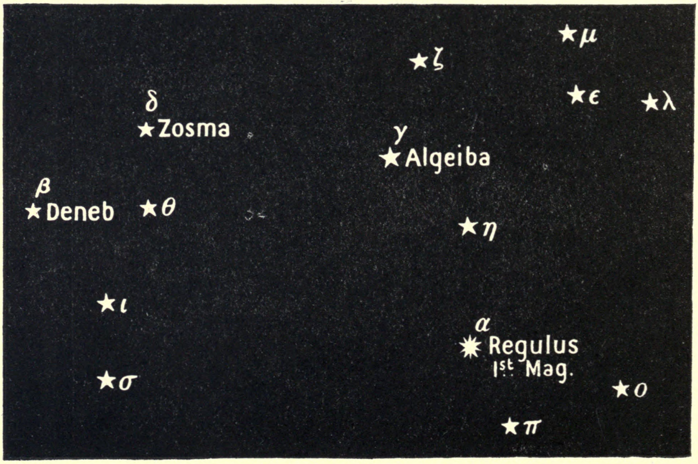


FIG. 50.—Leo. (The Lion.)

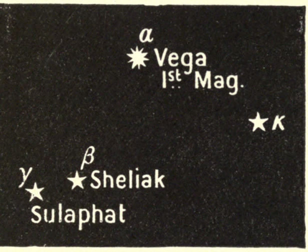


FIG. 51.—Lyra. (The Lyre.)

FIG. 52.—Orion. (The Hunter.)

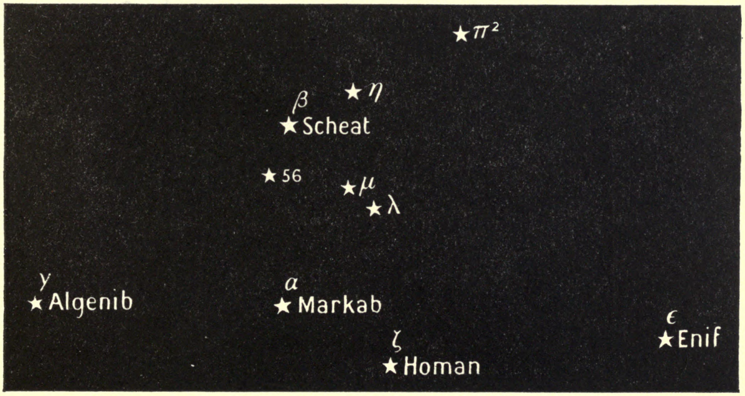


FIG. 53.—Pegasus. (The Winged Horse.)

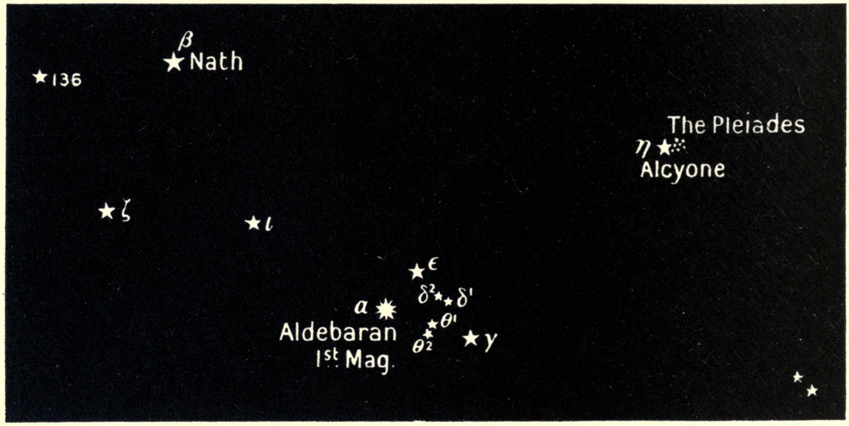


FIG. 54.—Taurus. (The Bull.)

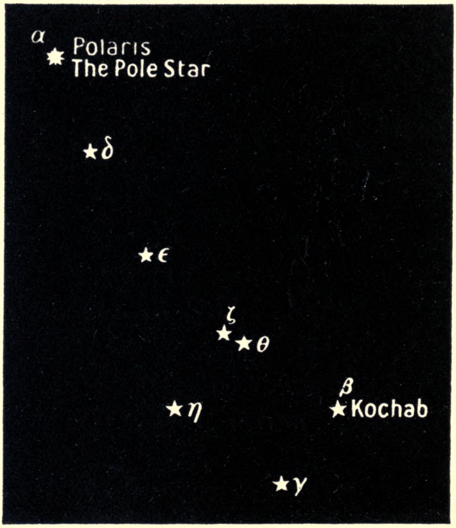


FIG. 55.—Ursa Minor. (The Little Bear.)

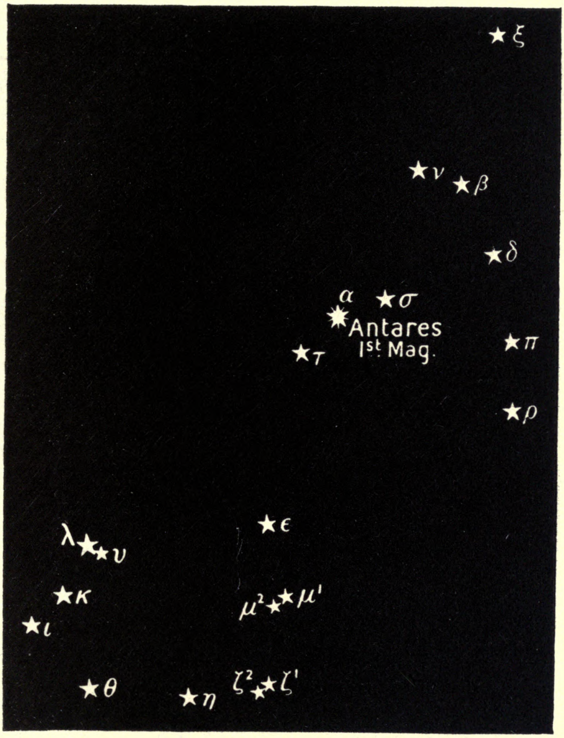


FIG. 56.—Scorpio. (The Scorpion.)

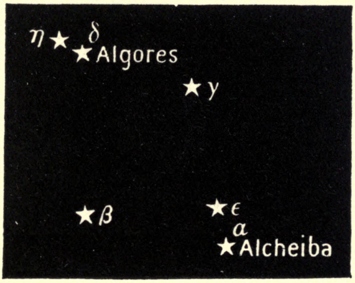


FIG. 57.—Corvus. (The Crow.)

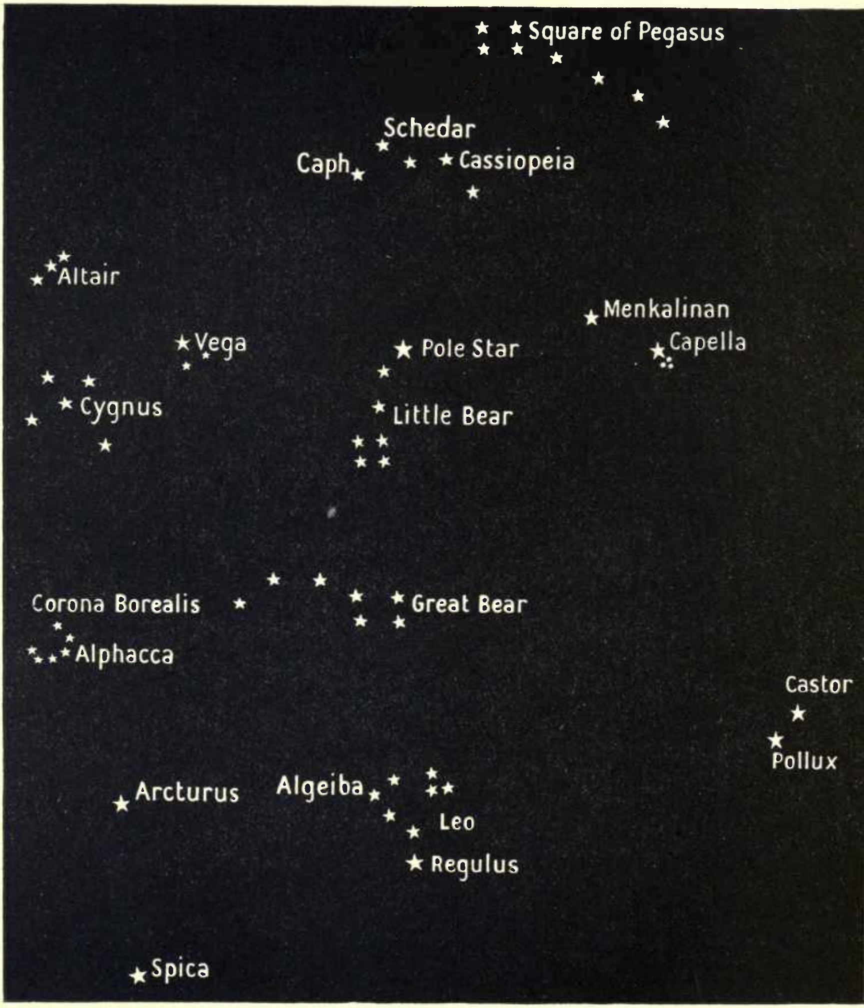


FIG. 58.—The Great Bear and the Stars it leads to.

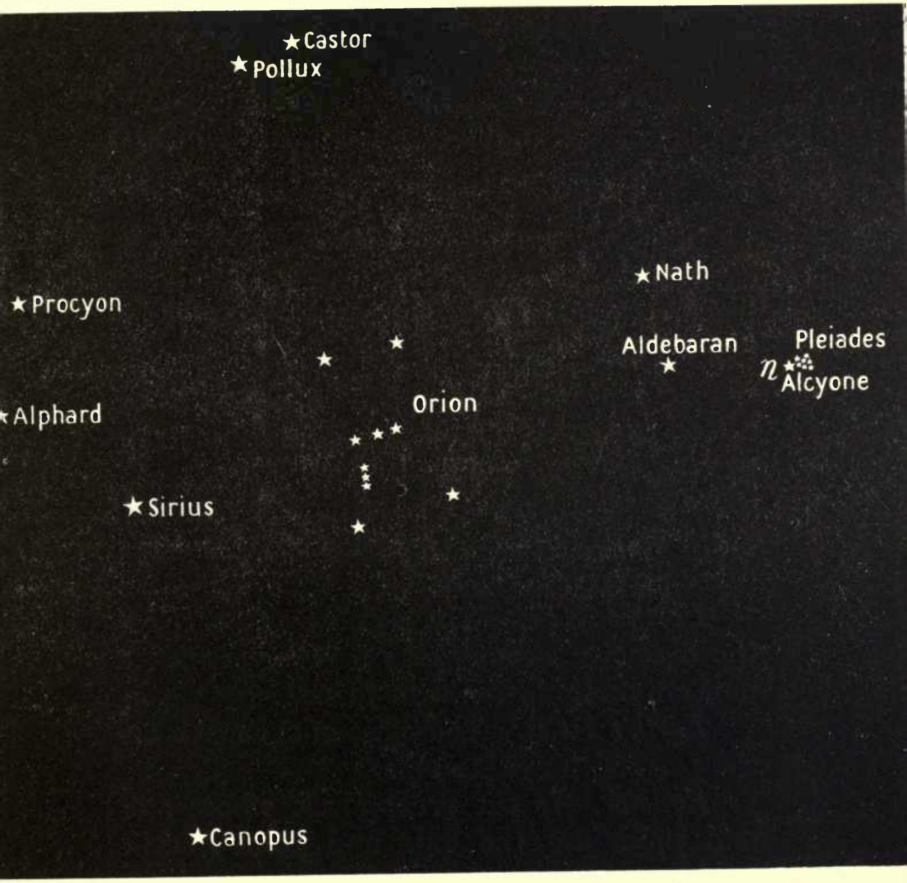


FIG. 59.—Orion and the Stars it leads to.

Before entering into the problems connected with the sun and moon, it would be as well to give some explanation of the various terms used.

The reader should make himself acquainted with the following definitions in Nautical Astronomy:

Definitions.—*A Sphere.*—A sphere is a solid bounded by a surface, every point of which is equally distant from a fixed point called the centre.

A Great Circle.—A great circle is a section of the surface of a sphere, made by a plane passing through the centre.

A Small Circle.—A small circle is a section of the surface of a sphere, made by a plane not passing through the centre.

Earth's Axis.—The axis of the earth is the diameter about which it revolves with a uniform motion from west to east.

Earth's Poles.—The poles of the earth are the extremities of its axis.

Equator.—Is the great circle whose axis and poles are the axis and poles of the earth.

Meridians.—Are great circles whose planes pass through the poles of the earth.

Meridian of a Place.—Is that meridian which passes through the place.

Prime Meridian.—Is that fixed meridian by reference to which the longitudes of all other places on the earth are measured.

Parallels of Latitude.—Are small circles whose planes are parallel to the plane of the equator.

Longitude of a Place.—Is the smaller arc of the equator, intercepted between the prime meridian and the meridian passing through the place.

Latitude of a Place.—Is the arc of a meridian intercepted behind the equator and the place.

Difference of Latitude between two Places.—Is the arc of a meridian intercepted between their parallels.

Difference of Longitude between two Places.—Is the smaller arc of the equator intercepted between their meridians.

Celestial Concave.—Is the interior surface of a globe bounded by the blue of space, and on which all the heavenly bodies appear to be situated.

Poles of the Heavens.—Are the points where the earth's axis produced, cuts the celestial concave.

Ecliptic.—Is the apparent path of the sun during the year on the celestial concave.

Equinoctial or Celestial Equator.—Is the great circle formed by the plane of the earth's equator produced, cutting the celestial concave.

The Equinoctial Points.—Are the two points on the celestial concave where the ecliptic and the equinoctial cut one another. One is known as the First Point of Aries (the point on the ecliptic where the sun's declination changes from south to north), the other as the First Point of Libra (the point on the ecliptic where the sun's declination changes from north to south).

Circles of Declination.—Are great circles which pass through the poles of the heavens; they correspond to terrestrial meridians.

Parallels of Declination.—Are small circles whose planes are parallel to the plane of the equinoctial.

Declination.—Is the arc of a circle of declination intercepted between the equinoctial and the place of the body. It is thus similar to latitude on the earth. It is measured north and south of the equinoctial from 0 at the equinoctial to 90° at each celestial pole.

Polar Distance of a Heavenly Body.—Is the arc of a circle of declination through the body intercepted between the elevated pole and the body, and is therefore (90° − dec.) or (90° + dec.) according as the declination is of the same or opposite name to the latitude.

N.B.—The elevated pole is that one situated in the same latitude as the observer.

Right Ascension.—Is the arc of the equinoctial intercepted between the First Point of Aries and the Circle of Declination which passes through the body, measured anti-clockwise from 0^h to 24^h.

Notes on Time.—As time plays a very important rôle in the sun and moon problems, a few notes on the subject are given here before going into the problems.

This should be thoroughly studied and understood; by doing so, half the difficulty of working out the problems is done away with —in fact more than half.

Time may be divided into two sorts—Civil and Astronomical.

Civil Time is divided into two periods called A.M. (*ante meridiem*), and P.M. (*post meridiem*).

Each of these is a period of twelve hours, the A.M. time being from midnight to noon, and the P.M. time from noon to midnight.

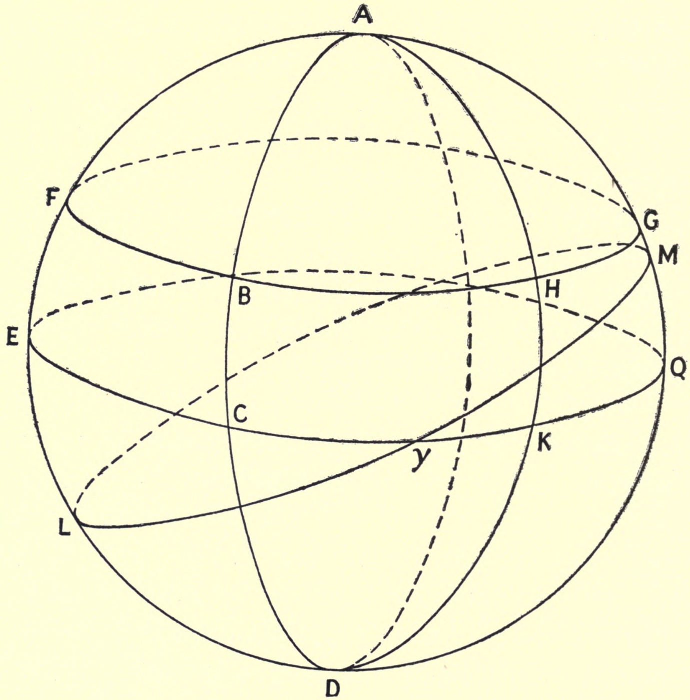


FIG. 60.—The Celestial Concave.

ECKQ is the equinoctial.
FBHG is a parallel of declination.
ABCD and AHKD are circles of declination.
L♈M is the ecliptic—♈ the First Point of Aries.
HK is the declination of the body H.
♈K is the right ascension of the body H.

The civil *day* and *date* commences at midnight and ends the following midnight.

Astronomical Time is reckoned in one period of twenty-four hours, the *day* and *date* commencing at noon and changing the following noon.

From this it will be seen that the civil *date* is always twelve hours ahead of the astronomical *date,* i.e. the former begins at midnight and the latter the following noon.

When working problems in time, it must be remembered that twenty-four hours can always be added to any time, provided that the date is placed one day back.

Examples :

$4^h\ 00^m\ 00^s$ on May 4, can, if necessary, be shown as $28^h\ 00^m\ 00^s$ on May 3.

$20^h\ 00\ \ 00^s$ on June 17, can be shown as $44^h\ 00^m\ 00^s$ on June 16.

Civil time can always be converted into astronomical time, and *vice versa,* remembering that civil date is always twelve hours ahead of astronomical date.

Examples :

Civil time 4 A.M. March 30.

Astronomical time, $16^h\ 00^m\ 00^s$ March 29.

Civil time, 11 P.M. March 30.
Astronomical time, 11^h 00^m 00^s March 30.

Civil time, 11^h A.M. March 30.
Astronomical time, 23^h 00^m 00^s March 29.

From No. 2 of the above examples it will be noticed that civil time and astronomical time are identical in *date* during P.M. civil time, but whilst the civil date changes at midnight, the astronomical date goes on for another twelve hours.

Examples:
Astronomical time, 15^h 00^m 00^s July 12.
Civil time, 3^h A.M. July 13.

Astronomical time, 10^h 00^m 00^s July 12.
Civil time, 10^h P.M. July 12.

Time is divided into two kinds—Apparent Solar Time and Mean Solar Time.

Apparent Time.—Is the actual time shown by the sun, but owing to the elliptical shape of the earth's orbit, the apparent proper motion of the sun is not uniform, so that the apparent solar day, hour, minute, and second are not quite of constant length.

Mean Sun.—Is an imaginary sun which moves in the equinoctial with the apparent sun's mean motion in R.A.

Mean Time.—This is the time shown by an imaginary sun whose motion is uniform in velocity, along the ecliptic, and to which our clocks are set.

The velocity of the apparent sun not being uniform, it follows that it will be sometimes ahead of the mean sun and sometimes behind it.

This difference is called the 'Equation of Time,' and is given in the Nautical Almanac for every two hours of the day throughout the year. In problems connected with the sun's bearing, the times given in the true bearing or azimuth tables are all apparent times, so that it is necessary to change the time by watch into apparent time.

The Effect of Longitude.—The way in which the longitude of a place on the earth's surface affects the time of that place, should be clearly understood, as it helps to give one a firm grasp on the problems later on.

The earth revolves from west to east in twenty-four hours, but it is more convenient to imagine the earth as stationary, and the celestial concave revolving from east to west about its own axis.

This comes to the same thing.

Consequently, as we measure our noon by the sun's passage across the meridian of our place, it follows that the sun must have already crossed the meridian of any place to the eastward of our position, and not yet crossed the meridian of those places to the westward of us.

In all our charts, the meridian passing through the transit instrument at Greenwich Observatory is taken as the prime meridian, from which all our measurements for the longitude of other places are made; hence the mean time of all places to the eastward of Greenwich is ahead of Greenwich mean time (or G.M.T. as it is usually called), and the mean time of all places to the westward of Greenwich is behind G.M.T.

As the revolution of the earth from noon to noon, at any place, occupies twenty-four hours for an angular value of the circumference of a circle, or, in other words, 360°, it follows that longitude may also be expressed in time.

Example:

Arc.	Time. h. m. s.
360°	24 00 00
180°	12 00 00
90°	6 00 00
15°	1 00 00
1°	0 04 00

As the meridian of every place is different, *local time* must differ at any place from any other place, and would cause endless trouble as regards setting clocks.

Consequently, different countries adopt what are known as 'Standard Meridians,' and all clocks in that country are set to the time of that standard meridian.

In the United Kingdom, except Ireland, the standard meridian is that of Greenwich Observatory, as mentioned before, and all clocks are kept set to it. *N.B.*—Ireland now keeps G.M.T.

N.B.—Since writing this, summer time has been introduced by Act of Parliament. By this, clocks are put on one hour on May 1 at midnight, and are put back at midnight on September 30.

An easy rule to remember how to apply longitude in time is given in the old rhyme:

> Longitude west, Greenwich time best,
> Longitude east, Greenwich time least.

In connection with time, it is interesting to understand what happens to the day and date when crossing the 180th meridian.

This is explained below.

On leaving the prime meridian, and

steering east, the ship's local time gradually gets ahead of Greenwich time, until in 180° she is just twelve hours in front.

Continuing to the eastward, she immediately enters a longitude which is twelve hours behind Greenwich, so that she must count that day and date over again.

For instance, supposing she crossed the 180th meridian at 9 P.M. on August 14, going east.

When she got to the 180th meridian it would only be 9 A.M. on August 14 at Greenwich, and, continuing her course, she would at once be twelve hours more behind Greenwich, i.e. 9 P.M. on August 13.

Hence her next day and date must again be reckoned as August 14.

On the other hand, suppose she sailed from the meridian of Greenwich, going west about.

She would gradually get more and more behind Greenwich time, until at the 180th meridian she would be twelve hours late. On crossing to the westward of this meridian, she would at once get twelve hours ahead of Greenwich time, therefore she must skip a day altogether.

For instance, supposing she crossed the 180th meridian, going west, at 9 P.M. August 14.

When she was there, it would be 9 A.M. August 15 at Greenwich, and, on going farther west, she would be twelve hours ahead of this latter date, so that it would be 9 P.M. on August 15.

Hence she must skip the 15th altogether, and call the next day the 16th.

Hour Angles.—By the term 'Hour Angle,' is meant the angular distance of a body from the observer's meridian expressed in time, either before or after its meridian passage.

By 'Meridian Passage' is meant the crossing of the body over the meridian of the observer.

All heavenly bodies rise to the eastward of the observer, and after a certain time attain their greatest altitude above the horizon—this occurs when the body is on the observer's meridian; they then decline in altitude, and finally set in the westward.

This meridian passage is known as the 'Upper Meridian Passage.'

Their lower meridian passage takes place twelve hours later in the case of the sun; slightly under (3^m 56^s) twelve hours in the case of a star; and an *average* of 12^h 24^m in the case of the moon.

When we talk of a body being so many hours away from the meridian, this does not mean any A.M. or P.M. time: it is simply a measure of time from its meridian passage. If we want to know the local time when a body is, say, three hours from its meridian passage, we must find out the sun time of the body crossing the meridian and apply these three hours to this latter time.

The reason for this is because the meridian passage of a body is reckoned by mean sun time, and so, to get the time of rising or setting of any body other than the sun, we must first find the sun time of the body's meridian passage and then apply its hour angle from the meridian when on the horizon.

This hour angle must, of course, be subtracted from the time of meridian passage for rising, because it must rise *before* it comes to the meridian, and be added to the time of meridian passage for setting, as it sets *after* crossing the meridian.

With reference to the times shown in the sun's true bearing tables of sunrise and sunset, it must be remembered that as we count our civil day as beginning at midnight, so the actual A.M. time of sunrise, as given in the tables, is counted from the *inferior* *meridian*; so that, to get the actual hour angle of the sun from the *superior meridian,* we must subtract the A.M. time from twelve hours.

This is, of course, not necessary in the P.M. time, as our afternoon time is measured from the superior meridian. The sun's hour angle, both from the inferior meridian to the superior meridian (A.M. time), and from the superior meridian to the inferior meridian (P.M. time) is, of course, apparent time.

Explanation of the Various Tables.—(1) *Nautical Almanac.*—This is a work published, giving all the data necessary for navigation by the sun, moon, planets, and stars. These data are given for every day in the year. It is published in two forms—an extended form, and an abridged form for the use of seamen.

The latter should be used in all problems of rising and setting, and is also sufficient for all problems in navigation.

On the first two pages of every month are given all the data for the sun and moon.

Each column indicates the contents of that column, so that there should be no difficulty in taking out what is wanted.

The only column that needs any explanation is the one headed 'Equation of Time.'

Here it gives, at the top of the page, instructions as to whether the equation of time is to be added to, or subtracted from, apparent time. In either case, if the equation of time is to be applied to mean time, the instructions must be reversed—e.g., suppose the instructions say the equation of time is to be added to apparent time, then it must be subtracted from mean time.

Again, it sometimes happens that there is a black line drawn both in the instructions and in the column giving the values.

This simply means that all the values in the column above the black line follow the instructions above the upper black line, and those below follow the instructions below the upper black line.

The next few pages give the data for the sun for every day of the month at two-hour intervals of Greenwich mean time (G.M.T.).

After that comes the same thing for the moon, and these must be made use of when getting moonrise or moonset. In the case of finding sunrise or sunset, it will be near enough to take the declination out for noon at Greenwich, as it does not alter enough in twenty-four hours to have any practical effect on the accuracy of the problem ; but in the case of the moon, her declination changes so rapidly, that a few hours may make an appreciable difference in the result.

On p. 160 of the Abridged Nautical Almanac will be found a table giving the hour angle of a body from the meridian when rising or setting.

Running right across the top of the two pages are the degrees of declination from 0° to 30°.

Down the left hand side of each page, and printed in thick type, are the degrees of latitude from 0° to 60°. In the body of the table are the hour angles.

To look out an hour angle, all that has to be done is to enter the table with the latitude of the place and the declination of the body.

Under the latter, and opposite the former, will be found the required hour angle.

The following rule is important and should be well learnt:

'If the latitude and declination are the same names, i.e. both north or both south, the hour angle can be taken straight from the tables; but if they are different names, i.e. one north and the other south, the hour angle found in the tables must be subtracted from twelve hours, and the result used instead.'

On p. 170 is a table of proportional parts which must be applied to the hour angle as a final correction. Across the top of the page are certain numbers, in the case of the moon these correspond with the daily difference as given in the column after the upper meridian passage. Running down the right hand side of each page are times ranging to twelve hours.

The final correction is simply a rule-of-three sum, which is given in this table.

'If the difference in twenty-four hours is so much, what will it be for an hour angle of so much?' This hour angle being the one just found.

This final correction is always additive to the hour angle, as the moon crosses the meridian of any place later every day.

(2) *Inman's Tables.*—On p. 116 will be found a table for the correction of the moon's meridian passage, depending on the longitude. The rule for adding or subtracting it is given on the top of the page.

Just below it, and running right across the page, is a row of thick figures, which represent the daily difference of the moon's meridian passage which is given in the Nautical

Almanac in the column next to the moon's upper meridian passage.

Running down either side of the page is a column showing the longitude of the place, and in the body of the table is the correction to be applied. This correction is given in minutes of time.

This table is merely a worked out rule-of-three sum.

'If the daily difference for 360° is that given in the Nautical Almanac, what is it for the longitude of the place?' Instructions whether to add or subtract it are given at the top of the table.

Haversine Table.—This table is of great use in giving the longitude in time anywhere. All that has to be done is to look up the longitude and take out the corresponding time shown at the top of the page and also down the sides.

Sun's True Bearing or Azimuth Tables (Davis and Burdwood).—These are printed for a limit of latitude of 60° north and south, and a limit of declination of 23° north and south, this latter being approximately the farthest limits of the sun's apparent motion north or south.

The times shown are, as the sun itself

is actually observed, apparent time: the intervals as given in the tables are four minute ones.

It should be noticed that the A.M. times run *up* the left hand side of each page, and the P.M. times run *down* each page on the right hand side.

With reference to the A.M. time of rising, it should be remembered that the time given for rising is counted from the inferior or midnight meridian, and therefore, to get the hour angle from the noon or superior meridian, the value given in the tables must be subtracted from twelve hours. This is not necessary for the P.M. hour angle, as P.M. is counted from the time that the sun crosses the superior meridian.

All the bearings given in the tables are for the sun's centre.

In both sun and star tables, the rules for naming the bearing are the same in principle, as the statement 'When apparent time is A.M.' means exactly the same thing as 'When the body is rising or east of the meridian,' and similarly for P.M.

In the sun tables, each degree of latitude appears over two separate headings, one when latitude and declination are the same name, i.e. both north or both south, and the other when they are opposite names, i.e. one north and the other south. Care should be taken not to confuse the two.

At the end of every degree of declination is given the apparent time of rising and setting, and the true bearing of the body.

The star tables (Davis') are the same in principle as the sun tables, except that instead of the apparent time being given, the hour angle of the star is shown.

We now come to the examples of sunrise and sunset, and moonrise and moonset, which are appended. In practice it is not necessary to work rigorously, so the declination and equation of time may be taken out at sight.[1] The elements, if taken out exactly, only add to the time in working out without any compensating advantages, and make no practical difference to the answer.

Sunrise Problem

Example 1.—Find the Greenwich mean time of sunrise and sunset and the true bearing at each time, in Latitude 50° N., Longitude 8° E., on May 7, 1916.

From Abridged Nautical Almanac, p. 50, on

[1] In the case of the sun to the nearest noon, but with the moon to the nearest hour.

May 7, we get: 'Sun's declination $16\frac{3}{4}°$ north. *Same* name as latitude.'

P. 207, pt. ii. of sun's true bearing tables, with Lat. 50° N. (same name as declination), under the columns headed 16 and 17, we get by interpolation as follows:

Rising.	h. m. s.	*Setting.*	h. m. s.
Apparent time of rising at place .	4 36 00	Apparent time of setting at place.	7 24 00
Equation of time, p. 50, Naut. Alm..	—3 30	Equation of time, p. 50, Naut. Alm.	—3 30
Mean time of rising at place . .	4 32 30	Mean time of setting at place .	7 20 30
Longitude in time .	0 32 00E.	Longitude in time .	0 32 00E.
G.M.T. rising A.M.	4 00 30	G.M.T. setting P.M.	6 8 30

Bearing.		*Bearing.*	
From p. 207, sun's true bearing tables, for Lat. 50° N., Dec. $16\frac{3}{4}°$ N. we get by interpolation	63° 23′ 00″	From p. 207, sun's true bearing tables, for Lat. 50° N., Dec. $16\frac{3}{4}°$ N. we get	63° 23′ 00″ 360° 00′ 00″ 296° 37′ 00″

Therefore the answer to the problem is that the

Sun rises at 4^h 00^m 30^s A.M., bearing 63° 23′ 0″.

Sun sets at $6^h\ 48^m\ 30^s$ P.M., bearing 296° 37′ 00″.

These of course are *true bearings*; should *magnetic bearings* be required, the variation must be applied.

If local mean time be required, of course the longitude in time would not be applied.

Example 2.—Find G.M.T. of sunrise and sunset and the true bearing at each time in Latitude 40° S., Longitude 10° W., on August 5, 1916.

From Nautical Almanac: 'Sun's declination is 17° north, i.e. contrary name to latitude.'

Rising.

		h. m. s.
Apparent time at place	. .	6 56 00
Equation of time	+	0 06 00
Mean time at place		7 02 00
Long. in time	W+	0 40 00
G.M.T. rising	A.M.	7 42 00

Setting.

		h. m. s.
Apparent time at place	. .	5 04 00
Equation of time	. +	0 06 00
Mean time at place		5 10 00
Long. in time	W+	0 40 00
G.M.T. setting	P.M.	5 50 00

Bearing.

S. 111° 05′ E.
i.e. 68° 55′ from rule given before.

Bearing.

S. 111° 05′ W.
i.e. 291° 05′ from rule given bef ore.

Examples on Moonrise Problem

Example 1.—Find the time of moonrise and moonset and the moon's true bearing at each in Latitude 40° N., Longitude 70° W., on June 5, 1916.

	h.	m.	s.
From Naut. Alm., p. 63, moon's mer. pass at upper transit on June 5	3	43	00
Correction in Inman's tables, p. 116 . . +	0	09	00
Corrected local mean time of passage . .	3	52	00
Longitude in time . +	4	40	00
Rough G.M.T. of passage, June 5 .	8	32	00
Moon's hour angle	6	25	00
Rough G.M.T. of rising, June 5 .	2	07	00
Rough G.M.T. of setting, June 5 .	14	57	00

Daily difference in next column to upper transit . . 44^m

Moon's declination for 8^h 32^m G.M.T. on June 5 . . . $7\frac{1}{4}°$ N.
Same name as Latitude.

From p. 160, Naut. Alm., with Lat. 40° N., Dec. $7\frac{1}{4}°$ N. Moon's hour angle is 6^h 25^m 00^s

This means that the moon, when rising and setting, is 6^h 25^m away from the time of her passage over the observer's meridian as shown by sun mean time:

Owing to the rapid change in the moon's declination, the example must now be reworked, using the rough G.M.T. times of rising and setting to get the declinations.

Rising.

Moon's dec. for 2^h 07^m, G.M.T., June 5 . 18° N.

Setting.

Moon's dec. for 14^h 57^m, G.M.T., June 5 . $15\frac{3}{4}°$ N.

Both *same* name as latitude.

Rising.	h. m. s.	*Setting.*	h. m. s.
Hour angle from p.160, Naut. Alm., with Lat. 40° N., Dec. 18° N. .	7 03 00	Hour angle from p.160, Naut. Alm., with Lat. 40° N., Dec. $15\frac{3}{4}$° N. .	6 55 00
Correction p. 170, Naut. Alm., with daily difference 44^m and hour angle 7^h 03^m	+ 13 00	Correction p. 170, Naut. Alm., with daily difference 44^m and hour angle 6^h 55^m .	+ 13 00
Corrected hour angle . .	7 16 00	Corrected hour angle . .	7 08 00
Corrected local mean time of passage, June 4 .	27 52 00	Corrected local mean time of passage, June 5 .	3 52 00
Moon rises June 4 .	20 36 00	Moon sets June 5 .	11 00 00
I.e. moon rises June 5, civil time . A.M.	8 36 00	Moon sets June 5, civil time P.M.	11 00 00

Moon's Bearing.		*Moon's Bearing.*	
With Lat. 40° N., Dec. 18° N., same name as lat. true bearing from tables . .	66° 13′ 00″	With Lat. 40° N., Dec. $15\frac{3}{4}$° N., same name as lat. true bearing from tables	69° 15′ 00″
			360° 00′ 00″
			290° 45′ 00″

Note.—In the second part of the foregoing problem, it should be noticed that under the rising heading the corrected local mean time of passage has been given as $27^h\ 52^m\ 00^s$. This simply means that 24^h has been added on to the original $3^h\ 52^m\ 00^s$., as $7^h\ 16^m\ 00^s$ has to be subtracted from it. By adding 24^h to it, the date has, of course, to be placed one day back.

Example 2.—Find the time of moonrise and moonset and the true bearing at each time in Latitude 50° S., Longitude 100° E., on October 12, 1916.

	h. m. s.
From Naut. Alm., p.111, moon's mer. passage at upper transit on Oct. 12	13 04 00
Correction in Inman's tables, p.116	—00 14 00
Corrected local mean time of passage, Oct. 12 .	12 50 00
Longitude in time .	— 6 40 00
Rough G.M.T. of passage, Oct. 12 .	6 10 00
Moon's hour angle .	4 26 00
Rough G.M.T of rising, Oct. 12 .	1 44 00
Rough G.M.T. of setting, Oct. 12 .	10 36 00

Daily difference in next column to upper mer. pass .	52^m
Moon's declination for G. M. T. of $6^h\ 10^m\ 00^s$ Oct. 12	$18\frac{1}{2}$° N.

Opposite name to latitude.

From p. 160, Naut. Alm., with Lat. 50° S., Dec. $18\frac{1}{2}$° N. Hour angle is $7^h\ 34^m$.

Subtract this from 12^h, because lat. and dec. are opposite names.

Moon's hour angle from meridian is therefore $4^h\ 24^m\ 00^s$.

Re-working the problem as in Example 1, we get as follows :

Rising.		*Setting.*	
Moon's dec. for $1^h\ 44^m$, G.M.T. Oct. 12 .	18° N.	Moon's dec. for $10^h\ 36^m$, G.M.T. Oct. 12 .	19½° N

Both *opposite* name to latitude.

	h. m. s.		h. m. s.
Hour angle from p.160, Naut.Alm., with Lat. 30° E., Dec. 18° N. .	7 31 00	Hour angle from p.160, Naut.Alm., with Lat. 50° S., Dec. 19½° N. .	7 40 00
Subtract from 12^h .	12 00 00	Subtract from 12^h .	12 00 00
Moon's hour angle .	4 29 00	Moon's hour angle .	4 20 00
Correction p. 170, Naut. Alm., with daily difference 52, and hour angle $4^h\ 29^m\ 00^s$ . .	+ 10 00	Correction p. 170, Naut. Alm., with daily difference 52, and hour angle $4^h\ 20^m\ 00^s$ . .	+ 10 00
Corrected hour angle of moon .	4 39 00	Corrected hour angle of moon .	4 30 00
Local mean time of passage, Oct. 12 .	12 50 00	Local mean time of passage, Oct. 12.	12 50 00
Moon rises Oct. 12.	8 11 00	Moon sets Oct. 12 .	17 20 00
I.e. civil time Oct. 12 . P.M.	8 11 00	I.e. civil time Oct. 13 . A.M.	5 20 00

Moon's Bearing.		*Moon's Bearing.*	
With Lat. 50° S., Dec. 18° N., opposite name to lat. bearing from tables . .	118° 44′	With Lat., 50° S., Dec. 19½° N., opposite name to lat. bearing from tables . .	121° 17′
Subtract from 180° .	180° 00′	Add 180″ . .	180° 00′
Moon's true bearing	61° 16′	Moon's true bearing	301° 17′

It cannot be too often stated that if the latitude and declination are of opposite names, the hour angle found on pp. 160-1 of the Abridged Nautical Almanac must be subtracted from twelve hours, and the result substituted.

The declination of the moon may go up as high as 29° on either side of the equator, so that after 23° the sun tables are not available ; in this case the star tables may be used, using vols. 1 or 2 according to the latitude.

The principle of looking out the bearings is exactly the same as in the sun tables, or the amplitude tables in Inman's may be used.

In the left-hand column of the star tables will be found the body's hour angle—that is, its angular distance from the meridian ex ressed in time.

Opposite the hour angle and under the declination of the body, will be found the true bearing.

These bearings are, however, only given for when the body is some degrees above the horizon, consequently interpolation will be necessary.

As the rate of change of the bearing of a body varies with its altitude, declination, and position of the observer, this interpolation will not be rigorously exact, but for compass work it will be quite near enough.

The rule for naming the bearing is, like in the sun tables, given at the foot of each page.

Example.—Lat. 40° N., Dec. 30° N. Required true bearing at rising and setting.

By table on pp. 160-1 of Nautical Almanac the body's hour angle when rising and setting is $7^h\ 56^m\ 00^s$.

On p. 33 of Davis' star tables, for 40° lat. and under 30° dec., same name, the first bearing given after the body is above the horizon, is for an hour angle of $7^h\ 50^m\ 0^s$, and is 50°·2.

Now the change between the bearing for $7^h\ 40^m$ and $7^h\ 50^m$ is 1°·6, and bearing increasing.

Therefore the change for six minutes is $\frac{6}{10}$ of 1°·6.

That is to say, the change is ·96 of a degree, say 1 degree. Therefore the bearing at rising and setting will be 50°·2 − 1°·0., i.e. 49°·2, named according to the rule at the foot of the page. So that bearing at rising will be 49°·2, and at setting 360°·00 — 49°·2., i.e. 310°·8.

As stated before, these bearings are not absolutely exact, but are near enough for compass work.

In connection with these bearings, there is another method of looking out the true bearings at rising and setting. This can be done by means of the 'Amplitude Table' given on pp. 138-41 of Inman's tables.

Before explaining the tables, it may be as well to state that an amplitude is merely the bearing of the body when rising or setting, reckoned from the *east* or *west* point according as to whether the body is rising or setting.

It differs from an azimuth, inasmuch as the latter is reckoned from the *north* point, *and the amplitude only applies to a body when on the horizon.*

Running across the top of the pages are the degrees of declination, and down the sides are the degrees of latitude from 1 to 64.

Under each degree of declination are two columns, one headed 'Time Amp.' and the other 'Bearing Amp.'

The time amplitude is merely an interval of time to be added to or subtracted from $6^h\ 00^m\ 00^s$, which will give the hour angle of the body from the superior meridian expressed in time.

Whether it should be added or subtracted from $6^h\ 00^m\ 00^s$ depends on whether the latitude and declination are of the same or opposite names.

If they are of the same name, the hour angle of rising must be greater than $6^h\ 00^m\ 00^s$; and if they are of opposite names, the hour angle of rising must be less than $6^h\ 00^m\ 00^s$.

Similarly in the case of setting.

Therefore, if the latitude and declination are of the same name, the time amplitude found in the tables must be *added* to $6^h\ 00^m\ 00^s$; and if they are of different names, it must be *subtracted* from $6^h\ 00^m\ 00^s$.

With regard to the bearing amplitude, if latitude and declination are of the same name, the body must rise north of the east and west line, and also set north of it. If they are of opposite names, the body must rise south of the east and west line and set south of it. This will at once show which way the bearing amplitude should be applied to the east or west point.

This paragraph refers to north latitude; for south latitude, if latitude and declination are the same names, the body will rise south of the east and west line and also set south of it, whilst if latitude and declination are of opposite names, the body will rise north of the east and west point and set north of it.

Taking the example given for the star tables, it is proposed to work it out by the amplitude table as well.

Example.—Latitude 40° N., Declination 30° N. Find hour angle of body when rising and setting, also true bearing at each time.

	h. m. s.
P. 141, Inman's tables, under 30° and opposite 40°, time amplitude is	1 56 00
Lat. and dec. being same names, add $6^h\ 00^m\ 00^s$+	6 00 00
Time amp. or hour angle of body from superior meridian on rising	7 56 00
Which agrees with the hour angle given in the last example.	
P. 141, Inman's tables, under 30° and opposite 40°, bearing amp. is	40° ·8
[As lat. and dec. are same names, this will be north of the east point.]	
East point	90° ·0
Bearing of body	49° ·2
Which agrees with bearing given in the last example.	

Similarly, the setting hour angle will be $6^h\ 00^m\ 00^s + 1^h\ 56^m\ 00^s$, which gives $7^h\ 56^m$ 00 from the meridian. And the bearing will be 40°·8 north of the west point, which gives a bearing of 270° 00′ 00″ + 40°·8 or 310°·8. Or 90°·0 – 40·8 = 49·2, west of the north point and $360^\circ{\cdot}0 - 49^\circ{\cdot}2 = 310^\circ{\cdot}8$. This agrees with the bearing given in the first example.

The east and west points are reckoned as being $6^h\ 00^m\ 00^s$ in time, and 90° in arc away from the north and south points.

The following figures may be of assistance for amplitude work.

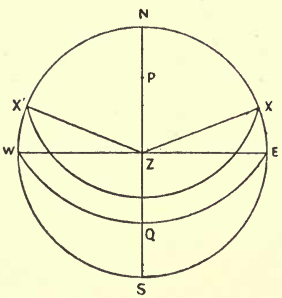


FIG. 61.—North Lat. Lat. and Dec. same name.

Body rises at X and sets at X′, XZE and X′ZW are the amplitudes from the tables, and X and X′ must be north of the east and west line, so that the hour angles SZX and SZK′ are greater than 90°, i.e. greater than $6^h\ 00^m\ 00^s$, so that amps. must be added.

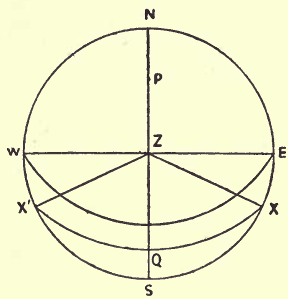


FIG. 62.—North Lat. Lat and Dec. opposite names.

Body rises at X and sets at X′, XZE and X′ZW are the amplitudes from the tables, and X and X′ must be south of the east and west line, so that the hour angles SZX and SZX′ are less than 90°, i.e. less than $6^h\ 00^m\ 00^s$, so that amps. must be subtracted.

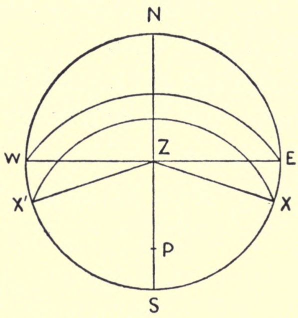


FIG. 63.—South Lat. Lat. and Dec. same name.

Body rises at X and sets at X′. Same remarks as in Fig. 61 apply.

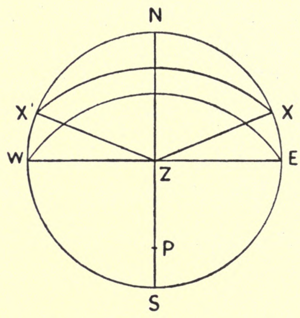


FIG. 64.—South Lat. Lat. and Dec. opposite names.

Body rises at X and sets at X′. Same remarks as in Fig. 62 apply.

CHAPTER X

CHART WORK

Admiralty Charts.—These are of two kinds—the 'Gnomonic' and the 'Mercator's.'

The gnomonic projection is used for plans of harbours, where the scale of the chart exceeds two inches to the mile, for charts above the latitude of about 70° north and south, and for polar charts.

It is constructed on the following principle:

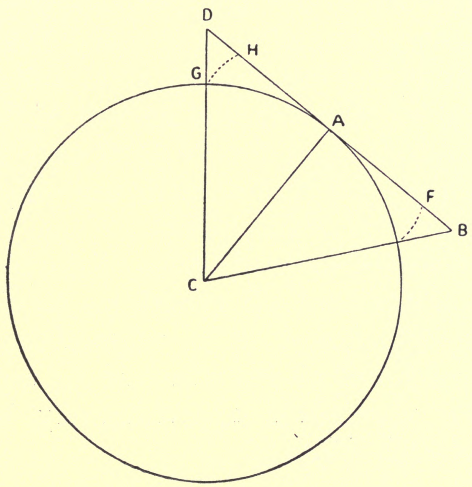


Fig. 65.

The observer is supposed to be situated at C, the centre of the earth, which is supposed to be transparent so that he can see the surface.

A is the central point of the part to be surveyed, and from this point a tangent DAB is drawn to the earth's surface. This point A is known as the 'Point of Tangency.'

The arc GAE of the earth's surface is the part to be surveyed, and lines CG, CA, CB are drawn, produced if necessary, to cut the tangent to the earth's surface at D, A, and B respectively.

Hence the arc GAE will be represented by the straight line DAB.

Reference to the figure will show that CA being at right angles to the line DAB, the observer is looking directly at A, and at any other point on this line he will be looking more and more obliquely as D and B, the extremities, are approached, the maximum being at the points D and B.

Hence at A there will be no distortion, but this will increase all round on leaving A, reaching a maximum at the edges of the chart.

The amount of distortion of the arc GAE will be represented approximately by the amount DH–BF.

The plan of a harbour, representing as it does such a very small portion of the earth's surface, has practically no distortion; but in a polar chart, embracing as it does a big area, may have a considerable amount.

The Mercator's Chart.—This principle is used for general charts, coasting sheets and between the limits of about 70° north and south. After about 70° the distortion becomes so rapid and excessive that its use is prohibitive.

The principle of construction is as follows:

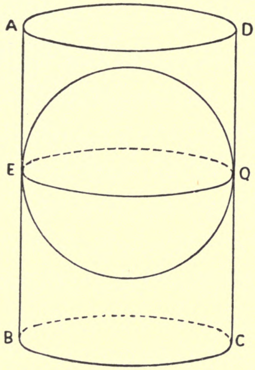


FIG. 66.

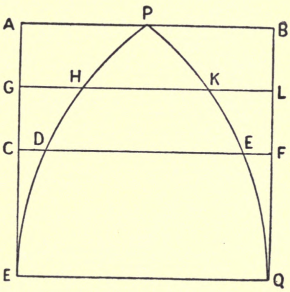


FIG. 67.

In Fig. 66 imagine a cylinder of paper ABCD to be wrapped round a flexible globe marked with the meridians and parallels, so that it is touching along every point round EQ, the globe's equator.

If the globe be now blown out until every point on its surface touches the cylinder, and the latter be then removed and laid out flat, it will be found that all the meridians and parallels are represented by straight lines at right angles to one another.

Fig. 67 gives a section of the earth from pole to equator.

It will be readily seen that along the line EQ, or, in other words, along the equator, there has been no distortion, as the cylinder was already touching the globe.

As one goes towards either pole, it will be seen from the figure that the parallel of latitude DE has been expanded to the length CF, and the parallel HK to the length GL. As the parallel HK is less than DE, and as GL and CF are equal to one another, it follows that HK must have been expanded a greater amount than DE.

Hence, as the poles are approached, the expansion must get greater and greater.

As AB, GL, CF, and EQ are all equal, the degrees of longitude on a Mercator's chart must be represented by parallel straight lines, and therefore they must be all equal to one another.

The degrees of longitude having been expanded on an increasing scale as the poles are approached, the proportion of the chart must be preserved by expanding the degrees of latitude in the same proportion as the degrees of longitude have been.

And as this expansion becomes greater as the latitude is increased, the degrees of latitude will become larger and larger from the equator to the north and south.

For this reason, when measuring distance on a Mercator's chart, the latitude scale should *always* be used, and if the two places are far apart in latitude, the mean of middle latitude must be taken as the measuring point.

Theoretically, a Mercator's chart can be constructed nearly up to the pole itself, but the construction fails here, because the pole, being a point, has, according to Euclid, no parts and no magnitude, and would therefore have to be expanded to infinity.

In practice, Mercator's charts are not constructed for a higher latitude than about 70° north or south, as after that the distortion increases very rapidly, and the degrees of latitude get so very long, that the chart would become unwieldy owing to its size.

A Mercator's chart is constructed according to the following method, of which an example is now given.

Supposing it is required to construct a Mercator's chart on a scale of 'x' inches to a degree of longitude, between certain limits of latitude and longitude.

The only table required is the one in Inman's tables, called 'Meridional Parts.'

This table merely gives the distance represented on a Mercator's projection, of any distance from the equator, instead of the true one.

For instance:

Latitude 50°, $50° \times 60' = 3000'$, i.e. the parallel of 50° is 3000′ from the equator. The table of meridional parts gives for latitude 50° 3474·47 miles; this means that, according to the Mercator's projection, the parallel of latitude 50° would be drawn in 3474·47 miles from the equator.

Example.—Construct a Mercator's chart between the parallels of 50° and 54° north latitude, and between the meridians of 3° and 7° east longitude, on a scale of two inches to one degree of longitude.

The rule is:

Length of a degree of latitude *equals* Difference between its limiting meridian parts *multiplied by* scale of longitude and *divided by* 60′.

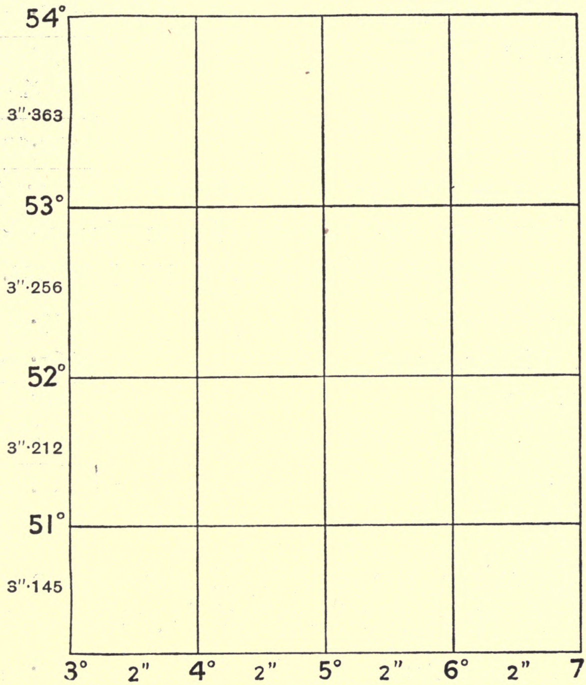


FIG. 68.

Draw in the lower horizontal line, and mark it off in equal spaces of two inches each to the limits of the longitude required.

Draw perpendiculars to each of the ends of this line. It is now required to measure off along these perpendiculars the length of each degree of latitude.

Lat. 50° Mer. Parts	3474·47
Lat. 51° Mer. Parts	3568·81
Difference	94·34
	×2
60	188·68
	3·145

Therefore the length of the degree of latitude between 50° and 51° is 3·145 inches.

Lat. 51° Mer. Parts . . .	3568·81
Lat. 52° Mer. Parts . . .	3665·19
Difference	96·38
	×2
60	192·76
	3·212

Therefore the length of the degree of latitude between 51° and 52° is 3·212 inches.

Lat. 52° Mer. Parts . . .	3665·19
Lat. 53° Mer. Parts . . .	3763·76
Difference	98·57
	×2
60	197·14
	3·286

Therefore the length of the degree of latitude between 52° and 53° is 3·286 inches.

Lat. 53° Mer. Parts	. . . .	3763·76
Lat. 54° Mer. Parts	. . . .	3864·64
Difference	. . . .	100·88
		×2
	60	201·76
		3·363

Therefore the length of this degree will be 3·363 inches.

These distances can now be measured off along the perpendicular lines and the remaining necessary meridians and parallels put in.

One great advantage of a Mercator's chart is, that the course between any two places can be found by joining the two, placing a parallel ruler along this line, and transferring it to one of the compasses engraved on the chart. Where the ruler cuts the graduated circle on the compass will be the course required.

CHAPTER XI

INFORMATION GIVEN ON AN ADMIRALTY CHART, CONVENTIONAL SIGNS AND SYMBOLS

THE information given on an Admiralty chart is expressed by means of certain signs and symbols, which should be carefully studied, as by knowing them thoroughly the various markings can be read at a glance like the print in a book.

On the seaward part of the chart are given the soundings or depth of water at a certain standard state of the tide, the various banks and shoals with the depths over them, arrows showing the direction of the tidal streams, the various harbours, lights, light vessels, buoys, etc.

Soundings on banks which are underlined may mean two things: either the amount they uncover, or the depth on them at high water. This can always be ascertained by looking at the title of the chart.

On the land part of the chart are given

the general topography of the coast, the nature of the coast line, whether rocky, cliffy, sandy, etc. ; the various lighthouses, towns, harbours, hills, roads, villages, railways, etc. The topography is, however, not given in such detail for any distance inland as it is in an ordnance map, as it is not so much required by the seaman.

On one side of the chart is engraved what is known as the 'Title of the Chart'; the information contained in this is important, and should be carefully studied for each chart.

The date of printing is given on the lower margin of the chart.

When using an Admiralty chart, it must be remembered that the nautical mile is used as a unit, which is equivalent to 6000 feet in length, and this nautical mile is subdivided into ten 'cables' of 600 feet each.

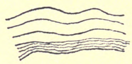
In the Admiralty chart drawn on the Mercator's principle, the latitude scale will be found running up and down the sides of the chart, and the longitude scale along the top and bottom.

This longitude scale must *only* be used for measuring the difference of longitude between two places, and *never* for distance.

In an Admiralty *plan* a scale of latitude and distance is always given, and usually a scale of longitude.

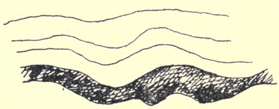
Should the latter not be shown, it is easy to construct one if required, and the method of doing this will be given later.

Conventional Signs and Symbols in Use on Admiralty Charts.



Steep coast.

Islands and rocks.



Cliffs.

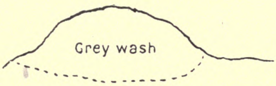
Sandy shore.

Shingle or stony shore.

Breakers.

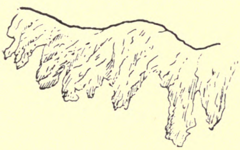
CHART SYMBOLS

Stones, shingle, or gravel, dry at L.W.O.S.

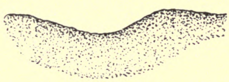


Mud, dry at L.W.O.S.

Sand, gravel, or stones, dry at L.W.O.S.



Rocky edges which cover and uncover.

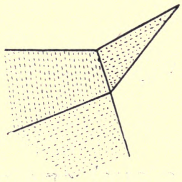


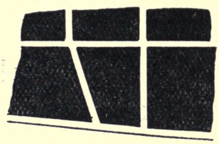
Sandy beach.

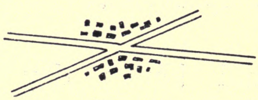
Sand banks, dry at L.W.O.S. Figures on banks denote either amount they uncover at L.W.O.S. or depth at H.W.O.S. This information is always given on title of chart.

Sand hills


Trees.


Cultivated land.


Towns.


Villages.


Swamp or marsh.

+ Church or chapel.

● Beacon, flagstaff, or chimney.


Windmill.

Roads:

1st Class.

2nd Class.

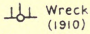
Track.

Railway.

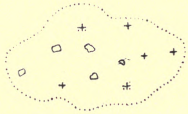
Tramway.

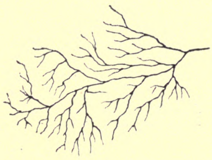

Rock awash at L.W.O.S.

+ Rock with less than six feet of water at L.W.O.S

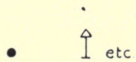


Wreck submerged.


Rocks with limiting danger lines.


Kelp.

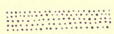

Fishing stakes.

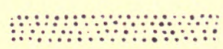


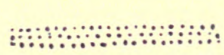
Beacons.


Light vessels.

Fathom Lines


1 fathom.


2 fathoms.


3 fathoms.

4 fathoms.

5 fathoms.

.... 6 fathoms.

so on till 10 ,,

·–·–·–·–·–·–·–·– 10 fathoms.

··–··–··–··–··–··– 20 fathoms.

so on till 90 ,,

.... 100 fathoms.

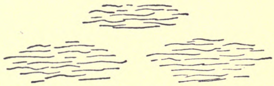
Quality of the Bottom of the Sea

b	Blue.	m	Mud.
blk	Black.	mus	Mussels.
br	Brown.	oz	Ooze.
brk	Broken.	peb	Pebbles.
c	Coarse.	r	Rock.
chk	Chalk.	s	Sand.
cl	Clay.	sft	Soft.
crl	Coral.	sh	Shells.
d	Dark.	shin	Shingle.
f	Fine.	spk	Speckled.
g	Gravel.	st	Stones.
gn	Green.	w	White.
grd	Ground.	wd	Weed.
gy	Grey.	y	Yellow.
h	Hard.		

Tidal Abbreviations

Equin^{l}.	Equinoctial.	L.W.O.S.	Low Water Ordinary Springs.
Fl.	Flood.	m.	Minute-s.
H.W.	High Water.	Np.	Neaps.
H.W.O.S.	High Water Ordinary Springs.	ord.	Ordinary.
h.	Hour-s.	Q^{r}.	Quarter.
kn.	Knot-s.	Sp. or Spr.	Springs.
L.W.	Low Water.		

 Eddies.

 Overfalls.

Abbreviations for Buoys

B., Blk.	Black.	S.B.	Submarine Fog Bell (sounded by wave action).
Cheq.	Chequered.	S.F.B.	Submarine Fog Bell (mechanically sounded).
G.	Green.	V.S.	Vertical Stripes.
Gy.	Grey.	W. Wh.	White.
H.S.	Horizontal Stripes.	Y.	Yellow.
No.	Number.		
R.	Red.		

ABBREVIATIONS ON CHARTS

Abbreviations for Lights

L^{t}., L^{ts}.	Light-s.
L^{t} Alt.	*Light Alternating.
L^{t} F.	*Light Fixed.
L^{t} Fl.	*Light Flashing.
L^{t} Occ.	*Light Occulting.
L^{t} Rev.	*Light Revolving.
L^{t}F.FL.	*Light Fixed and Flashing.
L^{t} Gp. Fl.(2)	*Light Group Flashing.
L^{t}F.Gp. Fl.(3)	*Light Fixed and Group Flashing.
L^{t} Gp. Occ.(3)	*Light Group Occulting.

Alt.	Alternating.
ev.	Every.
fl., fl^{s}.	Flash-es.
G., Gn.	Green.
Gp.	Group.
hor^{l}.	Horizontal.
irreg.	Irregular.
m.	Miles.
min.	Minute-s.
obsc^{d}.	Obscured.
occas^{l}.	Occasional.
R.	Red.
sec.	Second-s.
(U)	Unwatched.
vert^{l}.	Vertical.
vis.	Visible.
W., Wh.	White.

* Position of lights.

N.B.—Figures in parenthesis after the description of a light, denote the number of flashes or occultations in its cycle or phase.

General Abbreviations

B.	Bay.
Bat^{y}.	Battery.
Bk., Bks.	Bank-s.
Bn., Bns.	Beacon-s
Br.	Bridge.
C.	Cape.
Cas.	Castle.
Cath.	Cathedral.
C.G.	Coast Guard
Ch^{y}.	Chimney.

Conspic.	Conspicuous.
Cr.	Creek.
D.	Doubtful.
dist.	Distant.
Estab^{t}.	Establishment.
Fm., Fms.	Fathom-s.
F.S.	Flagstaff.
f^{t}, ft.	Foot, Feet.
F^{t}.	Fort.
h., hrs.	Hour-s.
H^{d}.	Head.
H^{n}.	Haven.
Ho.	House.
H^{r}.	Harbour.
I., I^{t}.	Island, Islet.
I^{s}.	Islands.
in.	Inch-es.
L.	Lake.
Lit.	Little.
L, La, Lag^{n}	Lagoon.
Lat.	Latitude.
L.B.	Life Boat.
L.B.S.	Life Boat Station.
L^{dg}.	Leading.
L^{e}., L^{es}.	Ledge-s.
L.S.S.	Life Saving Station.
L^{t} Ho.	Lighthouse.
L^{t}. Vess.	Light Vessel.
m.	Mile-s.
Mag^{z}.	Magazine.
Mon^{t}.	Monument.
Mon^{y}.	Monastery.
M^{t}.	Mountain.
Obs^{y}.	Observatory.
Ord.	Ordinary.
Pass.	Passage.
P.D.	Position Doubtful.
Pen^{la}.	Peninsula.
p^{k}.	Peak.
Pos^{n}.	Position.
Prom^{y}.	Promontory.
R.	River.
R^{f}.	Reef.
R^{d}., R^{ds}.	Road-s.
R^{k}., R^{ks}.	Rock-s.
R.S.	Rocket Station.
Ru.	Ruin.
R^{y}.	Railway.
s.	Second-s.
S^{d}.	Sound.
Sem.	Semaphore.
Sh.	Shoal.

Sig.	Signal.	Uncov.	Uncovers.
St^{n}.	Station.	Vil.	Village.
Str.	Strait.	W.T.	Wireless Telegraphy Stn.
Tel.	Telegraph.		
Temp^{y}.	Temporary.	Y^{ds}.	Yard-s.
Tr.	Tree.		

System of Lighting

Lights may be divided into two classes, as follows:

(1) Those whose colour does not change in its entire system.

(2) Those whose colour does change.

The following table gives the various descriptions of the different lights.

Lights whose Colour does not Change.	Characteristic Phase.	Lights whose Colour does Change.
Fixed	A continuous steady light	Alternating
Flashing	(1) A single flash at regular intervals, the period of light being less than the period of darkness (2) A steady light varied at regular intervals with a sudden and total eclipse, of greater duration than the light	Alternating Flashing
Group Flashing	Shows a group of two or more flashes at regular intervals	Alternating Group Flashing

Lights whose Colour does not Change.	Characteristic Phase.	Lights whose Colour does Change.
Occulting	A steady light varied at regular intervals by a sudden and total eclipse, the period of light being equal to or greater than the period of darkness	Alternating Occulting
Group Occulting	A steady light varied at regular intervals by a group of two or more occultations	Alternating Group Occulting
Fixed and Flashing	A steady light varied at regular intervals by a single flash of relatively greater brilliancy: this flash may or may not be preceded by a short eclipse	Alternating Fixed and Flashing
Fixed and Group Flashing	As above, but with a group of two or more flashes	Alternating Fixed and Group Flashing
Revolving	Light gradually increasing to full, then decreasing to eclipse	Alternating Revolving

The letter (U) against a light denotes that it is unwatched, and too much reliance must not, therefore, be placed on seeing it.

Certain details of the lights are given opposite them on the charts; should a fuller description be required, all details will be found in the Admiralty Light Lists, which are published every year.

The height stated against a light is the height of the centre of the lantern above high water springs.

The distance of visibility given in the light lists and against the light on the chart, is calculated for a height of eye of 15 feet above the sea level.

Light vessels are painted red in England and Scotland, and black in Ireland, with their name in white letters on each side. These latter are not shown during the war. They carry a distinguishing mark by day, and their light by night.

Should they be out of position, they strike their day mark by day ; and at night, instead of showing their light, they show a red light at each end of the vessel, and a red flare up.

The following problems all come under the heading of chart work, and will be found useful at times.

To Construct a Scale of Longitude if none is given on Chart :

Draw a straight line AB and divide it into a number of convenient units according to the scale of latitude of the chart.

From the point A, draw a line AC making with the line AB an angle BAC equal to the latitude of the place.

From each of the divisions *a*, *b*, *c*, *d*, etc., on the line AB, draw perpendiculars to the line AC, cutting it at the points *a′*, *b′*, *c′*, *d′*, etc.

The divisions A*a′*, *a′b′*, *b′c′*, *c′d′*, etc., will be the scale of longitude required.

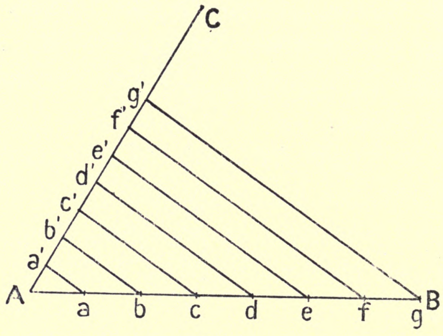


FIG. 69.

Since the triangle *a*A*a′* is a right-angled triangle, having its right angle at *a′*, the scale of longitude can be found as follows :

$$\frac{Aa'}{Aa} = \text{Cosine } aAa'.$$

$$\text{i.e. } Aa' = Aa \times \text{Cosine } aAa'$$

or scale of longitude = scale of latitude × cosine latitude.

To Lay Off a Course.—This is a comparatively easy matter, and can be done in two ways.

(*a*) By Parallel Ruler.

Join the points of departure and arrival by a straight line. Place the parallel ruler on this straight line, and transfer its direction to one of the compasses engraved on the chart so that the edge of the ruler is over the centre of the compass.

The reading on the outer edge of the compass card will give the course to be steered.

Care should be taken to take the side of the compass card nearest to the point of arrival.

(*b*) By Transparent Protractor.

Place the centre of the protractor on the point of departure, taking care that its sides are pointing true north and south.

Draw the string tightly along until it is over the point of arrival.

The degree on the protractor over which the string passes will be the true course to be steered.

Variation must be applied if the magnetic course is required.

To Allow for Drift Due to Wind.—It must be remembered that the compass only gives the direction of the machine *through the air,* and to get the direction of the actual course made good *over the land,* an allowance for drift will have to be made.

The direction of this allowance must, of course, be always into the wind, the amount depending on the speeds of the machine and wind, and the relative angle between the course of the aeroplane and the direction of the wind.

The method of finding the allowance for the drift is as follows :

Example:

It is required to fly from A to B. The wind is blowing in the direction shown by the arrow at 10 units (miles, knots, kilometres, etc.) per hour. The speed of the machine is 86 units per hour. What is the course to steer, and what will be the distance made good over the land in one hour ?

Join AB.

From A lay off a line AC parallel to, and *with* the wind's direction, and mark off along it a distance AC equal to, say, one hour's effect, i.e. 10 units.

With centre C and radius equal to 86 units (1 hour's machine speed), sweep an arc cutting AB at D.

Join CD and draw AE parallel to CD.

AE referred to the compass is the course to steer, and AD is the distance in units made good *over the land* in one hour.

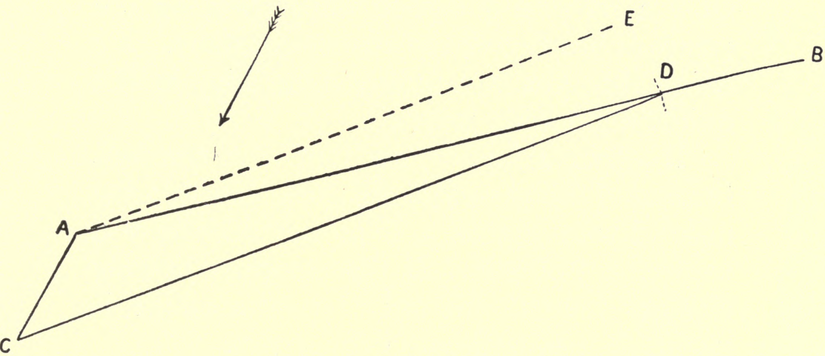


FIG. 70.

Intercepting Hostile Aircraft.—Three cases come under this heading as follows :

(*a*) When the enemy is in sight of the pilot.

(*b*) When they are out of sight of one another, but in a wind of the same direction and strength.

(*c*) When they are out of sight of one another, and in winds of different direction and strength.

N.B.—In case (*c*) it is presumed that the force and direction of the wind at the place where the enemy passed over has been telephoned to the air station.

Case (*a*).—When the pilot is in sight of the enemy.

Upon all these occasions endeavour to steer a *converging* course whilst keeping the compass bearing of the enemy constant. By doing this, you are approaching him in the quickest possible way.

If observation shows that the compass bearing of the enemy is changing towards the nose of your machine, it means that he will pass ahead of you. If the compass bearing changes towards the tail of your machine, it means that he will pass behind you.

In the first case, the course should be altered *away* from the enemy; and in the second case, the course should be altered *towards* him.

This, of course, is only the principle of the problem; the two machines may be flying at different altitudes, one may be faster than the other, the enemy may alter course, etc., so that much must be left to the pilot's discretion; but if he acts on the above principle, he will be doing all he can to close the enemy.

Example:

A pilot at A sights an enemy machine at B, bearing 100°, and steering approximately in the direction BM.

A steers in the direction AC at first, and on

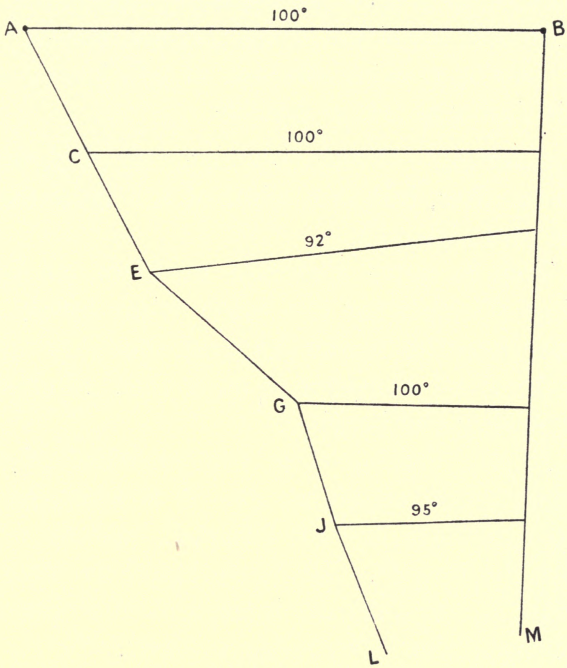


FIG. 71.

arriving at C, finds the bearing of the enemy machine to be still 100°. He therefore keeps on his course.

At E he finds the bearing of the enemy to be 92°, showing him that he is going ahead of the enemy.

He therefore alters his course to EG.

At G he finds that the enemy is bearing 100°, showing him that the latter is going ahead of him.

He then alters course to the direction GJ, and on arrival at J, finds the bearing is now 95°.

He then steers the course JL, and finding that the bearing remains constant at 95°, knows that he is closing as fast as possible.

Case (*b*).—When they are out of sight of one another, but in a wind of the same direction and strength.

This is quite a simple problem, as both being affected by the same wind force, the latter may be neglected, and the only thing to do is to consider it as a case of closing preserving the bearing.

In the figure, C is the position of the enemy when reported, and A the aerodrome you are stationed at, situated east 60 miles from the former. He is reported as steering north at 45 miles an hour, and the speed of your machine is 85 miles an hour.

Firstly. — To find the course necessary to steer, the following procedure should be adopted.

Join AC.

From C lay off the enemy's course CE, and mark off along this line a part CB equal to the enemy's speed for one hour, i.e. 45 miles.

With centre B and a radius equal to your speed for one hour, i.e. 85 miles, describe an arc cutting CA, produced if necessary, at D.

Join BD.

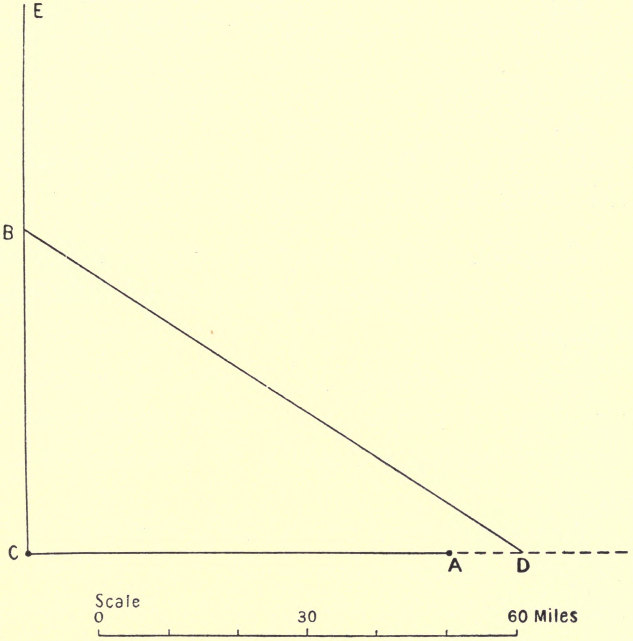


FIG. 72.

BD will be the course to steer from A.

Secondly.—To find the rate of closing, or, in other words, to find how long you will be before you will catch him.

Measure the number of units contained in the line CD. This will be the rate of closing in one hour, and in this case is 71 units.

So that the time taken to catch the enemy will be :

$\frac{AC}{CD}$. This equals $\frac{60}{71} = 0{\cdot}84$ of an hour or 50·4 minutes.

N.B.—This problem can be worked out either on a chart or on a mooring board, whichever is found most convenient.

Case (*c*).—When they are out of sight of one another, and flying in winds of different strength.

Example.—Information is received at your aerodrome that a hostile machine has passed over a station A, *making good* 290° at the rate of 40 miles per hour.

Your aerodrome is 190° 42 miles from this point, and you have a machine capable of a speed of 70 miles per hour. The wind at your station is north-east (45°) at 12 miles per hour.

What course must you steer to intercept the enemy, and how long will you be getting there ?

Note.—It should be remembered that the enemy, as reported, is making good course and speed given. If his course and speed and direction and force of the wind are signalled, you will have to work out *first* what he is *making good,* and then proceed as given below.

A is the position of the enemy, and B your aerodrome. From A lay off AC equal to one

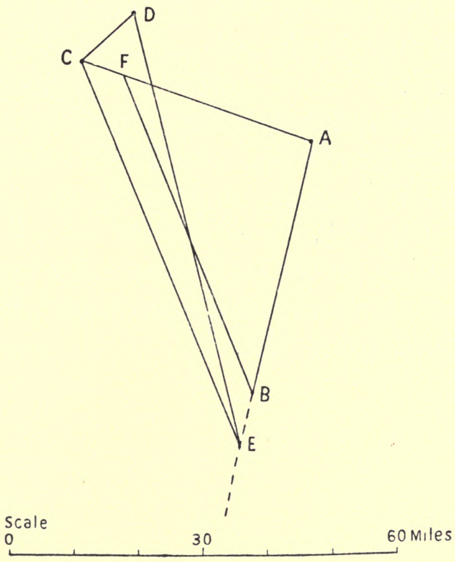


FIG. 73.

hour's course and distance made good by the enemy.

From C lay off CD in the direction the wind is coming *from,* equal to the speed of your wind for one hour.

With centre D and a radius equal to one

hour's speed of your machine, sweep an arc cutting AB, produced if necessary, at E.

Join DE and EC.

From B draw BF parallel to EC.

DE will be the course to steer, and EC will be the course and distance made good by your machine in one hour.

BF is the course and distance made good by steering a course parallel to DE, and the two machines will meet at F. The time taken will be $\frac{AF}{AC}$, i.e. $\frac{32}{40} = 0{\cdot}8$ hrs. or 54 mins.

These distances can be actually measured on the chart or mooring board, and the time ascertained from that.

CHAPTER XII

FIXING POSITIONS

In an aeroplane, one of the best methods of fixing one's position is to be able to read a chart or map thoroughly so that, if flying over the land, one can tell just what spot is vertically under the machine.

As, however, this is not always possible in a seaplane, it is proposed to explain one or two methods of fixing. The last method given will be more suitable for airships or observation balloons, where there is a great deal more room than on an aeroplane.

(*a*) *Fixing by 'Cross Bearings.'*—Choose two objects that are marked on the chart as nearly 90° apart as possible, as this will give a very definite cut.

Correct these bearings for variation and deviation, and you are ready to lay off on the chart.

Place the parallel rulers over the centre of the compass engraved on the chart, and turn it round until the edge of the ruler is cutting the corrected bearing on the edge of the compass.

Transfer this line to the first object, and draw a line through it in the *opposite* direction to your bearing. Do exactly the same with your second bearing.

The intersection on the chart of these two lines will be your position.

Example :

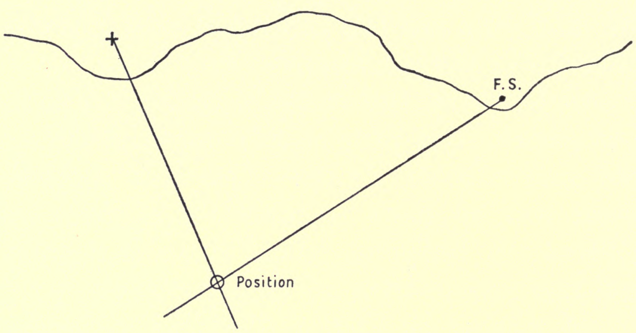


FIG. 74.

After correction the church bears 336° true and the flagstaff 57° true.

Draw your lines in the direction 156° and 237°, i.e. from the objects, and the intersection at the circle will be your fix.

(*b*) ***Fixing by Doubling the Angle on the***

Bow.'—This is a very simple method, and merely consists of taking a bearing of an object ' x ' degrees on the bow of your machine and noting the time, and again taking the bearing when it is ' 2 x° ' on the bow with, of course, the time again. Knowing your engine speed, or your speed over the land, you get your distance run in the interval of time between the two bearings and :

Distance run in the interval = Distance off at second bearing.

Example :

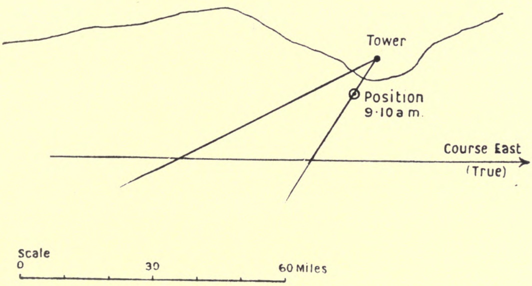


FIG. 75.

Speed, 60 miles per hour. Course, east (true).

9 A.M. Tower bore, 54° (true).

9.10 A.M. Tower bore, 27° (true).

Distance run in 10 minutes is 10 miles.

Therefore position at second bearing is, with tower bearing 27° (true), distant 10 miles.

Fixing by Station Pointer.—To understand this method of fixing, it will be necessary to go into the theory a little.

Fixing by station pointer does not call for the use of a compass : all that is required is a sextant and an instrument known as a station pointer.

The station pointer fix depends on a certain theorem in Euclid (iv. 5), which states that a circle can be drawn through any three points.

If, therefore, three points on the chart be chosen, and taking our position as the fourth point, it is obvious that we can draw two circles as follows :

One circle passing through the left-hand object, the middle object, and our position.

The other circle passing through the right-hand object, the middle object, and our position.

From this we see that these two circles will intersect at two common points, viz. at the centre object and at our position, and as we cannot be at the former, the second intersection must be our fix.

Another theorem that the station pointer fix depends on is Euclid (iii. 21), which states that the angles on the circumference of a circle, subtended by the same chord, and on the same side of the chord, are equal to one another. So that all we have to do is to observe two angles to our three chosen objects, and place these angles on the station pointer and fit them in on the chart. This does away with the necessity of actually drawing in the circles. The size of the circles is, of course, governed by the dimensions of the observed angles.

The following figure shows why we must be at the second intersection of the two circles.

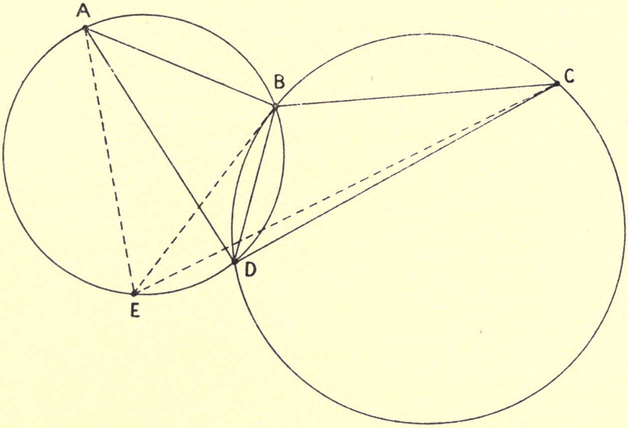


FIG. 76.

The angles ADB and BDC are the angles actually observed. Now D is the only point we can be at, for, supposing we were at E, although the angle AEB is equal to the angle ADB, yet the angle BEC is not equal to the angle BDC, which latter was the one taken with the sextant. Hence there can be only one place that will fit in with our observed angles, and that is the point D which is common to both circles.

In practice, all that has to be done is to take two angles between the three objects chosen, place these angles on the station pointer, fit its three legs over the three points on the chart, and the small nick in the centre leg indicates your position.

A certain amount of care is necessary in the selection of the objects. The following examples are worth remembering:

(1) The objects may lie in the same straight line.

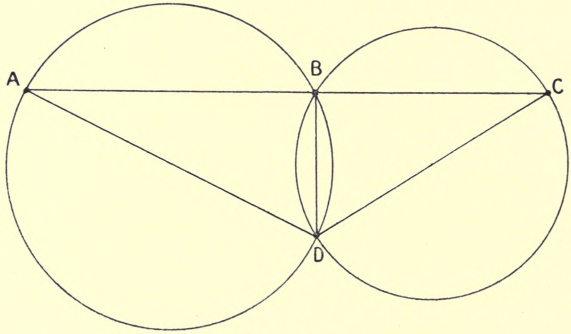


FIG. 77.

(2) The objects may lie in a curve, with the middle object nearest to the observer.

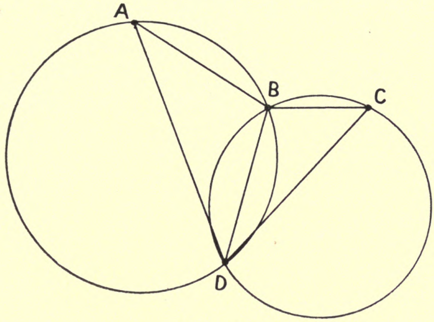


FIG. 78.

(3) The objects may lie in a curve, concave to the observer, provided the latter is on or within a line joining the right and left hand objects.

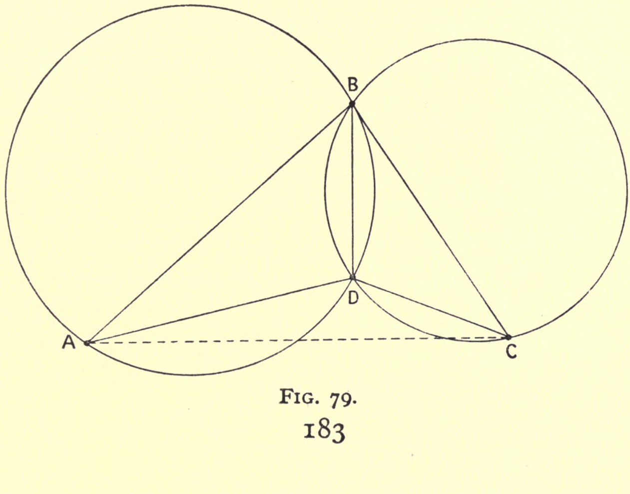


FIG. 79.

(4) The objects may lie in a curve, concave to the observer, provided the latter is well *outside* the circle passing through the three objects.

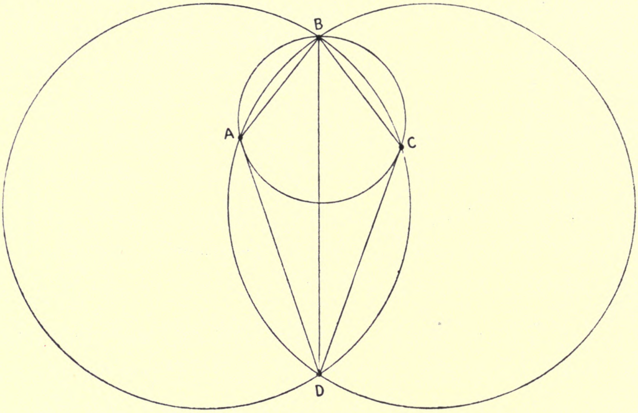


FIG. 80.

(5) Two of the objects may be in transit with the observer. In this case one angle to the third object is all that it is necessary to take.

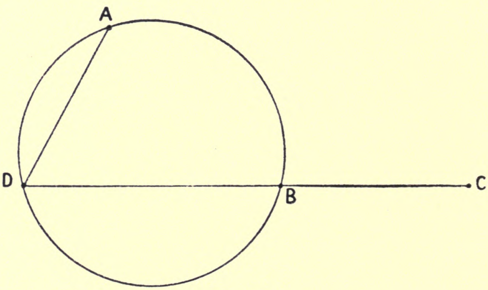


FIG. 81.

(6) If two of the objects are much nearer to the observer than the third, and seem about equidistant from the observer, at whose position they subtend an angle of between 60° and 120°, the fix is a good one.

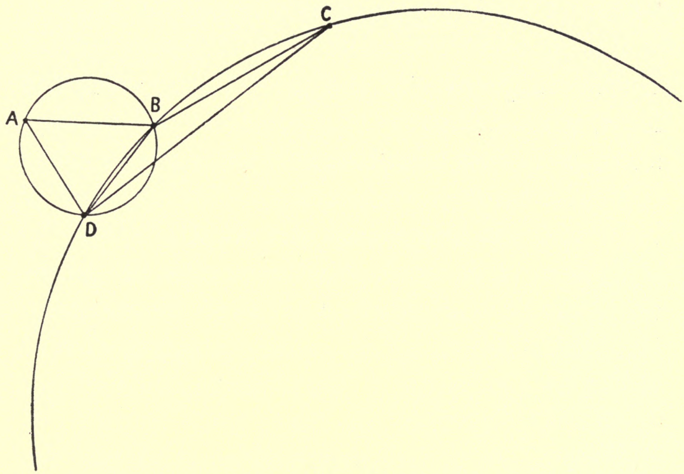


FIG. 82.

CHAPTER XIII

ORDNANCE MAPS

THESE maps are to the pilot flying over the land, what a chart is to a seaman navigating a ship, with the advantage that, given a clear day, the pilot can always see the land below him, which is impossible in a ship.

There is a much greater wealth of detail, as regards the land, in an ordnance map than in a chart, as obviously a navigator at sea does not require the topography for any distance inland.

Ordnance maps are constructed on the gnomonic projection, and are not provided with any magnetic compass, so that all courses have to be referred to the true north and south, which direction is given on the inner border of the map. The sides of an ordnance map are not graduated like a Mercator's chart, but a scale is provided at the bottom of each map in whatever unit of length it is drawn to, i.e. miles, yards, or feet.

The *statute* mile of 5280 feet is used in ordnance maps, unlike the Admiralty chart, where the unit is a sea mile.

In using an ordnance map which is not squared, it is convenient to draw a series of parallel lines to the true north and south lines to facilitate laying of courses. It is also better to cross these lines with east and west ones.

Conventional Markings.—These are as follows:

Hills are shown in brown, their heights being those above a certain level, which is given at the foot of each map.

Rivers and canals are coloured blue.

First class roads are coloured red.

Second class roads are left uncoloured.

Railways are denoted by thick black lines.

If the map shows any part of the sea, this is coloured blue.

Towns and villages are represented by black blocks of rectangular or other shape, with the streets running through them, the amount of detail shown depending on the scale of the map.

Woods are coloured green.

Lakes are coloured blue.

Isolated houses are denoted by black dots.

All other symbols conform to those given on Admiralty charts.

To Lay Off a Course.—A celluloid protractor is supplied, marked from 0 to 360 in the same way as a compass card.

It is pierced in the centre, and a string is let through the hole.

To lay off a course, the centre of the protractor is placed on the starting-point, with its sides parallel to the true north and south line.

Place the string over the point it is desired to go to, and draw it tight.

The degree on the protractor that the string passes over will be the *true* course required.

To Measure a Distance.—This is done by means of a pair of dividers. Place one point of the latter on the starting-place and the other point on the place you wish to go to. Transfer this distance to the scale at the bottom of the map.

Should the distance be too big for the dividers, put a certain or convenient distance on the latter from the scale, and run this distance along a straight line joining the two points, noting how many times it goes into the total distance.

Squared Maps.—These are ordnance maps divided into large rectangles, each named by a letter.

These rectangles are divided into thirty or thirty-six squares, each of whose sides are 1000 yards long.

The squares are numbered from 1 to 30, or 1 to 36, starting at the top left-hand corner and running across to the right.

Each of these squares is divided into four squares, each of whose sides is 500 yards long.

These squares are lettered as shown below.

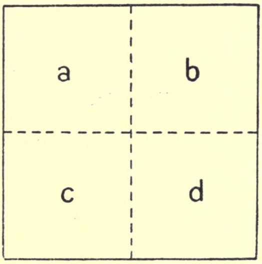


Fig. 83.

In any report sent in, the centre of the small square is taken as the spot mentioned; but if more accuracy is required, a cardinal or semi-cardinal point can be introduced, giving the direction of the object from the centre of the small square.

If great accuracy is required, each side of the small square can be divided into ten equal parts, each 50 yards long, always starting from the south-western end of the square. In this case, the number along the east and west line is always mentioned first.

Example:

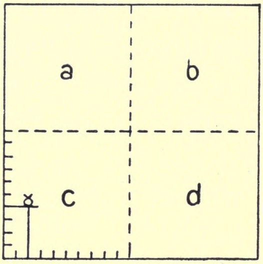


FIG. 84.

Supposing there was a windmill in square 'c' as shown, and it was required to report its position accurately.

It was located in rectangle B. 26 c., but to be absolutely accurate, it should be reported as Windmill B. 26 c. 2, 4.

A sketch of the whole rectangle is given below.

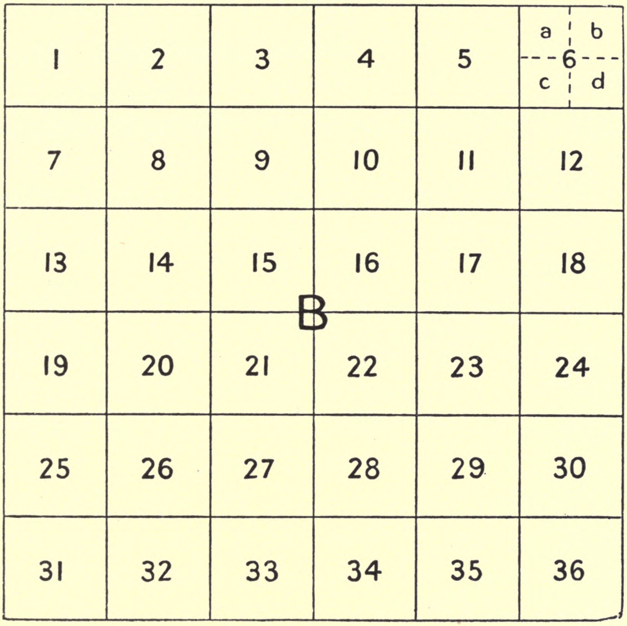


FIG. 85.

Only one of the squares of each rectangle is marked *a, b, c, d.* This is to prevent over-crowding, but all the others follow the same law.

A scale is provided at the bottom of each squared map, and a magnetic compass is printed on the north-west corner. The topography is the same as on an ordinary ordnance map.

Selection of Suitable Landmarks, etc.—When flying from one place to another, it is desirable to check the position as frequently as possible.

This can easily be done in clear weather, provided the pilot can read his map thoroughly.

If possible before a flight, the pilot should look over his map, and note what he would expect to pass over on his way. During the flight he should endeavour to pick up each of these marks as he passes them.

Roads, rivers, canals, railways, bridges, lakes, woods, villages, and towns are all good marks, as are tall chimneys, churches, clumps of trees on hills, etc.

Very often a distant mountain peak or other conspicuous object will give him a good mark for direction, either by steering straight for it, or keeping it a little on one side of the machine.

Variation of Wind Velocity with Height, page 206.

The Gradient Wind, page 208.

These Tables have been included here by the kind permission of the National Physical Laboratory, Teddington, Middlesex.

printed on the north-west corner. The topography is the same as on an ordinary ordnance map.

these marks as he passes them.

Roads, rivers, canals, railways, bridges, lakes, woods, villages, and towns are all good marks, as are tall chimneys, churches, clumps of trees on hills, etc.

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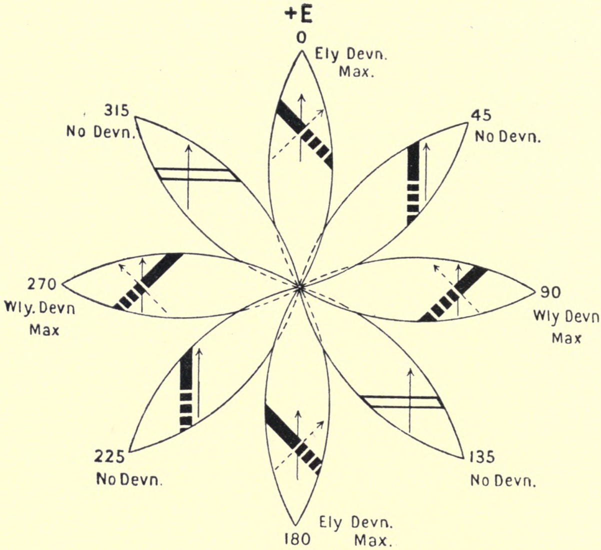
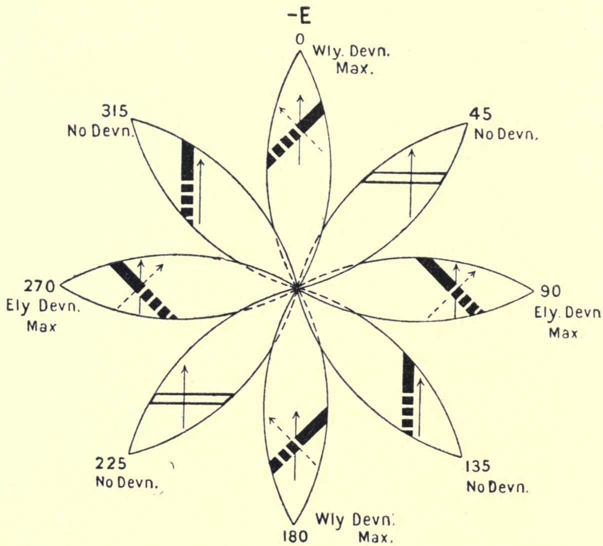
APPENDIX





Coefficient E

APPENDIX

Coefficient E.—This is due to the effect of induction in horizontal soft iron running diagonally.

If it runs from left front to right rear, ' E ' is + ; if from right front to left rear, ' E ' is —

It is maximum on the cardinal points, diminishing to zero on the quadrantal points.

It is found by taking the mean of the deviations on the cardinal points, changing the signs of those on east and west.

It is called ' Quadrantal ' because it changes its sign in each quadrant.

It is corrected in conjunction with Coefficient ' D ' by placing the spheres at an angle θ with the transverse line, if ' D ' is + ; and with the longitudinal line, if ' D ' is —; so that

$$\text{Tangent } 2\theta = \frac{E}{D}.$$

If ' E ' is + the left-hand sphere goes in front : vice versa for — E.

The amount to be corrected is

$$\sqrt{D^2 + E^2}$$

See Diagram on opposite page.

Composition of the Air.—Air is an invisible gas largely composed of nitrogen and oxygen in the following proportions:

Nitrogen	77·11 per cent.
Oxygen	20·65 ,,
Water Vapour . . .	1·40 ,,
Argon	0·79 ,,
Carbonic Acid . . .	0·04 ,,

Height of the Air.—From various observations, the most important of which is that of meteors, it is estimated that the major portion of the atmosphere extends about one hundred miles above the earth's surface, also that it exists from there to a height of 400–500 miles, but of course in a very much thinner form.

Density of the Air.—The atmosphere is densest at the surface of the earth, and gets gradually more and more attenuated until its confines are reached. At a height of about seven miles it has only one-quarter of the surface density; about fourteen miles, one-sixteenth; whilst at twenty-one miles merely one-sixtieth.

The Meteorological Elements.—Under this heading come the following:

Pressure, Temperature, Humidity, Wind, and Cloud. The last has already been dealt with in the body of the book, and wind partly dealt with.

(1) *Pressure.*—By this is meant the capability of the density of the air at sea level to support a column of mercury enclosed in a glass tube.

This pressure is nearly always changing, hence the reading of the barometer scale indicating the height of this column is scarcely ever the same from hour to hour.

Pressure is measured by a barometer, which is merely a glass tube filled with mercury, which is then boiled to expel any particles of air or water vapour, and then inverted into a cup mercury.

The mercury will fall in the tube until the pressure of the outside air balances its fall and prevents any further drop in the tube. The space between the top of the enclosed column of mercury and the top of the tube is the nearest known approach to a perfect vacuum, and is known as a 'Torricellian Vacuum.'

If now the pressure of the air increases, it will press more heavily on the mercury in the cup. This will be communicated to the mercurial column, causing it to rise in the tube. Conversely, if the atmospheric pressure decreases, it will, by not pressing so heavily, cause the column to fall in the tube. This is known as the rise or fall of the barometer, and its amount is measured by a fixed and also a movable scale at the side of the tube; the latter is known as the Vernier.

Owing to friction at the sides of the glass tube, the top of the mercury assumes a convex form, as shown below.

When reading the barometer, the bottom of the pointer of the vernier plate should be brought down by the milled screw at the side so as to touch the top of the mercury, as seen in the sketch.

Owing to what is known as the 'Vertical Pressure Gradient,' barometer readings, when sending in reports, are corrected for their height above sea level to reduce them to the latter, this being the

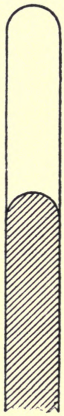


FIG. 86.

common level used on meteorological charts. The barometer has also to be corrected for the tempera-

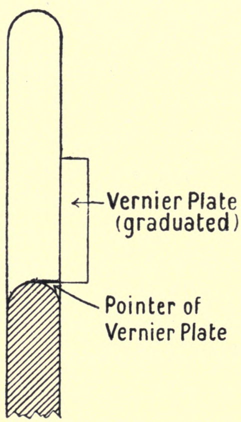


FIG. 87.

ture, owing to the column of mercury in the tube expanding or contracting according to the rise or fall of the temperature.

(2) *Temperature* is the thermal condition of a body which determines the exchange of heat between it and some other substance. Heat may be imparted in three ways:

(1) Radiation. (2) Conduction. (3) Convection.

(3) *Humidity.* — Interspersed between the molecules of nitrogen and oxygen, which are the chief constituents of air, are also molecules of water vapour invisible because of their transparency.

This water vapour is caused by the continued evaporation which is always taking place from water, ice, snow, or any moist surface. This quantity of water vapour is constantly changing owing to the evaporation from the earth's surface becoming faster or slower. As the temperature rises, the capacity of dry air for holding moisture increases, so that the warmer the air, the greater quantity of water vapour it can sustain in an invisible state. Now any given volume of dry air can only take up a certain invisible quantity of water vapour, and when this amount is exceeded the latter becomes visible as cloud mist or fog. The humidity, or in other words, the amount of moisture in the air, can be gauged by means of the wet and dry bulb thermometer.

Heating and Cooling of the Atmosphere.—The air receives its heat from the sun, but being a bad conductor, only gets a very little of it by *conduction.* The sun's rays pass through the air and strike the earth, the amount of heat the latter received depending on the obliquity of the rays. The earth *radiates* this heat received, which warms the layer of air in immediate contact with it; this warm air rises and cold air fills its place. This latter is known as *convection,* so that the air is chiefly warmed by radiation and convection and only slightly by conduction.

Measurement of Temperature.—Temperature is measured by means of a thermometer, an instrument consisting of a glass bulb and tube, the latter partly filled with mercury or alcohol, the latter for use in very cold climates. In graduating the thermometer we know of two fixed points which are always the same at sea level, viz. the boiling and freezing points of distilled water.

The thermometer being placed in each, marks are made showing the level which the mercury attains, and the space between is divided into a convenient number of divisions called degrees.

Two kinds of thermometers are in use:

The Fahrenheit thermometer.

The Centigrade thermometer.

(1) *Fahrenheit Thermometer.*—The boiling and freezing points having been marked, the space between them is divided into 180 equal parts.

When this thermometer was first invented, it was also put into a mixture of ice and salt, which produced the lowest known cold in those days. The point to which the mercury descended was taken as the zero of the scale, and was thirty-two divisions below the freezing point of distilled water. Hence, in a Fahrenheit thermometer, freezing point is represented by 32° and boiling point by 212°.

(2) *Centigrade Thermometer.*—In this thermometer the space between the freezing and boiling points of distilled water is divided into 100 parts; so that freezing point is represented by 0° and boiling point by 100°.

The Absolute Zero.—By this is meant the temperature at which gases would have no volume and exert no pressure if they went on contracting with cooling as at ordinary temperatures.

This temperature is about 459° below zero of Fahrenheit.

Measurement of Pressure.—Pressure is measured by the barometer or aneroid, whose scale is marked in inches or millibars.

The latter is about the thousandth part of the ordinary atmospheric pressure at sea level, and is also known as a 'pressure limit.'

A table giving the equivalents of mercury inches, millimetres, and millibars is given on p. 9 of the 'Handbook of Meteorology.' 29·92 mercury inches, *which is the normal* pressure in the British Islands = 1013·2 millibars; 10 millibars = 0·03 mercury inches.

The Vertical Pressure Gradient.—This is the decrease in the height of the mercury in the barometer owing to the rarefied air being unable to support the same column that it could on the sea level. This fall amounts to 1 inch of mercury in about 900 feet.

Deflection of Wind due to the Earth's Rotation.—The maximum velocity of the rotary motion of the earth occurs at the equator and diminishes to zero at either pole.

In consequence of this, a mass of air flowing from a high to a lower latitude, i.e. towards the equator, will be deflected to the westward, owing to the increased velocity of the earth. On the other hand, a mass of air flowing from a low to a higher latitude, will be deflected to the eastward, owing to the earth's decreasing velocity.

For example, a southerly wind in the Northern Hemisphere, i.e. a wind blowing from the equator towards the pole, will be deflected to the right and becomes south-westerly; and a northerly wind, i.e. setting from the pole towards the equator, is also deflected to the right and becomes north-easterly.

The direction right or left is obtained by standing with your back to the wind.

The reverse holds good in the Southern Hemisphere, the northerly wind being deflected to the left and becoming north-westerly, and the southerly wind being deflected to the left and becoming south-easterly.

From this we see that when an air current sets towards an area of low pressure, from the surrounding high pressure, it is deflected to the right and left

Example :

(1) Northern Hemisphere.

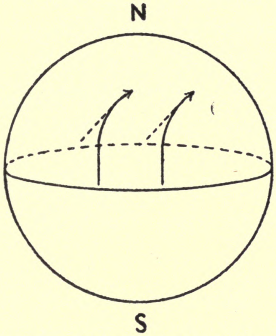


FIG. 88.—Northern Hemisphere. Southerly wind.

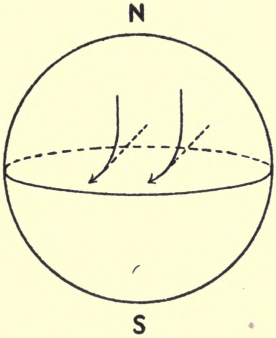


FIG. 89.—Northern Hemisphere. Northerly wind.

(2) Southern Hemisphere.

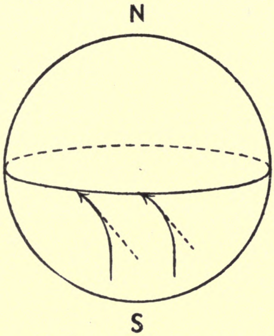


FIG. 90.—Southern Hemisphere. Southerly wind.

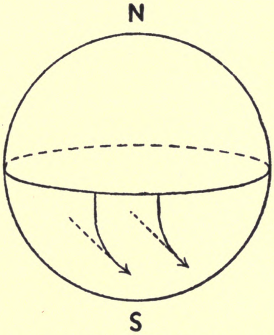


FIG. 91.—Southern Hemisphere. Northerly wind.

in the Northern and Southern Hemispheres respectively. This air current does not set directly towards the low pressure, but acquires a motion round it, but inclined inwards towards the centre of the low pressure. This circular motion is against the hands of a watch in the Northern Hemisphere, and with the hands of a watch in the Southern Hemisphere.

Again, when the air from an area of high pressure flows towards an area of low pressure, it is deflected to the right or left according to its hemisphere, and acquires a motion round the high pressure area inclined outwards.

This motion is with clock hands in the Northern Hemisphere, and against clock hands in the Southern Hemisphere.

The Different Forms of Isobars.—Isobars are divided into seven different groups, of which the cyclonic and anti-cyclonic types have already been given; the remainder, together with the weather encountered in them, are given below.

(3) Secondary Cyclone.

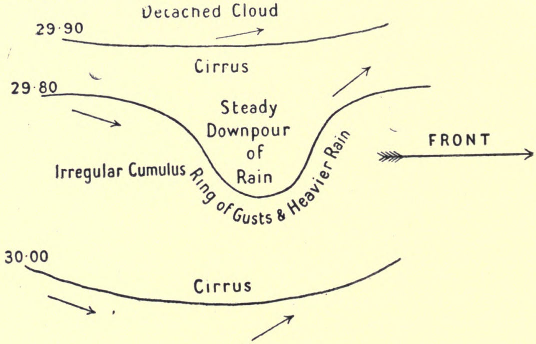


FIG. 92.

A secondary cyclone is usually found on the edge of a cyclone, but very often on that of an anti-cyclone.

(4) The Wedge.

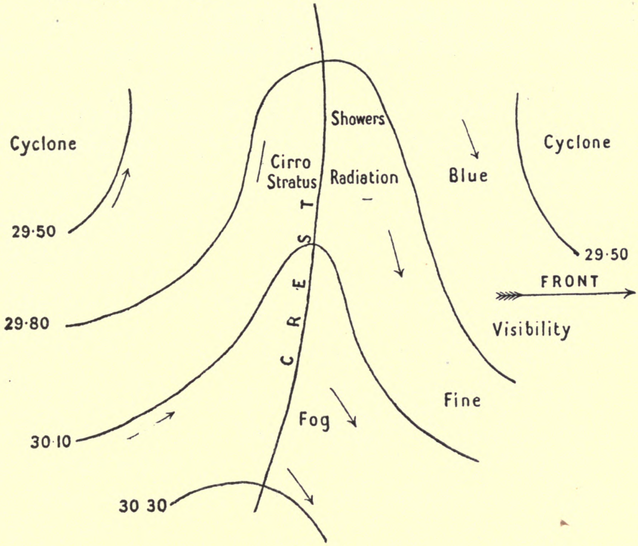


FIG. 93.

(5) The Straight Isobar.

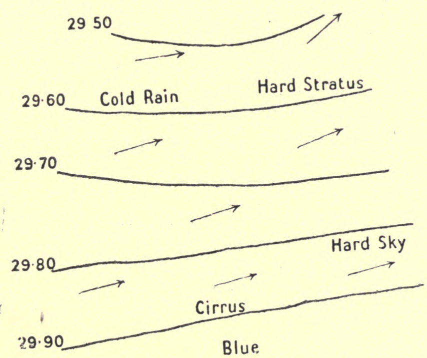


FIG. 94.

The wedge is an area of high pressure interposed between two cyclonic depressions.

The gradients are slight and the wind never strong.

The isobars may run in any direction. The wind is generally strong or gusty but does not attain gale force.

(6) The V Depression.

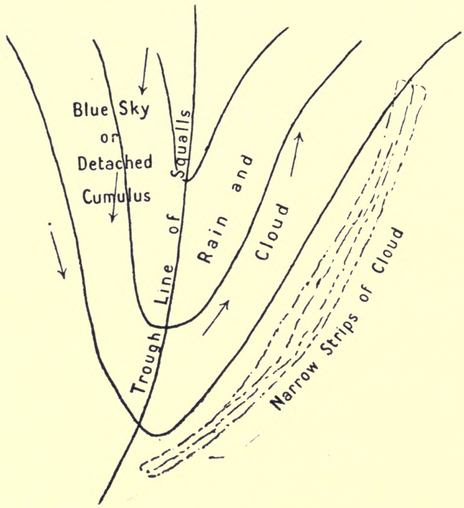


FIG. 95.

The point of the V is generally directed towards the equator, and in the Northern Hemisphere the convex side of the trough is usually facing to the eastward.

The wind does not veer in the usual manner, but the passage of the trough is marked by a sudden shift of wind and a violent squall.

(7) The Col.

This is an area of low pressure between two areas of high pressure. No typical weather is met with, but the presence of a col indicates unsettled conditions.

N.B.—Arrows show direction air currents are flowing towards.

Land and Sea Breezes.—These are met with in the tropics and also in the temperate regions during fine settled weather.

They are caused by the unequal heating of land and water.

After sunrise the land gets heated quicker than the sea, consequently the air above the former rises, and the cool air over the latter flows in to take its place, causing the 'sea breeze.'

After sunset, the land parts with its heat quicker than the sea, so that the warm air above the latter rises and the cooler air from the land flows out to take its place, causing the 'land breeze.'

Variation of Wind Velocity with Height.—It has been found by experiment that the velocity of the wind increases with the height, and tends to gradually become parallel to the isobars.

The veering of the wind with height may be roughly estimated in degrees from a certain formula.

Where 'V' is the veering and 'H' the height :

$$V = \frac{30 \times \frac{H}{1000}}{\frac{H}{1000} + 2}$$

Height.	Veering.
0	0°
1000	10°
2000	15°
3000	18°
4000	20°
5000	21°
6000	$22\frac{1}{2}$°
7000	$23\frac{1}{2}$°
8000	24°
9000	$24\frac{1}{2}$°
10000	25°
11000	$25\frac{1}{2}$°
12000	$25\frac{3}{4}$°

Fluctuation and Gustiness.—The velocity of the wind is seldom uniform, but varies in gusts and lulls.

The difference between the average maximum velocity of the gusts and the average minimum velocity of the lulls is known as the 'fluctuation of the wind.'

The gustiness of the wind is found as follows :

$$\text{Gustiness} = \frac{\text{Fluctuation}}{\text{Average velocity}}$$

Let V be the maximum and v the minimum velocity.

$$\text{Then Gustiness} = \frac{V - v}{\frac{V + v}{2}}$$

It has been found that the gustiness of the wind at any particular place for a given direction is practically constant.

Twilight.—This is caused by the air reflecting a certain quantity of light from the sun when the latter is below the horizon.

Thus, twilight occurs twice a day, in the morning and evening. There are two kinds of twilight—Astronomical and Civil. Astronomical twilight begins and ends when the sun's centre is 18° below the horizon, when only first magnitude stars are visible. It will last all night if the latitude and declination are of the same name, and their sum is not less than 72°.

Civil twilight begins and ends when the sun's centre is 6° below the horizon, when stars of the first magnitude are not visible.

The Gradient Wind.—Observation has shown that a wind due to a difference of pressure between two places is greater the bigger the difference of pressure and the closer the isobars.

If the differences of pressure over a certain area are marked on a chart by means of isobars, it is possible to calculate the force of the wind by means of a formula.

This wind is known as the 'Gradient Wind,' but the formula does not take friction into account. The gradient direction should be regarded as along the isobars.

APPENDIX

The following was table issued for finding the gradient velocity of the wind: *

V is the velocity of the wind, and D the distance apart of the isobars in nautical miles.

Then $V = \frac{2800}{D}$ at a height of about 2000 feet, where D is the distance between the isobars corresponding to $\frac{1}{10}$ of an inch of mercury.

D	V
280	10
140	20
100	28
70	40
40	70

$V = \frac{4200}{D}$ when D = distance apart of the isobars corresponding to 0·5 of a centibar.

If the standard distance apart of the isobars, i.e. fifteen miles, is used, the following table gives the velocity of the gradient wind, assuming ordinary conditions of pressure and temperature and making no allowance for the curvature of the path:

Barometric Pressure Difference per 15 Nautical Miles.	Velocity.
0·01 inch	19 miles per hour.
0·02 ,,	39 ,, ,,
0·03 ,,	58 ,, ,,
0·04 ,,	77 ,, ,,
0·05 ,,	97 ,, ,,

The observed velocity is seldom the same as the theoretical velocity, the latter being usually considerably in excess of the former.

* Permission to reprint above table has been given by the Controller of H.M. Stationery Office.

APPENDIX

High and Low Pressure Areas.—On account of the circulation of the air, the latter in high latitudes is moving faster than the earth's surface. This increases its centrifugal force, making it press on the air in low latitudes. The expansion of the air over the tropics, due to the heat, causes it to press on that in higher latitudes.

This combined effect causes a distribution of pressure as shown roughly in the figure below.

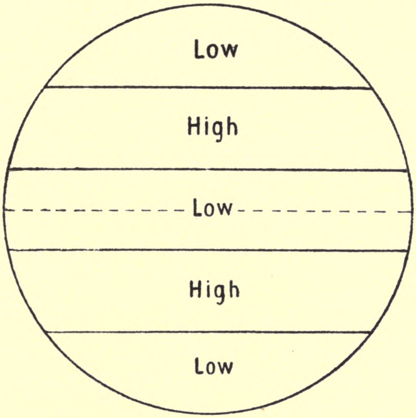


FIG. 96.

The land being more quickly affected by change of temperature than water, bigger changes are experienced, due to change of seasons, on land than on sea.

Triangle of Velocities.—Velocity not only signifies the rate of pace but embraces the quarter from which any force travels. The velocity of a point may be represented by a straight line, the speed being measured by scale, and the direction it is moving in by the direction of the line.

If a point A has two velocities AB and AC, the resultant velocity is represented by the line AD, which is the diagonal of the parallelogram ABCD.

In practice, it is only usual to draw the two lines AC and CD, of which the third side AD is the resultant.

Example :

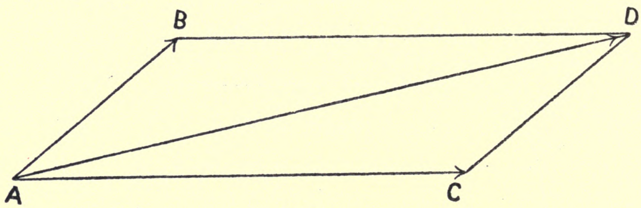


FIG. 97.

Speed of Machine	. .	North, 60 knots.
,, ,, Wind	. .	N.E., 20 knots.

Required, resultant velocity both in magnitude and direction. Scale 10 knots = 1 inch (see Fig. 98).

Radius of Action.—The radius of action in a particular direction is the farthest distance in that direction that a machine can go and return. *The area of action* is the area to every point of the perimeter of which an aeroplane can just go and return.

$$\text{Distance} = \text{Speed} \times \text{time}$$

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$$

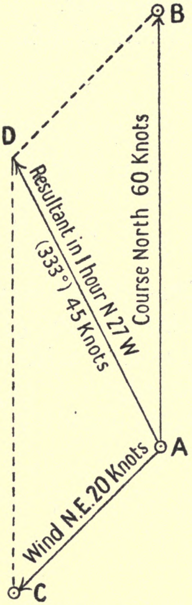


FIG. 98.

Example :

Wind ahead, 20 knots.
Speed of machine, 80 knots.
Fuel for 5 hours.

Let R = Radius of action.

Then $$\frac{R}{60} + \frac{R}{100} = 5.$$

$$R = 187{\cdot}5.$$

A machine flies 1 mile in 60 secs. with wind, i.e. 60 M.P.H.

A machine flies 1 mile in 100 secs. against wind, i.e. 36 M.P.H.

Find its speed in still air.

Let V and v be velocities in still air and in the wind respectively.

$$V + v = 60$$
$$V - v = 36$$

Then

$$2V = 96$$
$$V = 48 \text{ M.P.H.}$$

Radii of Action.—These can be worked out graphically, knowing radius of action with and against the wind together with fuel hours, and the results plotted on squared paper, the resulting radii being afterwards drawn in.

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