# CHARTS

## Charts Projection and Distortion

To create a charts. The 3-dimensional surface is transferred onto a flat surface in a process known as PROJECTION.

**When a 3-D surface is flatted to become 2-D the resulting image always suffers dome distortion.**

## TYPES OF PROJECTION

### The Reduced Earth

Chart projections originate from inside a curved, reduced Earth. They are projected physically or mathematically onto an external surface.

A spherical reduced Earth is used for physical projections.

### Parallel of Origin

It's determined by the type of projection and desired properties of charts. It may a:

- SINGLE POINT (azimuthal projection-polar stereographic chart)
- GREAT CIRCLE OF TANGENCY (cylindrical- Direct MERCATOR CHART)
- SMAL CIRCLE OF TANGENCY (conical-lambert's chart)

Projecting a curved surface onto a flat or other curved surface always cause some distortion of projected features, other than at the point of contact.

Charts are required to have certain properties. Distortion is always away from the parallel of origin. But navigation charts are reliable, provide that you navigate with their usable area. (1% distortion is accepting of navigation purposes)

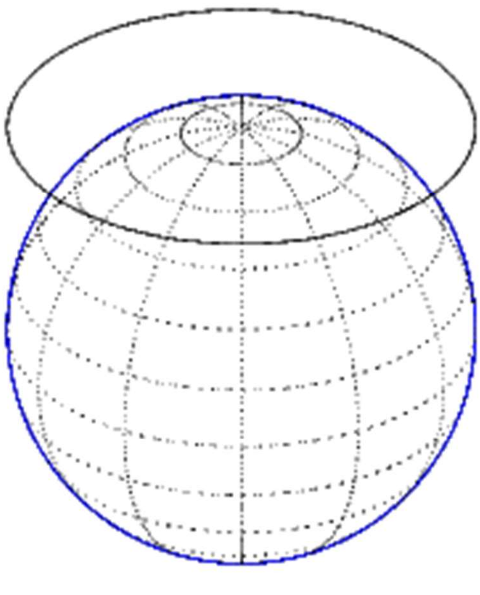
## AZIMUTHAL PROJECTIONS

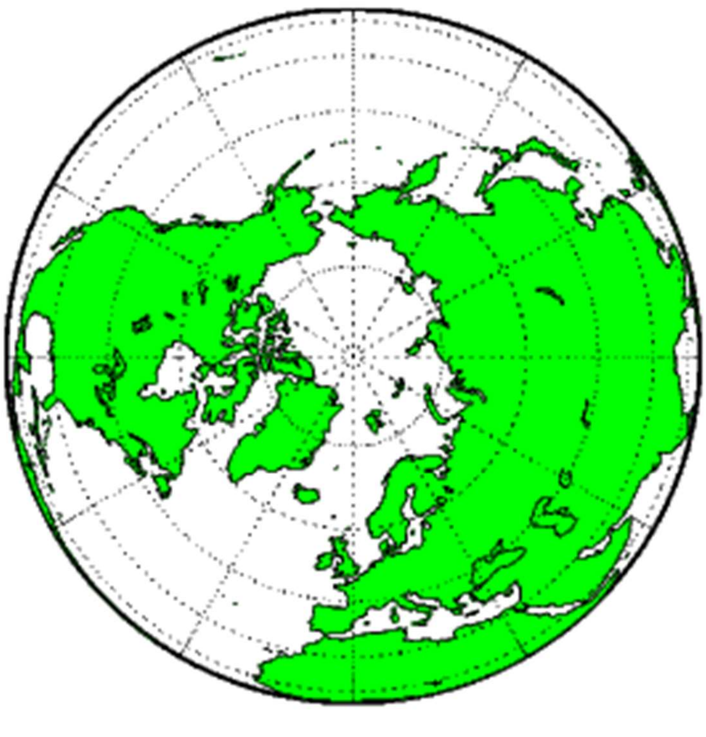
The azimuthal projections uses a simple flat plate. The reduced Earth contact the plate at a single point.

An azimuthal projection always originates from a point opposite the point of contact.

The most common type is a stereographic projection. The North Pole is projected from the South Pole and vice versa.

There is no distortion at the pole, but distortion increases with increasing distance from the pole.





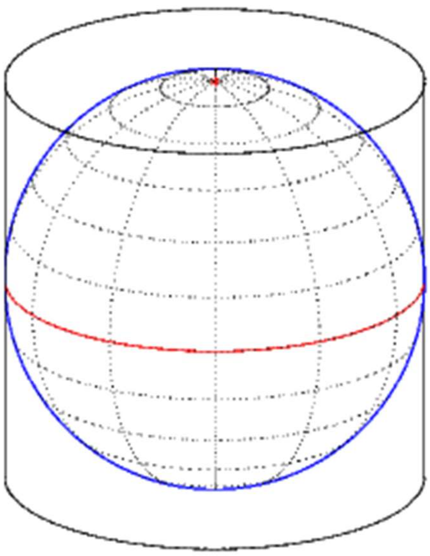
## CYLINDRICAL PROJECTIONS

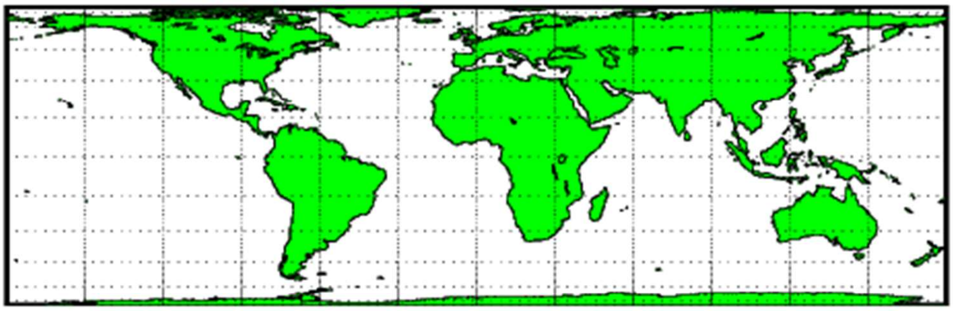
A cylindrical projection wraps around the reduced Earth, to form an open ended cylinder.

It contacts the reduced Earth around its circumference forming a ***great circle of tangency*.**

MERCATOR as the example pf cylindrical projection. The cylinder is tangential to the reduced Earth's ***great circle* of tendency** at the Equator.

The cylinder opens to form 2-D, rectangular, flat plan projection. There is no distortion at the Equator but distortion INCREASES with INCREASING DISTANCE from the EQUATOR





## CONICAL PROJECTIONS

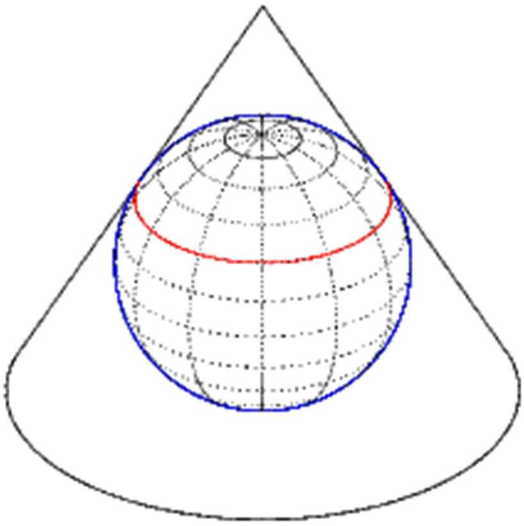
A conical projection is commonly used for mid-latitudes and uses a cone placed over the reduced Earth.

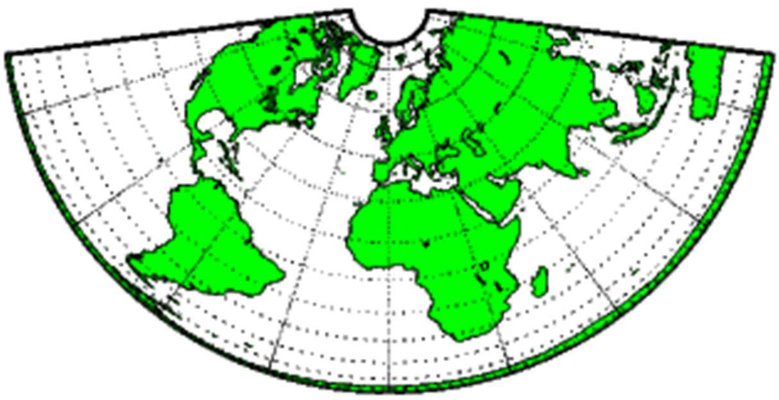
The apex of the cone is above the North or South Pole.

The cone contacts the reduces Earth at a single parallel of latitude, forming a small circle of tangency, known as PARALLEL OF ORIGIN

A shallow cone is used for higher latitudes whereas a steep cone is used for lower latitudes.

- THE PROJECTION FOCUS IS AT THE CENTRE OF THE REDUCED EARTH.
- THE CONE IS FLTATTENED OUT TO CREATE 2-D, CIRCULAR FLAT PLANE PROJECTION.
- THERE IS NO DISTORTION AT THE PARALLEL OF ORIGIN, BUT DISTORTION INCREASES WITH INCREASEING DISTANCE FROM IT.





## CONFORMAL AND ORTHOMORPHIC CHARTS

A conformal chart projection is a projection in which any angle on the surface of the Earth is accurately reproduced in the projected image.

To be conformal, a chart MUST SHOW

- A right-angled graticule
- Constant scale in all direction

Provided these a 2 conditions are met, with acceptable limits.

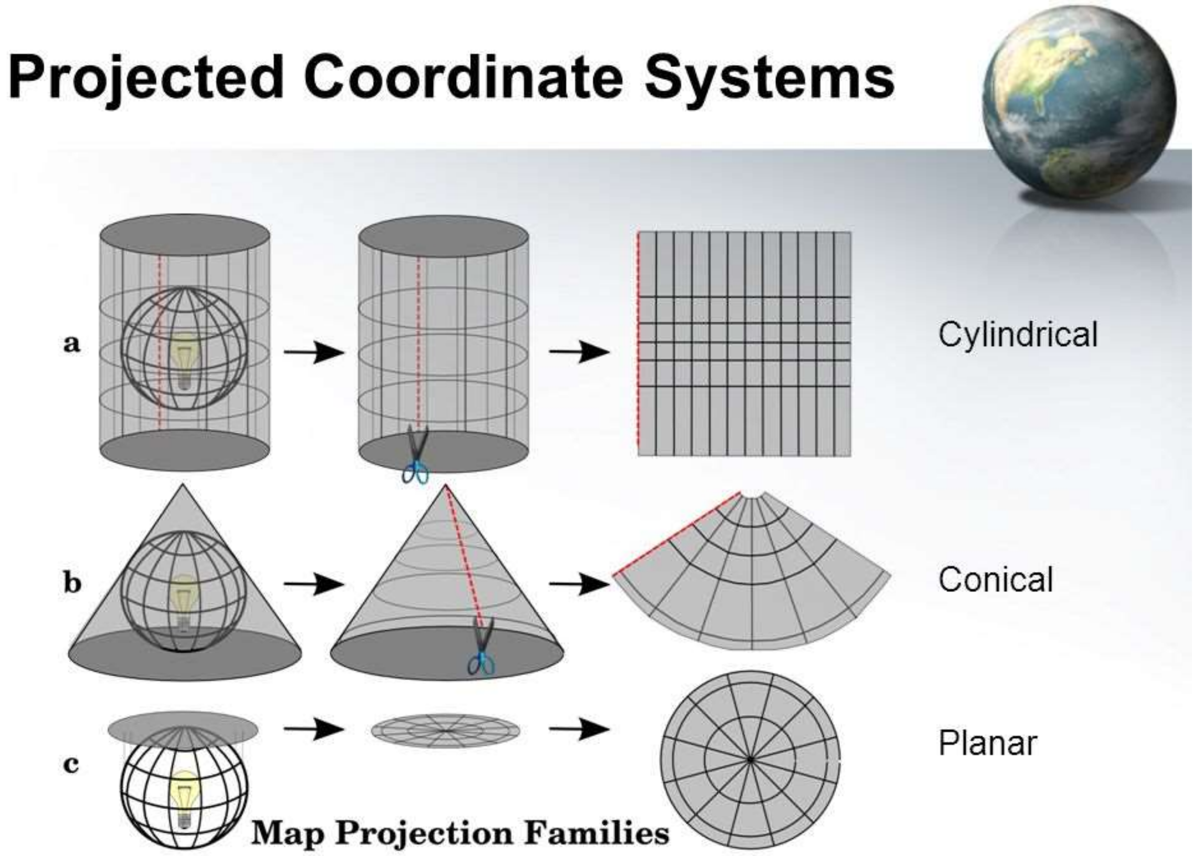
- Shapes are shown correctly
- Angles measured on the chart and the Earth are the same.
- Distance are accurately depicted.

Additionally, the ideal chart projection should.

- Show either a rhumb line or a great circle as a straight line
- Cover the area to be navigated
- Produced charts line up, when adjacent sections are fitted together.

## RIGHT-ANGLED GRATICULE

Any angle measured on a chart must accurately represent the same angle on the Earth. This means that the angle of intersections between meridians of longitude and parallels of latitude must be 90° because this is what happens on the Earth.




## CONSTANT SCALE

A chart should ideally have a constant scale over its entire surface.

However, at any point on a chart, the scale must be the same in all directions. COSTANT SCALE in all directions from a point is essential.

When the scale is constant, shapes are correctly represented and angles between shapes can be correctly measured.

| Chart Type | Projection | Origin |
|---|---|---|
| Direct Mercator | Cylindrical | Equator |
| Lambert's Conical Conformal | Conical | Parallel of Origin (Average of Standard Parallels) |
| Polar Stereographic | Azimuthal / Planar | Pole |

| Chart Type | Coverage | Usable Area |
|---|---|---|
| Direct Mercator | Equatorial regions | Approximately 500 nm (8° 20') north and south of the Equator (*Exam question states N10° - S10°) |
| Lambert's Conical Conformal | Equator to N80°/S80° Usually mid-latitudes<br><br>(*May be used between N80°-N84°) | Maximum 24°<br><br>12° north and south of the Parallel of Origin |
| Polar Stereographic | Polar regions | Between 70° and 90° |

| Chart Type | Scale | Equator |
|---|---|---|
| Direct Mercator | Correct at Equator<br><br>Expands at an equal rate north and south of the origin (Equator). | Straight, horizontal line |
| Lambert's Conical Conformal | Correct at Standard Parallels Expands north and south of origin (Parallel of Origin) Contracts inside Standard Parallels, expands outside Standard Parallels | N/A |
| Polar Stereographic | Correct at Pole<br><br>Expands away from the origin (the Pole). | N/A |

| Chart Type | Meridians of Longitude | Parallels of Latitude |
| --- | --- | --- |
| Direct Mercator | Straight, vertical, parallel equally-spaced lines | Straight, horizontal, parallel, unequally-spaced lines |
| Lambert's Conical Conformal | Straight lines converging towards the nearer pole | Curved lines concave to the nearer pole |
| Polar Stereographic | Straight lines converging at the pole | Curved (circular) lines concave to the nearer pole |

| Chart Type | Great Circles | Rhumb Lines |
| --- | --- | --- |
| Direct Mercator | Curved lines, concave to the origin (the Equator) | Straight lines |
| Lambert's Conical Conformal | Curved lines, concave to the origin (the parallel of origin) | Curved lines, concave to the nearer Pole. |
| Polar Stereographic | Curved lines, concave to the origin (the Pole) | Curved lines, concave to the Pole. |

# CRP-5 AIRSPEED CALCULATIONS

Before start to speak how to calculate the AIRSPEED we look forward (from MET) how to calculate the Temperature.

## HOW TO CALCULATE THE TEMPERATURE?

The ISA describe model atmosphere used for aviation:

***ISA SEAL LEVEL:***

- Temperature = +15°C
- PRESSURE= 1013.25hpa
- Density= 1.225kg/$m^3$

***Laps Rate:***

- Temperature= -2C/1000ft
- Pressure= 1hpa/30ft

***Tropopause:***

- ALTITUDE= 11 000m/36 000ft
- TEMPERATURE=-56.5°C

## EXAMPLE

What's the ISA temperature at FL 150?

ISA SEA LEVEL TEMPERATURE= +15°C

ISA= 15°C-( 15 000/1000) x 2= -15°C

## ISA DEVIATION

***<u>ISA DEVIATION= OAT- (ISA STANADRD TEMPERATURE)</u>***

EXAMPLE

The OAT at FL240=-13°C? What's this as an ISA DEVIATION?

- ISA=15°C-(24 000/1000) x2= -33°C
- ISA DEV= OAT- (ISA STANDARD TEMPEARUTE)
- ISA DEV= -13+33°C= +20°C

Remember that, when removing the brackets, a "minus" will produce a "plus"

## RAM-RISE

The difference between SAT and TAT just add or subtract the ram-rise as applicable.

**TAT= SAT+ RAM RISE**

**SAT= TAT- RAM RISE**

**SAT and OAT are one and same**

# RAM-RISE ON THE CRP-5

Ram-Rise is read from “TEMP RISE” scale on the CRP-5

- LOCATE the TEMP RISE scale on the CRP-5 calculator side
- LOOK UP the TAS on the upper scale of TEMP RISE scale
- READ the ram-rise on the lower scale of the TEMP RISE scale

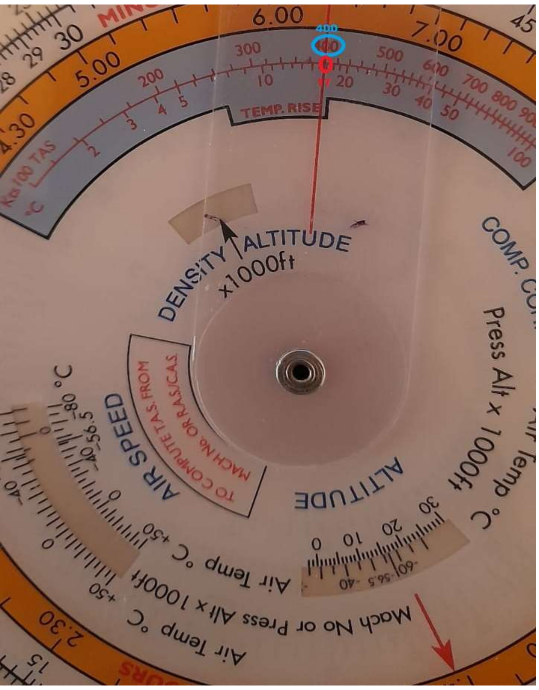
EXAMPLE:

An Aircraft cruising at a TAS of 400kt indicated an OAT of -35°C.

What’s the SAT?

LOOK UP TAS = 400kt on the upper scale

READ RAM-RISE = 17°C on the lower scale

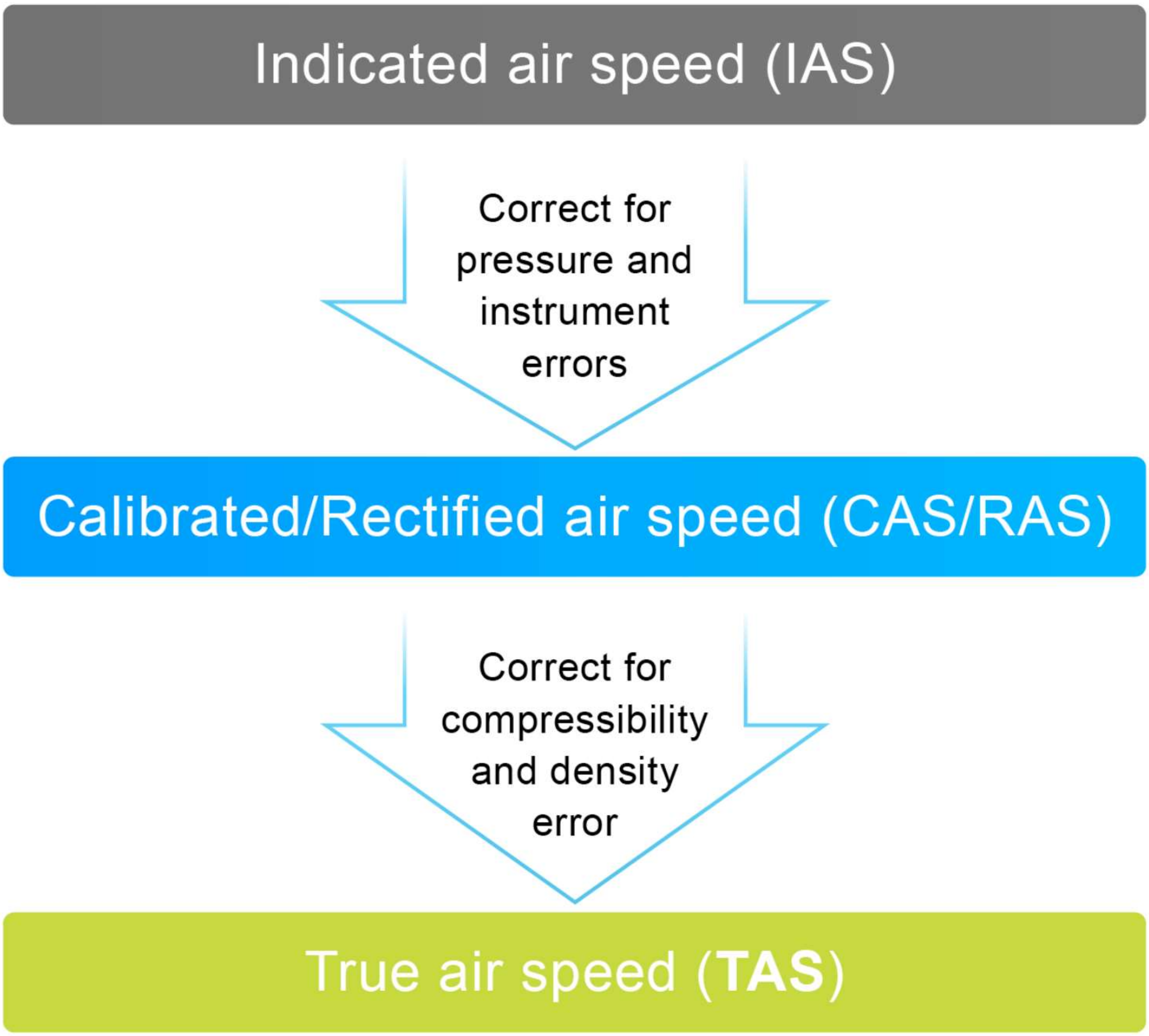


SAT= TAT- RAM RISE

SAT= -35°C- 17°C= **-52°C**

**AIRSPEED**

This image show the steps need to convert from the simple ISA shown by ASI to the TAS of aircraft.




MACH NUMBER(MN): This is the ratio between TAS and LSS (Local Speed of Sound). MN 1.0 is the ratio when TAS=LSS.

**MN= TAS/LSS**

## CALCULATION OF CAS and TAS by Rule-of Thumb

TAS can be calculated from CAS by applying a rule-of-thumb which increase TAS from CAS by 2% per 1000ft

***CAS INCREASE= CAS x 0.02 x (Altitude /1000)***

When you have calculated the increase, simply add it to original CAS to find the TAS

**TAS= Original CAS + CAS INCREASE**

EXAMPLE

An aircraft is in level flight at FL 100 in ISA CONDITIONS at CAS of 100kt.

What is the equivalent TAS?

- CAS INCREASE= CAS x 0.02 x (Altitude/1000)
- CAS INCREAE= 100 x 0.02 x (Altitude /1000) = 20kt
  - TAS= ORIGINAL CAS + CAS INCREASE
  - **TAS= 100+20= 120kt**

USING THE CRP-5 to calculate TAS from CAS

To set ISA sea level conditions, rotate the INNER SCALE to align PRESSURE of 0 inside the Air Speed window with an OAT of +15°C on the scale outside the window.

- LOOK UP CAS= 100kt on the inner scale
- Read TAS= 100kt on the outer scale
- This is exactly what we would expect in ISA sea level conditions.

**EXAMPLE**

What's the equivalent TAS for an aircraft cruising at FL 120 (OAT -10°C) at a CAS of 120kt?

1. **Align a pressure altitude of 12 000 ft (12) inside the Air Speed window with an OAT of -10°C on the scale outside the window.**
2. **Look up CAS= 120kt (12) on the inner scale**
3. **Read TAS= 144kt (14.4) on the outer scale**

## THE EFFECT OF COMPRESSIBILITY

The effect of compressibility is mostly able to be ignored for practical plotting purpose. But above 300kt, compressibility effects become significant.

Compressibility corrections cannot be calculated when the TAS is unknown, to resolve this problem, we first calculated a UNCORRECTED TAS from CAS.

- USING A COMPRESSIBILITY FACTOR.
- USING THE COMPRESSIBILITY CORRECTION WINDOW ON THE CRP-5

**COMPRESSIBILITY FACTOR (CF) = CORRECTED TAS/ UNCORECCTED TAS**

Example : Given a compressibility factor of 0.944, what is the TAS of an aircraft cruising at FL350 (OAT: -60°C) at a CAS of 340 kt?

Align a pressure altitude of 35 000' (FL 350) inside the Air Speed window with an OAT of -60°C on the scale outside the window.

Look up CAS = 340 kt (34) on the inner scale

Read TAS = 590 kt (59) on the outer scale.

TAS > 300 kt, therefore, compressibility correction must be applied.

Corrected TAS = Uncorrected TAS x Compressibility Factor.

Corrected TAS = 590 kt x 0.944

- TAS = 557 kt

Example 13: What is the TAS of an aircraft cruising at FL 350 (OAT: -30°C) at a CAS of 216 kt?

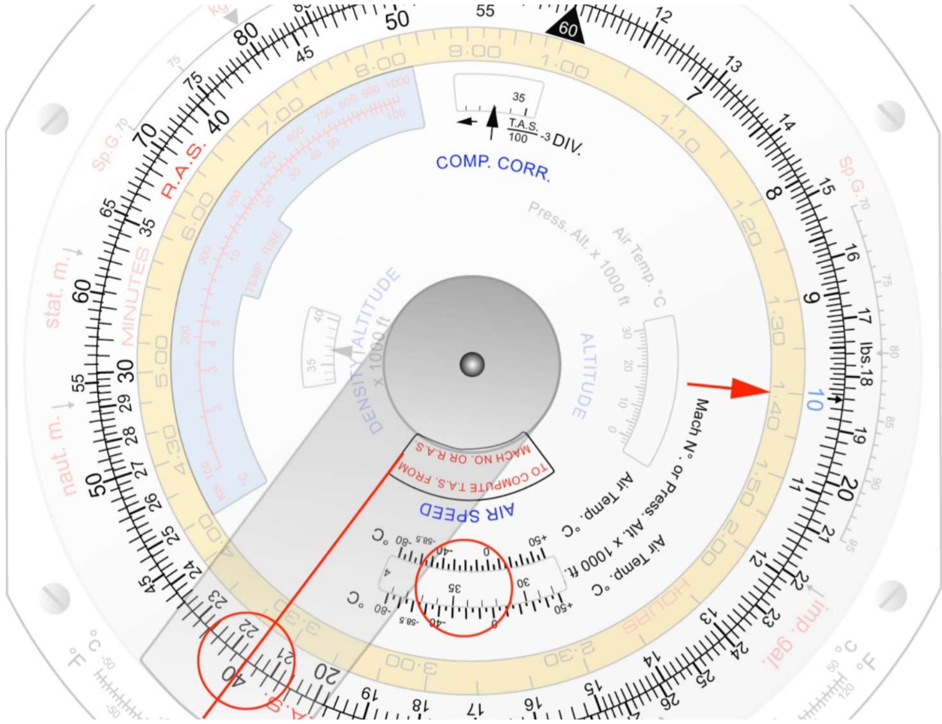
Rotate the inner scale to align the Air Speed window with the pressure altitude scale (inside the window).

Align a pressure altitude of 35 000' (35) inside the window with an OAT of -30°C on the scale outside the window.

Look up RAS = 216 kt (21.6) on the inner scale.

Read TAS = 400 kt (40) on the outer scale TAS.

- Provisional answer: 400 kt (uncorrected).




Locate the COMP.CORR. window, opposite the Air Speed window.

Calculate the compressibility correction value:

TAS/100 – 3 DIV.

Comp. Corr. = (TAS / 100) - 3

Comp. Corr. = (400 / 100) - 3

Comp. Corr. = 4 - 3 = 1

Rotate the inner scale to the left to move the division indicator a number of divisions equal to the compressibility correction value.

In this example the division indicator shows 36.5, rotate it to 37.5.

Look up RAS = 216 kt (21.6) on the inner scale.

Read TAS = 393 kt (39.3) on the outer scale.

- TAS (corrected) = 393 kt

# MACH NUMBER

MACH NUMBER is proportional to the speed of sound. For Example, aircraft travelling at Mach 0.5 is travelling at 0.5 x the speed of sound.

**MACH NUMBER= TAS/LSS**

Mache number is specifically related to the Absolute (KELVIN) scale of Temperature

To convert a temperature from CELSIUS to KELVIN simply add 273

**LSS= 38.98 √(Absolute Temperature)**

**EXAMPLE**

An aircraft is cruising at FL100 (OAT +15°C) and TAS of 516kt.

What's the MN?

LSS= 38.98 √(Absolute Temperature)---> 15+273= 288°C

LSS= 38.98 √(288°C)= 661

**MACH NUMBER= TAS/LSS**

MACH NUMBER= 516/661= 0.78

## THE CRP-5 METHOD

- ROATE the inner scale to place the Air Speed window at approximately the 12 o’clock

- An arrow and Mach NO. INDEX can be seen inside the window

- Rotate the inner scale to align the Mach No Index arrow with the OAT = +15°C

- Look up Mach 1 (10) on the inside scale, which is equal to the LSS indicated by the red arrow just inside the Time Scale.

- Read LSS=660kt on the outer scale

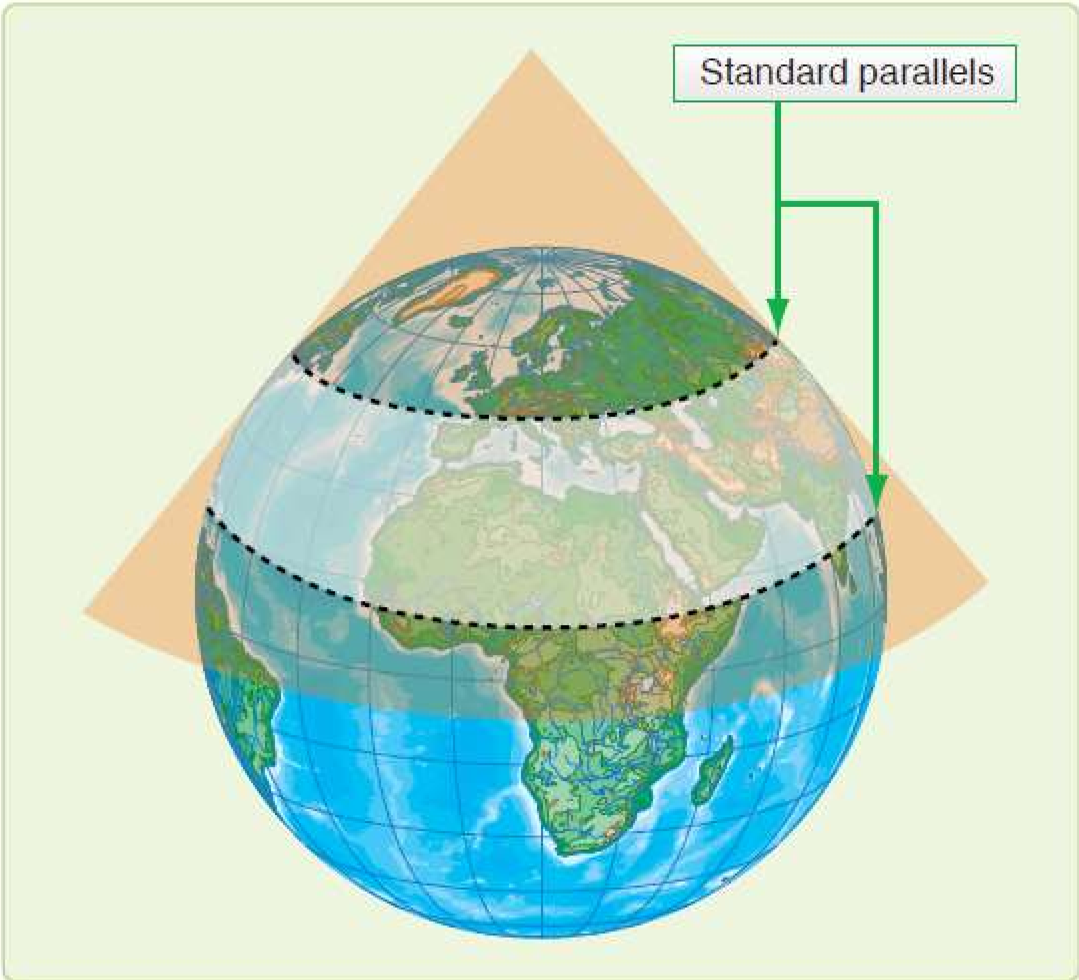
- LSS=660KT

# LAMBERT

The Lambert's Chart is a type of conic projection, where the **APEX** of the cone is directly above a pole. Cone touches the reduced Earth along a simple parallel of latitude (THE PARALLEL OF ORIGIN). This forms the small circle of tangency.

Latitude the only great circle is the Equator; Parallels of latitude are small circles.

This cone (external to the surface of the Earth) is known as a TANGENT CONE.



## THE GRATICULE

By placing the apex above the small circle of tangency coincides with a parallel of latitude.

- MERIDIANS THAT ARE STRAIGHT LINES, CONVERGING ON THE APEX AND DIVERGING TO INFINITY
- PARALLELS OF LATITUDE THAT ARE ARCS OF CONCENTRING CIRCLES
- A RIGHT ANGLED GRATICULE

## CONVERGENCY

On a conic projection the meridians are not parallel to another, so we have to deal with convergency.

- Earth convergency depends on latitude, specifically to the angle between the tangents to meridians.
- ***Chart convergency is similar, but it depends on the parallel of origin.***

Where the parallel of origin is at a low latitude, chart convergency is small.

Large values of convergency occur if the parallel of origin is set at a high latitude.

**AT HIGHRT LATITUDES EARTH CONVERGENCY > CHART CONVERGENCY**

**AT LOWER LATITUDES CHART CONVERGENCY > EARTH CONVERGENCY**

The formula will be:

**CHART CONVERGENCY = CH Long x Sin Parallel of Origin**

PARALLEL of origin is constant for a particular chart there is no need to keep recalculating it.

The *SINE* of the parallel of origin is known as the convergence factor of simply “n”

**EXAMPLE**

What’s the value of constant of the cone for a conic projection with a parallel of origin N45°?

Constant of the cone = Sin Parall of origin

Constant of the cone = Sin (45°) = 0.707

**EXAMPLE**

A conic projection has a convergence factor of 0.3955. At which latitude on the chart does Earth Convergency equal Chart Convergency?

Parallel of Origin= $Sin^{-1}$ (Convergence Factor)

**Parallel of Origin= $Sin^{-1}$ 0.3955= 23°18’**

**HOW TO CALCULATING THE PARALLE OF ORIGIN FORM CONE FRACTION?**

When flattened out, the angular circumference of the cone forms an **angle** (EX 245°) out of a whole circle of 360°. As a friction, this means that the cone forms 245/360 of a circle.

STEP 1: CONVERTING THIS INTO A DECIMIAL: 245/360= 0.68056

STEP 2: WE FIND THE PARALLEL OF ORIGIN: $SIN^{-1}$ 0.6856 = 42°.887

STEP 3: PARALLEL OF ORIGIN= 43°00' approx.

# LAMBERT'S CONFORMAL PROJECTION

It solves then thin usable area problem of the simple conical projection by lowering the external tangent cone, so it cuts into the Earth.

This internal cone is known as a secant cone.

- The secant cone intersects the Earth's surface along 2 further small circles, known as the STANDARD PARALLES.

- The parallel of origin is at the latitude where an external cone, would form a tangent to the Earth's surface.

It's important to know the parallel of origin because this lets you calculate the convergence factor. The parallel of origin isn't exactly half-way between the 2 standard parallels. (Slightly closer to the near pole)

## LAMBERT'S CONFORMAL CALCULATIONS

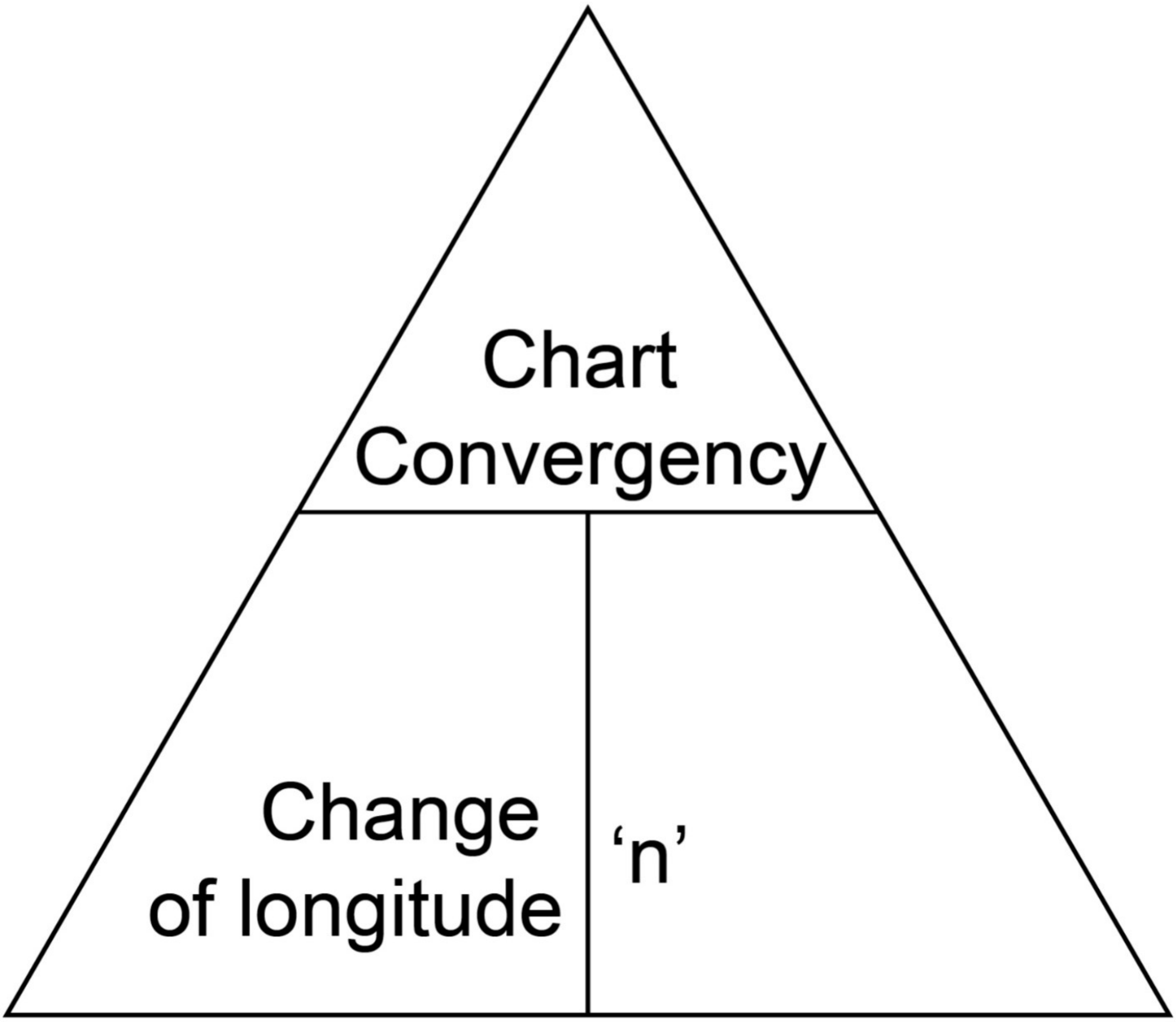
Difference in track directions may need to be calculated. Chart convergency is equal to Earth convergency at the parallel of origin.

This provides a convergence factor (N) for the whole chart. The converge factor, derived from a cone, is constant for the whole chart. **It's known as the constant of the cone**

- CHART CONVERGENCY= CH LONG X CONVERGENCE FACTOR (n)

- Ch Long= Chart Convergency / n

- N= Chart convergency / change of longitud



# UNITS AND CONVERSIONS

VISIBILITY= defined for aeronautical purpose as the greatest distance at which an object can be seen in daylight

Runway visual range (RVR)= Defined as the distance over which a pilot of an aircraft positioned on the centreline of the RNW can see the RNW surface markings which delineate the RNW or identify the rnw centre line

RNW length= Measured in metres

## Metric Units of Distance

The metre is the basic measure of distance in the Systeme International:

- The distance from pole to the Equator is approximately 10 000KM
- The length of a meridian of longitude (20 000km)
- The circumference of any great circle (40 000 km)

## Imperial Units

A nm is a unit of length, defined as 1852m, and equal in length to:

- 1.852km
- 1.1508 sm
- 6076.1ft

## The foot

The foot (ft) is an imperial unit of length, equal to 12 inches (in)

The international foot is defined as 0.3048m

1= 3.28ft

## Conversion factors

1NM= 1.852KM= 1852m

gg

KM= nm x 1.852km

M= nm x 1852

### FROM nm to FT

1. From nm to feet, multiply by 6080ft

2. From feet to nm, divide by 6080ft

### Converting Between FEET, METRES AND STATUTE MILES

| To/From | nm | sm | km | m | ft |
|---|---|---|---|---|---|
| nm | x 1 | x 1.15 | x 1.852 | x 1852 | x 6080 |
| sm | ÷ 1.15 | x 1 | x 1.609 | x 1609 | x 5280 |
| km | ÷ 1.852 | ÷ 1.609 | x 1 | x 1000 | x 3280 |
| m | ÷ 1852 | ÷ 1609 | ÷ 1000 | x 1 | x 3.28 |
| ft | ÷ 6080 | ÷ 5280 | ÷ 3280 | ÷ 3.28 | x 1 |

# DISTANCE, SPEED, TIME

The DST relationship can be using any of 3 simple formulae

- DISTANCE= SPEED X TIME
- SPEED= DISTANCE / TIME
- TIME= DISTANCE / SPEED

# The Earth

The Earth is only approximately spherical, but is, in fact, very slightly elliptical.

The Earth has 2 principal axes:

1. Vertical axis= The Earth's vertical axis is the axis of rotation, around which the Earth rotates at a constant speed.
2. Horizontal axis: The horizontal axis is perpendicular to the vertical axis of rotation.

The Earth's of rotation intersects the surface at 2 points known as the poles

- Top of the Earth = North pole
- Bottom of the Earth= South pole

An imaginary line around the Earth and at equal distance from both poles is Known as the Equator.

The horizontal axis is commonly referred to as the Equatorial axis, the Earth rotates from west to the east “Anti clockwise” the speed is 000mph.

When measured at the Equator, it’s subject to centrifugal force. This causes the Earth to be very slightly wider at the Equator than it is from pole to pole and slightly flatter at the poles than it’s at the Equator.

## Earth Tilt and Daylight

The length of day and night changes throughout the year. The amount of daylight depends on where you’re on the Earth’s surface and the current position of the Earth along the ecliptic

The axial tilt remains constant at 66° but the changing position of the Earth on the ecliptic results in apparently changing elevation of the Sun relative of the Earth.

# LATITUDE AND LONGITUDE

The lines are measured relative to 2 datums. They are the:

- Parallels of latitude, which define positions north and south of the central datum, the Equator.

- Meridians of longitude, which define positions east and west pf central datum, the *Greenwich Meridian*.

❖ Latitudes are stated as 2 figures between 00° and 90°

❖ Longitudes are stated as 3 figures between 000° and 180°

Coordinates are always defined in the order: latitude the longitude.

Example:

N05° W120°

S30° E055°

N78° W002°

The intersection of parallels of latitude and meridians of longitude create a right_ angled graticule.

A graticule is a network of lines representing parallels of latitude and meridians of longitude on map or chart.

**Central Datums**

Latitude and the Equator.

An equator is an imaginary line around the middle of a celestial bosy. It's located halfway between the North and South Poles ( N/S 00°), also divided a planet into a Northern Hemisphere and Southern Hemisphere.

**Longitude and the Greenwich Meridian**

A prime meridian is an imaginary line, running from South Pole to the North Pole.

# Units of Measurement

The international standard unit of angular measurement is the radian.

- There are 360° in a complete circle, such as the circumference of the Earth, or from one pole via the opposite pole back to the original pole

- There are 180° in half-circle, for example from the South pole to the Equator.

Plotting positions by sole reference to degrees would be very crude and inaccurate.

- 1° is divided into 60' of arc

- 1' of arc is also subtended into 60'' of arc

It’s standard practice, when stating angles in navigation, to use leading zeros to show values less than 1 or less than 10

Example 9 degreed, 23 minutes and 18 seconds north of the Equator is :

N 09° 23’ 18’’

## The Nautical Mile

The international nautical mile is defined as being equal to 1.852 km.

- 1° change of longitude at the Equator = 60 nm
- 1’ change of longitude at the equator= 1nm
- 1°change of latitude along any meridian = 60 nn

1 nautical mile is the distance equivalent to approximately 1 minute of arc along a great circle.

## LATITUDE

The measurement of latitude is derived from ***the angle measured between the plane of the Equator and a line joining the Equator to a position on the surface of the Earth***

Latitude is expressed as a 2-figure number prefixed with N or S to show whether the angle is NORTH or SOUTH of the Equator

## Geographic Latitude

Geographic latitude, represented by the Greek letter "PHI" is the true latitude, is defined by the angle between the plane of the Earth's Equator and a line perpendicular to the Earth at a specific point on the Earth's surface.

## Co-Latitude

CO-LATITUDE is the complementary angle of the latitude, to calculate the co-latitude, simply subtract the latitude from 90°.

Example

A latitude of 60° has a co-latitude of 30° = 60°-90°= -30°

## Parallels of Latitude

A line joining of equal latitude on the Earth's surface creates a circle centred on the Earth's vertical (polar).

Lines of equal latitude are all parallel to the Equator and to each other, and are thus known as parallels.

They all from circumferences of the Earth at their respective latitudes, but they are all smaller than the Equator.

## Longitude

The datum for east/west position is the Greenwich Meridian (GM).

The GM divides the Earth into its eastern and western hemisphere

Position east or west of the GM are defined as degrees of longitude. The GM is W/E000°

**Meridian of Longitude**

A meridian is direct path on the surface of the datum that is shortest distance between the poles.

# CHANGE OF LATITUDE AND LONGITUDE

The distance between successive parallels of latitude is assumed to be equal:

KEY VALUES TO MEMORIES ARE:

- CH LAT OF 1° = 60NM

- CH LAT OF 1’= 1NM

## RULES FOR CALCULATING CHANGES OF LATITUDE

Change of latitude are relatively easy to calculate.

Firstly, check whether the longitudes are same or different

- If longitudes are the same, check the hemispheres of the latitudes are same or different: ( SAME HEMISPHERE = SUBTRACT , DIFFERENT HEMISPHERE= ADD)

- If the longitudes are different, add them together to check if they add up to 180° (If they add up to 180° this is a polar transit, subtract both latitudes from 180° to calculate the change of latitude)

**EXAMPLE 1**

N65°00’ ~~E055° 00’~~ and N22°00’ ~~E055°00’~~ (SAME HEMISPHERE= SUBTRACT)

CH Lat =N65°00’ – N22° 00’ = 43°00’

**EXAMPLE 2**

N64°12’ ~~W101°15’~~ and S14°13’ ~~W101°15’~~ (different hemisphere= ADD)

CH Lat = 64°12’+ 14°13’ = 78°13’

If I want the nm--> 78°13’ X 60NM= 4693NM (RB… 1°=60nm)

If I want the KM---> 4693 X 1.852 = 8691. 43 KM

Change the latitude can never be more than 180°, WHICH IS THE **DIFFERENCE FROM POLE TO POLE**

## CALCULATING LATITUDE FROM DISTANCE

To calculate the change of latitude, take the distance, in NM and divide this by 60

EXAMPLE

1’=1NM

420nm= 420’/60= **7° change of latitude**

**EXAMPLE 2**

An aircraft filies due north from N28°30’ E030°40° for a distance of 2260km

WHAT’S ITS FINAL APPROXIMATE LOCATION?

1) NM=2260/1.852= 1220.30 NM = 1220.30’ ( 1’=1nm)

2) CH Lat = 1220.30 / 60= 20.33= 20°20’

3) New Latitude= N28°30’+ N20°20’ = N48°50’ (**CH LAT = Old latitude + CH LAT**)

**ESTIMATING POSITION WHEN CROSSING THE EQUATOR**

When you need to calculate your approximate location using a change of latitude

- When moving NORTH to NORTHERLY latitude you need to ADD the change of latitude

- When moving SOUTH to SOUTHERLY latitude you need to ADD the change of latitude

- When moving NORTH to SOUTHERLY latitude you need to SUBTRACT the change of latitude

- When moving SOUTH to NORTHERLY latitude you need to SUBTRACT the change of latitude

## But WHY I need to subtract?

Because the problem is that you crossing the EQUATOR...

**CH Lat = Old latitude – CH Lat** (If I crossing the EQUATOR)

# CHANGE OF LONGITUDE

In the same way that calculations of change of latitude are needed, we also need to be able to work out the change of longitude (CH LONG).

**First check the latitudes are the same or different**:

- If the latitudes are the same, check the hemispheres of the longitudes are the same or different (SAME HEMISPHERE= SUBTRACT, DIFFERENT HEMISPHERE= ADD)

- If the sum of the 2 longitudes adds up more than 180°, this route between the 2 positions. To find the shorter route subtract the sum of the 2 longitudes from 360°

**EXAMPLE 1**

~~N45°00'~~ E031°12' and ~~N45°00'~~ E012° 02'

CH LONG = 031°12'**-** 012°02' = 19°10' (SAME HEMISPHERE **= SUBTRACT**)

**EXAMPLE 2**

~~N38°30'~~ W065°42' and ~~N38°30'~~ E022° 35'

CH LONG = W065°42' **+** E022°35' = 88°17' (DIFFERENT HEMISPHERE **= ADD**)

### Taking the short Route

When the change of longitude is greater than 180°, a smaller change in longitude is possible by going the short way round the Earth.

To calculate the short route, SUBCTRACT your initial calculation from 360°

**EXAMPLE**

W095° 30' and E120°30'

1) Ch Long= W095°30' **+** E120°30'=216°00' (DIFFERENT HEMISPHERE= **ADD**)

2) To find the short way around = Ch Long = 360°00' - 216°00'= ***144°00'***

# DEPARTURE

The circumference of a circle and the length of an arc around any given angle of a circle depends on the radius of the circle.

As we move to north or south from the Equator both radius and the circumference of the Earth reduces.

To calculate the length of an arc at any latitude, we need to know the radius of small circle of latitude that we are following

The Earth's circumference at the Equator is equal to 360° change of longitude X 60' expressed in NM

360° x 60'= 21 600 nm

- **Departure= CH Long x cos lat**
- **Ch Long= Departure / cos Lat**
- **Cos lat= Departure / Ch long**

***For fixed change of longitude***

- As latitude increases the departure decreases
- As latitude decreases the departure increases

***For a fixed departure (distance)***

- As latitude increase the change of longitude increases
- As latitude decreases the change of longitude decreases

Example Position A is at N00°00' W090°00', Position B is at N00°00' W150°00'. What is the distance between A and B?

First, check for common reference. In this case, the latitudes are the same (N00°00'); this problem requires you to calculate a distance over a change of longitude and is therefore a departure problem.

Departure = Ch long x cos lat

Next, check hemispheres of longitudes:

Same hemispheres = subtract

Ch long = W150°00' - W090°00'

Ch long = 060°00'

Convert degrees into minutes (of arc) by multiplying by 60'.

60° x 60' = 3600'

Enter this information into the formula:

Departure = 3600' x cos 00°

Departure = 3600' x 1

- Departure = 3600 nm

# THE DIRECT MERCATOR

## INTRODUCTION

The Direct Mercator projection is sometimes used for navigation at sea and is commonly used for geographical atlases and wall charts.

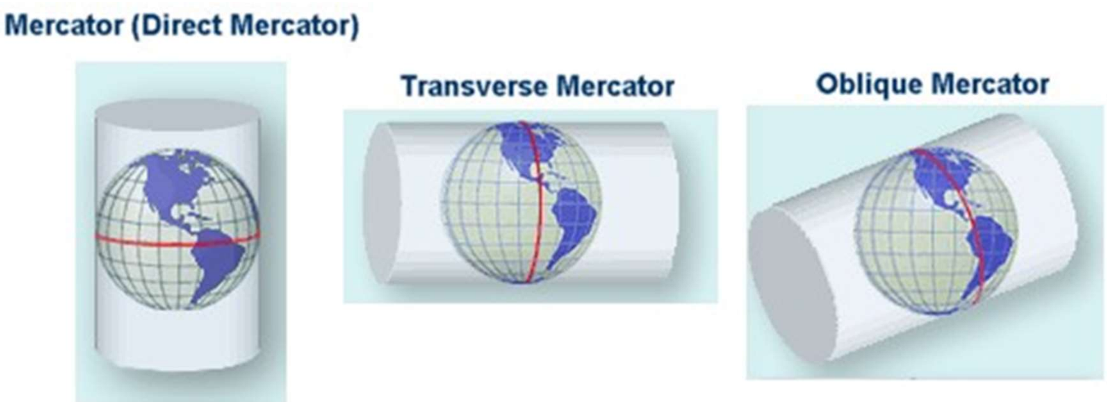
There are 3 main types of Mercator projection. This type of Mercator is determined by which great circle of tangency is used.

- DIRECT MERCATOR: As standard Mercator chart. The parallel of origin of the chart is the Equator, which forms the GREAT CIRCLE of tangency

- TRANSVERSE MERCATOR: The Transverse Mercator has its origin along a meridian of longitude, which forms the great circle of tangency

- OBLIQUE MERCATOR: The oblique Mercator has its origin along any oblique GREAT CIRCLE OF tangency other than Equator or a meridian.

The DIRECT MERCATOR is not recommended for aeronautical navigation, but is ideal for marine navigation.



# THE DIRECT MERCATOR PROJECTION

The only place where the projection is 100% accurate is at the GREAT CIRCLE of tangency.

All parallels of latitude, meridians of longitude and terrestrial features demonstrate a degree of distortion when projected from the reduced Earth onto the projecting surface.

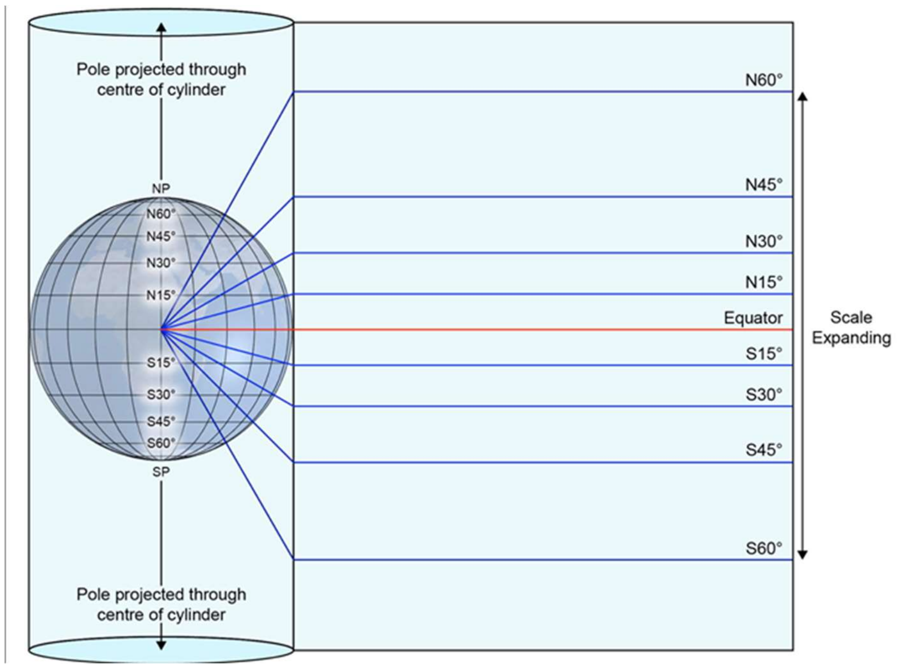
This is controlled by limiting the usable area of the chart (N10°-S10°)

# DIREC MERCATOR GRATICULE

The origin of the chart is the equator, which appears as a straight line on the chart.

The distance on the chart increases between each 15° change of latitude, also the distance on the Earth between these parallels of latitude is constant at 900nm (15x60nm).

The poles can't be projected onto the chart because, at 90° latitude the projection exits the cylinder.



## DIRECT MERCATOR CONFOMALITY

- Parallels of latitude are represented on the chart as **parallel (UNEQUALLY SPACED), horizontal straight lines.**

- **Meridian**s of longitude are represented on the chart as parallel, **(EQUALLY SPACED) vertical straight lines.**

Although constant scale isn't achieved over the whole chart, equal scale in all directions is achieved at any particular point.

## SCALE AND DISTANCE

Earth distance between successive parallels pf latitude is constant but the chart distance is changing therefore, the chart must be changing.

Scale is related to DEPARTURE (DP= Ch long x Cos lat)

To calculate the scale at a particular latitude the formula is:

Scale (lat)= Scale (Eq) x 1/Cos lat

EXAMPLE

A Mercator chart has a scale of 1:4 000 000 at the Equator. What's the approximate scale of chart at S60°?

Scale (lat)= Scale (Equator) x 1/Cos Lat

**Scale (S60°)=** 1/4 000 000 x 1/Cos (60°)= **1/2 000 000**


## ABBA FORMULA

EASA exam questions may require you to calculate an unknown scale at one latitude (A) from known scale at another scale latitude (B) neither latitude being equator.

For this reason, is good way to use the ABBA formula.

**Scale of A x Cosine of B= Scale of B x Cosine of A**

**EXAMPLE**

---

Example 3: A Mercator chart has a scale of 1: 1 800 000 at N40°. What is the approximate scale of the chart at S25°?

There are 2 points to note:

- The hemisphere is irrelevant because the scale at S25° is the same as the scal at N25°.
- Scale expands with increasing latitude. The denominator gets smaller.

At S25° (lower latitude) scale will have contracted from that at N40° and the denominator will be larger.

Scale of Φ A x Cosine of Φ B = Scale of Φ B x Cosine of Φ A

Scale S25° x Cos N40° = Scale N40° x Cos S25°

Ignore the numerators:

Scale S25° x 0.766 = 1 800 000 x 0.906

Scale S25° x 0.766 = 1 630 800

*Transpose the formula*

Scale S25° = 1 630 800 ÷ 0.766

Scale S25° = 2 128 982

- Answer: Scale (S25°) $= \dfrac{1}{2\ 130\ 000}$

## APPEREANCE of GREAT CIRCLES

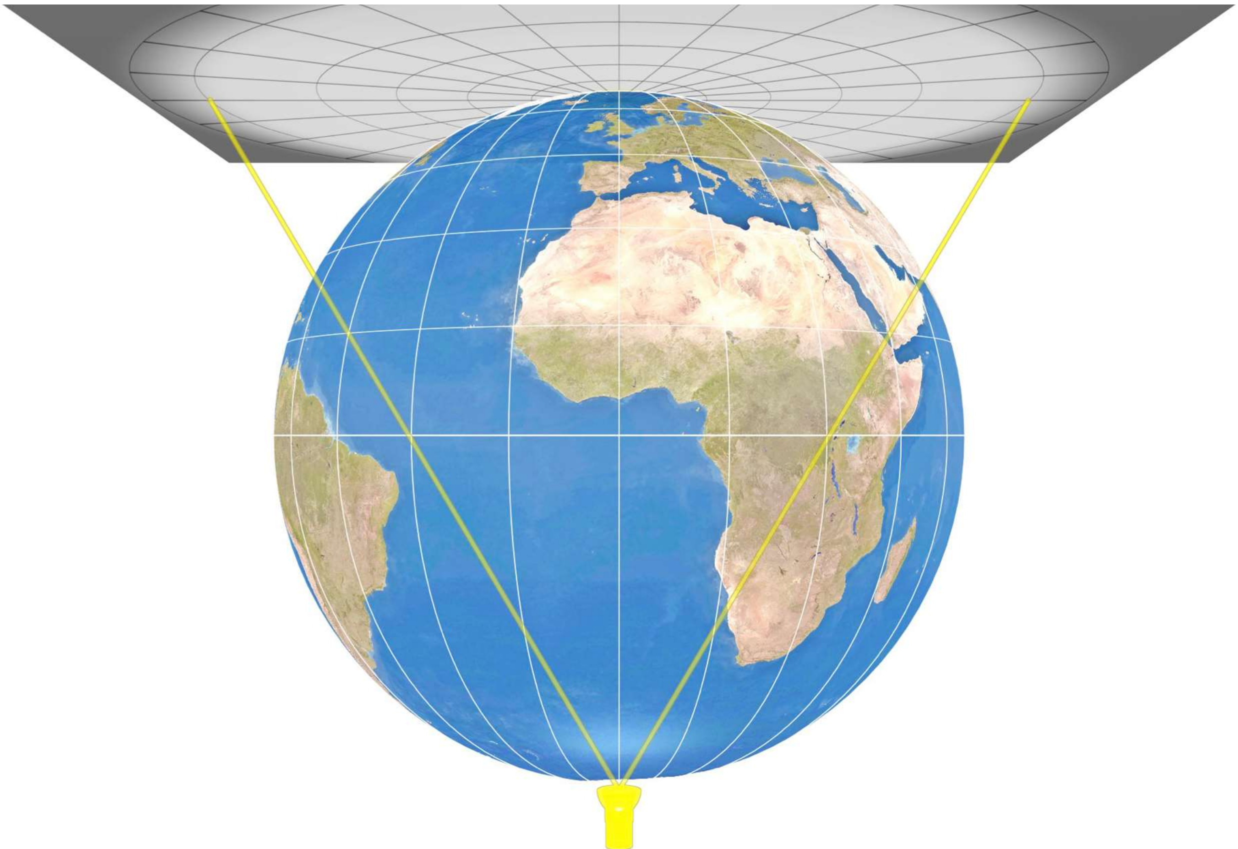
The Central Meridian is a **straight line**, as are any great circle that cross it at right angles. **Great circle are curves concave to the Central Meridian,**

## APPERANCE of RHUMB LINES

**Rhumb Lines appear as curves concave to the nearer pole**. With the exception of **rhumb lines that are also great circle**.

# POLAR STEREOGRAPHIC

Polar regions are normally charted using an azimuthal stereographic projection with a single point of tangency at one pole

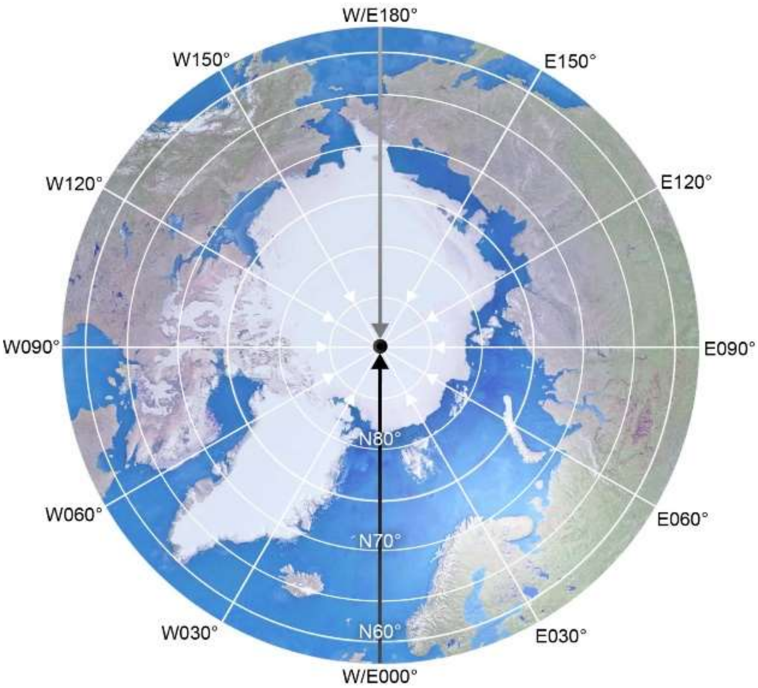


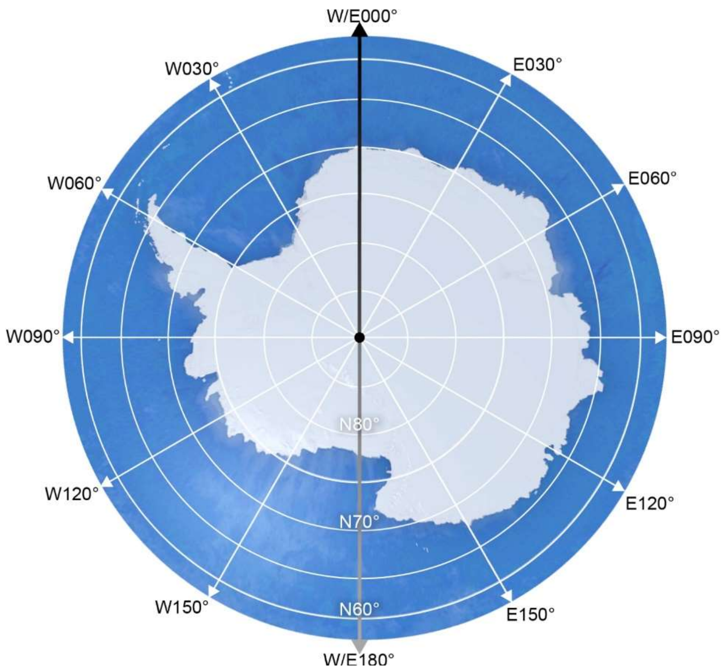
This produces a conformal right-angled graticule:

- Meridians of longitude, meet at the pole and diverge from the pole, to infinity
- Parallels of latitude form concentric circles, radiating away from the poles. They are further apart from each successive parallel, as distance from the pole increase.

**IN THE SOUTHER HEMISPHERE, all MERIDIANS point AWAY from SOUTH POLE;**

**IN THE NORTHER HEMISPHERE, all MERIDIANS point IN TOWARDS THE NORTH POLE**




## SCALE

Scale expands away from the pole, but the scale expansion effect changes. Projecting the from the opposite pole, reduces scale expansion and allows a larger area of the Earth to be projected.

At a latitude 70° the scale expansion is only 3% compared to the scale at the pole, so this projection has an approximately constant scale.

## STRAIGHT LINES, GREAT CIRCLES AND RHUMB LINES.

On polar stereographic chart, ***great circles approximate to straight lines***

A straight lines passing through to pole follows the path of meridian and its anti-meridian, a great circle. A meridian is also a rhumb line.

**Any straight line passing through the pole is a great circle and rhumb line**

## Convergency and Conversion Angle

- **CONVERGENCY = CH LONG (X1)**
  - The value of n on polar stereographic chart =1

- **CONVERSION ANGLE= ½ X CONVERGENCY**

# RADIO PLOTTING

## RADIO NAVIGATION

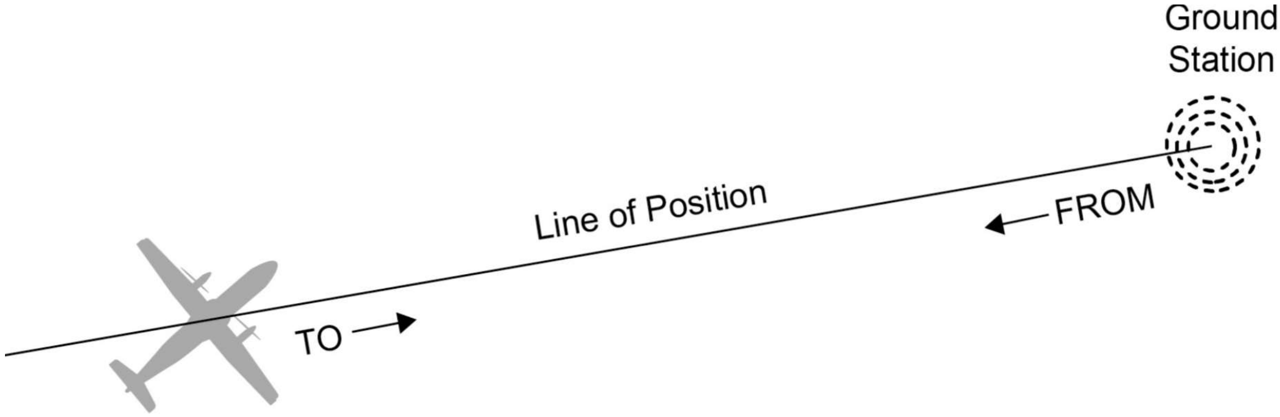
It's possible find the position using information from radio navigation aids.

- BEARING: The direction to the navaid from the aircraft's position, measured at the aircraft's position.
- RADIAL: The bearing from the navaid to the aircraft's position, measured at the facility
- RANGE: The distance between the navaid and the aircraft's position, measured at the aircraft or radar facility.

## LINE of POSITION

A line from a NAVAID to the aircraft's position is a ***line of position***.

It's classified as either TO or FROM a navaid. An arc of equidistant range from a navaid is a CIRCULAR LINE of POSITION.



## BACK-BEARINGS

The reciprocal of the bearing TO a navaid, is KNOWN as a Back-bearing.

Beck-Bearings are useful because they indicated a ***direction FROM a ground station TO an aircraft***

Converting a radio bearing TO a NAVAID into a back-bearing FROM the navaid is a technique used extensively for plotting.

- For values LESS than 180° ADD, 180°
  - The back-bearing of 090° is 270° = 090°+180°=270°

- For values of 180° or greater SUBTRACT 180
  - The back-bearing of 240 is 060 (240°-180°= 060°)

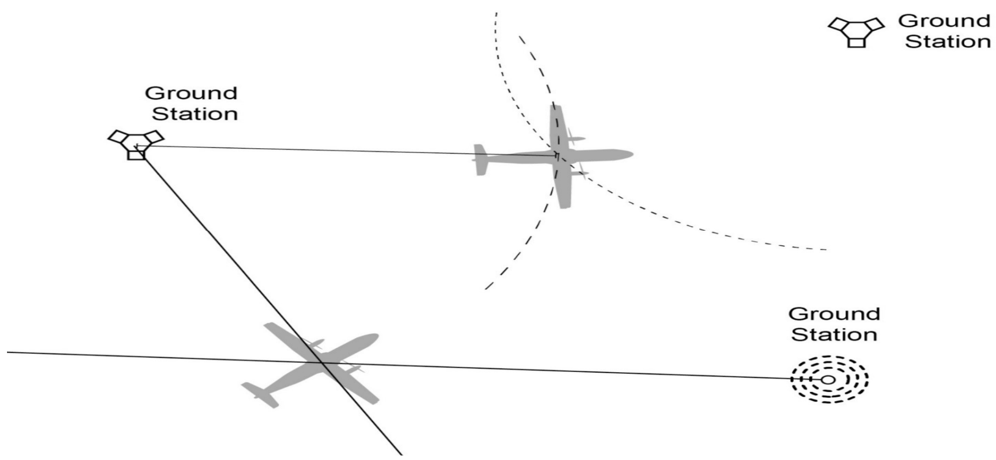
## POSITION FIX

A single line if position indicates a bearing only. To obtain a position fix, you need:

- A LINE of POSITION PLUS A DISTANCE

- THE INTERSECTION OF 2 LINES OF POSITION

- 2 CIRCULAR LINES OF POSITION



**Q CODES**

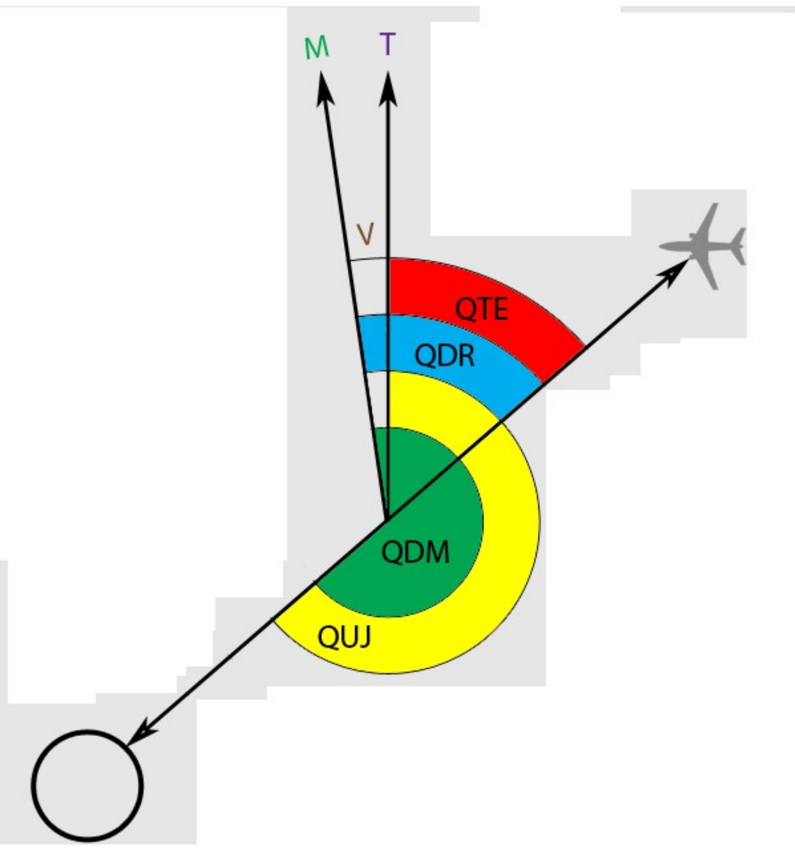
The "Q" is short for "question". For example, the 3 letter QDM stands for "Question": Direction Magnetic?

- **QDM: MAGNETIC BEARING TO** the navaid/ feature from the aircraft

- **QDR: MAGNETIC BEARING FROM** the navaid/ feature from the aircraft

- **QUJ: TRUE BEARING TO** the navaid/ feature from the aircraft

- **QTE: TRUE BEARING FROM** the navaid/ feature from the aircraft



## EXAMPLE

The QDM from an aircraft to a navaid is 240°M. Local magnetic variation is 5°W.

At short range, such that convergency is negligible, what are the QDR, QUJ, and QTE?

QDR= 240°-180°= 060°

QUJ= 240°-5°W=235°T

QTE= 060°-5°W= 055T

## PLOTTING NDB/ADF

The ADF detects the direction of the radio signals transmitted by the NDB , and this is measured on the RBI/RMI at the aircraft.

If the aircraft equipment only provides relative bearing, convert to a QDM as described earlier.

- **QDM= HEADING+ RELATIVE BEARING**

- ***Convert this to a QDR by applying the reciprocal.***

- **QDR= QDM ± 180°**

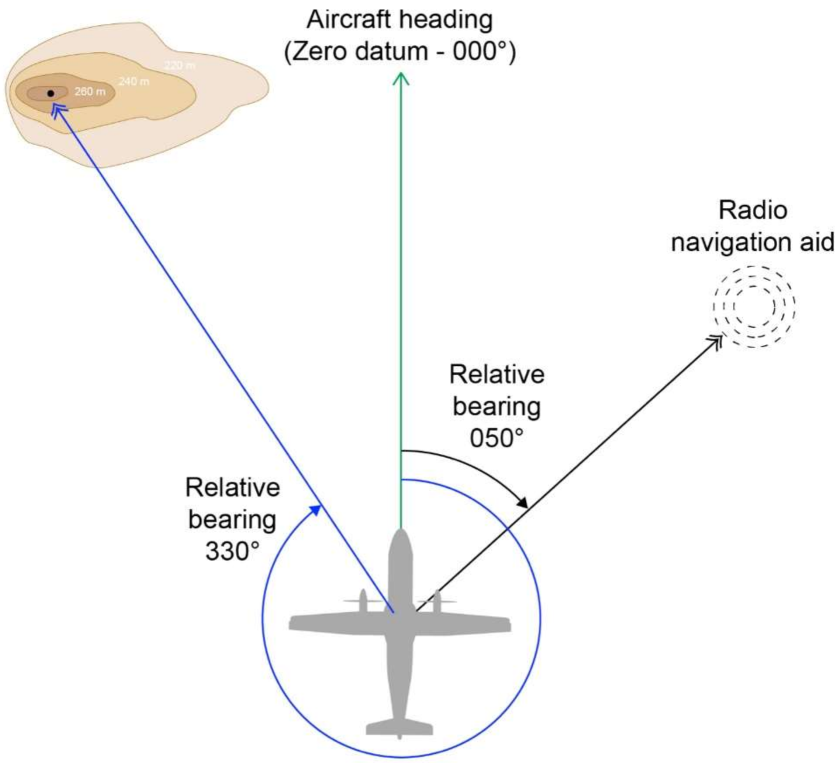
- **Apply a correction for variation at the aircraft to convert the QDR to a QTE**

# RELATIVE BEARINGS

A relative Bearing is the bearing measured from the aircraft to a navigation aid a ground feature or another aircraft.

In other words:

***<u>The aircraft's longitudinal axis is the zero datum for measuring a relative bearing</u>***.




The nose of the aircraft points to its heading. To convert a relative bearing into a track bearing across the ground you must consider the aircraft's heading.

**HEADING + RELATIVE BEARING= BEARING TO**

The datum of the aircraft's heading gives the datum for the track bearing:

- **HDG(°M) + RB= BRG TO (°M)**

- **HDG(°T) + RB= BRG TO (°T)**

Example 1: An aircraft on a magnetic heading of 040°M indicates a relative bearing of 020° to a ground station: What's the magnetic bearing to the ground station?

HDG=040°M

HDG(°M) + RB= BRG TO(°M)

040°+020°=060°M

If the value is negative you have to add +360°

## Left Relative Bearing

A relative bearing is occasionally expressed as a number of degrees left of the aircraft's nose. For example, "That hill is 30° left of the nose"

This is sometimes expressed as a negative value (-30°--> LEFT). Negative value should be converted to a positive value by adding +360°

-30° + 360° = 330°

***EXAMPLE***

An Aerodrome is 45° to the left of the nose of an aircraft on a heading of 170°M.

What's the magnetic bearing of the aerodrome from the aircraft?

HDG=170°M -----> HDG+RB=BRG TO

170°M-45°M= 125°M or----> add 360 from (-45°M) and then when you found 485°M subtract 360°

# BEARINGS TO/FROM

Occasionally you may have to calculate true bearing to or from a navigational facility or a ground feature.

STEP 1: APPLY the magnetic variation to calculate the true heading

STEP 2: APPLY the relative bearing to the true heading to calculate the true track bearing to the facility

STEP 3: APPLY the reciprocal to calculate the true track bearing from the facility (±180)

***EXAMPLE***

An aerodrome is on a relative bearing of 125° from an aircraft on heading of 290°M. Local magnetic variation= 5°W (-). What's the true bearing of the aerodrome from the aircraft?

HDG=290°M

- Apply magnetic to convert magnetic heading to true heading

290°M-5°W= 285°T

HDG+RB=BRG TO

285°+125=410°

- Apply the reciprocal at this stage

BRG TO= 410°T

BRG FROM= 410°-180° = 230°T

# SCALE

One of the most fundamental properties of any chart is its scale. When a chart is drawn to ***scale.***

The relationship between measurements on the chart are exactly proportional to the real world measurements it represents.

## SCALE AS A RATIO

Scale can be expressed as the ratio **BETWEEN CHART DISTANCE(CD) and EARTH DISTANCE(ED)**.

**This is expressed as CD: ED**

A ratio of 1:25 000 means that 1 unit on the chart is equal to 25 000 units on the Earth.

SCALE as a FRACTION

The scale ratio can also be stated as a fraction, such as:

**SCALE=CD/ED**

So 1:25 000 could also be expressed as

SCALE=1 / 25 000

## LARGE AND SMALL SCALE CHARTS

Charts are described as being large scale or small scale. It's important to understand what this means.

ON A LARGE SCALE CHART, OBJECTS APPEAR LARGER THAN ON A SMALLER SCALE CHART.

For example, 1:25 000 map **has a larger scale** than a 1:500 000 chart

A simple way of remembering this is

**LARGE SCALE:**

- Large amount of detail
- Large fraction

**SMALL SCALE:**

- Small amount of detail
- Small fraction

# SCALE CALCULATIONS

For the purpose of calculations, it's easier to express scale as a fraction.

This allows it to be used mathematically.

**CHART DISTANCE (CD)**

**SCALE FRICTION= -------------------------------**

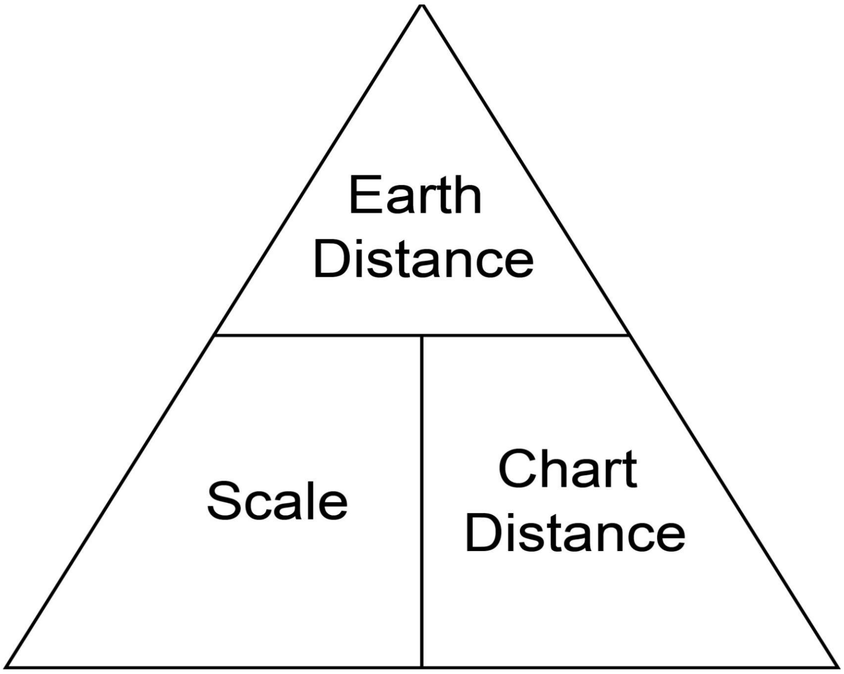
**EARTH DISTANCE (ED)**

When performing these calculation, scale is written as “1” over “S” where “S” represents the unknown value of the scale.

**1/S= CD/ED**

We can transpose this formula to read

**ED= S x CD**




## METHODOLOGY

Many questions require you to carry out unit conversions as well as understand the concept of scale.

- STEP 1: Convert Earth distance into the same units as chart distance.
- STEP 2: Carry out the calculation

EXAMPLE

A chart has a scale of 1:500 000. On the chart, the distance between points A and B is measured as 5 inches. What's the distance between A and B, measured in NM?

S = CD/ED

ED = S x CD

ED= 500 000 x 5”

ED= 2 500 000”

- **Convert form IN to FT**

2 500 000” $\div$ 12= 208 333.333ft

- **Divide by 6080 to convert feet to NM**

208 333.333ft $\div 6080 = 34.3\mathrm{nm}$

# TIME

## APPARENT AND MEAN SOLAR TIME

The Earth rotates around its vertical axis from West to East, anti-clockwise as viewed from above the North Pole.

- The definition of "APPARENT" is CLEARLY, VISIBLE, ACTUAL, TRUE.
- The visible SUN is Known as the apparent SUN.

Relative to an observer, the apparent Sun is at its highest point in the sky when it is directly overhead the observer's local meridian. This is Known as the transit of the Sun.

The time taken between 2 transit of the apparent Sun over the observer's local meridian defines the apparent solar day.

## The Mean Sun and the Mean Solar Day

The APPARENT SOLAR day for measuring time.

The Average of all APPARENT SOLAR days is taken, OVER A YEAR. This is known as the MEAN SOLAR DAY, which is based on the MEAN SUN.

The mean sun travels along the Celestial Equator at a constant speed and makes 2 transit over the LOCAL MERIDIAN of an OBSERVER, at intervals of exactly 24 hours on every day of the year.

This MEAN SOLAR DAY is the period on which the 24h clock day is based.

## Apparent and Mean Time Synchronicity

As each 24-hour period passes, the MEAN and APPARENT solar days move gradually IN and OUT of SYNCHRONISATION.

The apparent time lags or leads mean time by about +16.5 to -14 minutes.

- APPARENT SUN is when it's directly overhead the observer's local meridian, IRRESPECTIVE of its POSITION.

- MEAN SUN varies, but always occurs at 12.00 noon, IRRESPECTIVE of its position.

# LOCAL MEAN TIME

Time measured by reference to the Mean Sun is known as LOCAL MEAN TIME (LMT)

The length of the day in LMT is based on the Mean Solar Day of 24hours.

- MIDNIGHT (00:00:00 LMT). The day starts at midnight, which is when the Mean Sun is transiting the **observer's anti-meridian**.

- MIDDAY or NOON (12:00:00 LMT). The mean Sun is overhead the observer's local meridian.

## ARC to TIME RELATIONSHIP

The Earth takes exactly 24 hours to male one rotation of 360° relative to the Mean Sun. Using this we can relate the arc between 2 positions to the difference in LOCAL TIME.

This is known as the ARC TO RELATIONSHIP and is fundamental to time calculations.

- 360° equates to 24 hours.
- 360°/24hours = 15°---------> 1 hour = 15°

Every 15° of longitude, there is a 1h in difference in LOCAL TIME.

***MEMORISE***

- **15°= 1h**
- **1°= 4 min**
- **15'= 1min**

The arc to time relationship is used to convert from LMT at one position to LMT at another. BY FINDING THE CHANGE IN LONGITUDE

## CONVERTING ARC TO TIME

We look at problems concerning LMT at different locations.

The sun is overhead all latitudes on any given meridian of longitude, so latitude is of no consequence when calculating changes of longitude to solve LMT problems.

EXAMPLE 1

Longitude= 112°. What is the time difference between the 2 position?

Change of time= Change of longitude (°)/ 15

Change of time= 112° / 15° = 7.47h----> 7h,28m

EXAMPLE 2

What's the time difference between N30°W025° and S45°E130°?

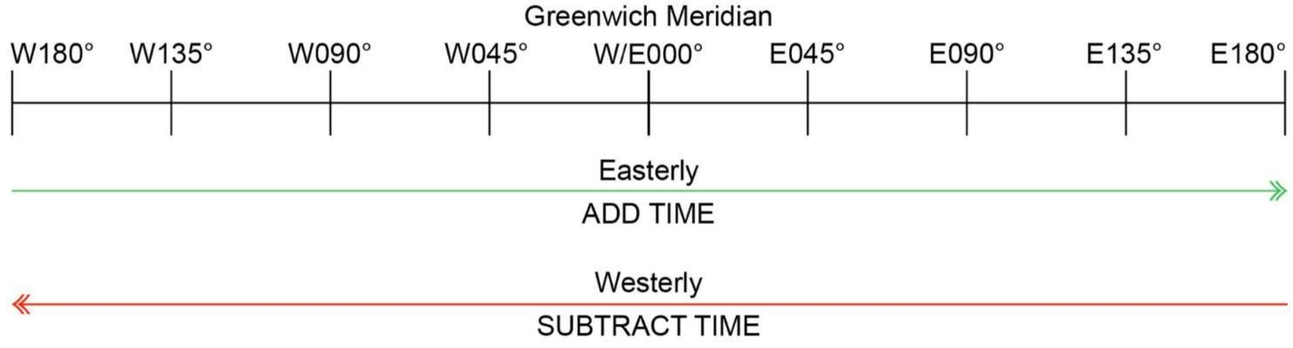
- CH-LONG=W025+130= 155° (DIFFERENT HEMISPHERE=ADD)

- Change of time= 155°/15°=10.33h-----> 10h,20m

→When calculating time in an EASTERLY direction time is ADDED.

→When calculating time in WESTERLY direction time is SUBRACTED.

The PDT (Position, direction and time line) shows that...



# GMT, UTC and ZULU

Local Mean Time (LMT) is different at each meridian of longitude. LMT also exits at the Greenwich Meridian, which passes through Greenwich. At the Greenwich Meridian, LMT is called Greenwich Mean Time (GMT).

GMT was accepted as the international standard for time measurement in 1884 but since 1927 was change and made the TIME STANDARD calling *UNIVERSAL COORDINATED TIME* (UTC)

The difference between both (GMT and UTC) are close enough. The UTC is based on atomic clock measurement, where GMT is based on an LMT.

UTC is the reference time used by aviation industry and defines the time at the Greenwich Meridian.

The Greenwich Meridian is the ZERO MERIDIAN, which is why GMT time are sometimes followed by a Z (zulo) suffix.

- GMT=LMT at the Greenwich Meridian
- GMT= Zulu Time
- UTC=GMT

UTC= Means that is the same everywhere irrespective of latitude or longitude.

## Converting LMT to UTC

LMT to UTC conversion is easy , because depend the change of longitude whre you need to calculate the time difference.

This time value UTC is applicable to all locations on the Earth.

- 13.45LMT at E055°30 (*3h,42’) is covert to LMT at W/E000°00’ *(055°30’/15°)

  When calculating time in WESTERLY direction time is SUBRACTED

  UTC= 13.45 LMT- 03.42= 10.03 (UTC)

- 01.03LMT at W135°00’ (*09h.00’) is convert to LMT at W/E000°00’ *(135°00’/15°)

  When calculating time in an EASTERLY direction time is ADDED.

  UTC=01:03 LMT+09.00= 10.3 (UTC)

# STANDARD TIME

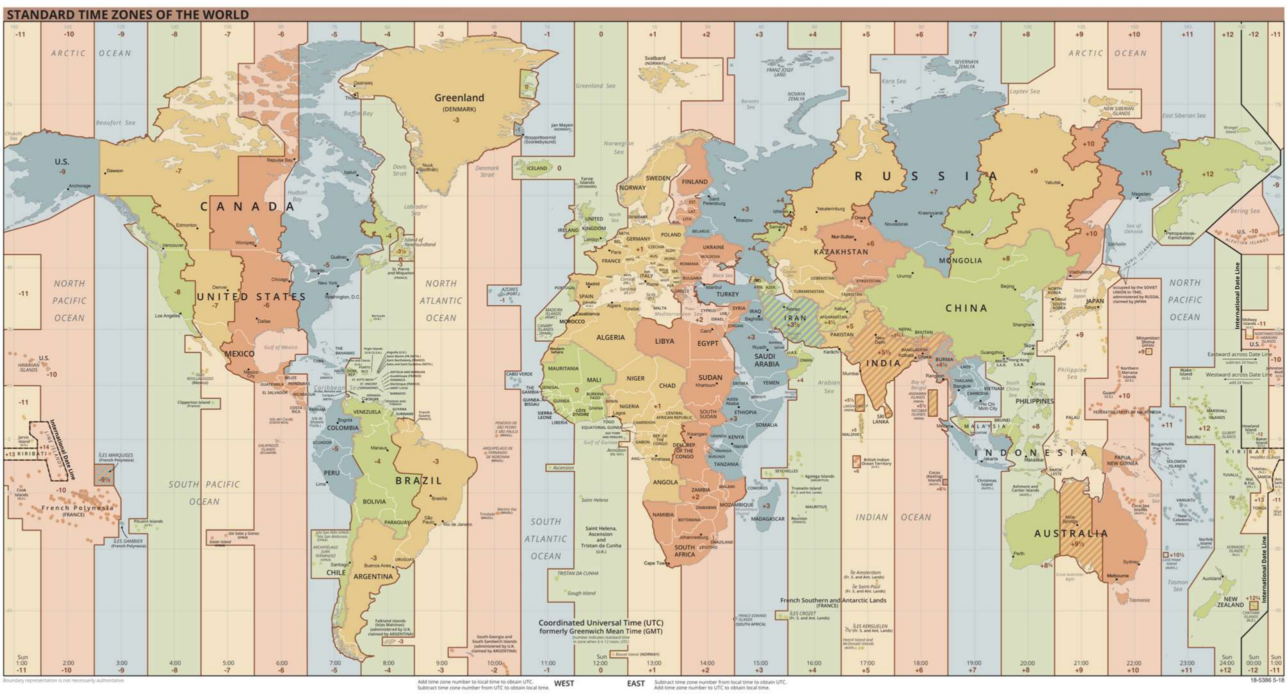
LMT is impractical for everyday use. UTC/GMT are only of practical value in those countries close to the Greenwich Meridian.

In terms of Local Mean Time, each meridian of longitudes has a different time which causes an issue. Across the region the change in longitude is 12° (48’) difference in LTMs from one side of the region to the other. So for small regions, using the LT is impractical.

The solution is to find a convenient meridian and have all countries or regions near that meridian keep time by the LTM of that meridian.

Such a time is known as a Standard Time (ST) and the area that uses it is known as a Standard Time Zone

The whole time zone can then be related to UTC by statinf the number of hours difference between the time zone and UTC.



## CHANGE OF DATE

The boundaries between them are as follows.

- The International Date Line (IDL)
- The midnight boundary between 2 times zones where ST in the westerly zone is 23.59 and ST in the easterly zone is 00.00

The IDL is a fixed datum that approximately follows the W/E180° meridian of longitude.

Crossing the IDL involves a change of date:

- In an easterly direction, the date decrease by 1 day
- In westerly direction, the date increase by 1 day

## Calculating Standard Times

The method for calculating the Standard Time (ST) at any location, is similar to that used for converting LMT with one very significant exception

ST conversion uses fixed values based on the country or region.

Example 8: The time at Mumbai, India (N18°58' E072°45') is 12.45 ST on 12/02/2018. What is the equivalent ST at Rio de Janeiro, Brazil (S22°55' W043°15')?

This is an ST to ST conversion. Therefore, only the ST conversion tables are relevant to this question.

- Step 1: convert from ST at the first position to UTC.

Mumbai, India = E072°45'

E072°45' indicates List I - refer to Air Almanac List I

India = UTC + 5 hrs 30 mins

To convert from ST to UTC, subtract this time

UTC = 12.45 ST at India - 05.30

UTC = 07.15 UTC

- Step 2: convert from UTC to ST at the second position.

Rio de Janeiro, Brazil = W043°15'

W043°15' indicates List III - refer to Air Almanac List III

Rio de Janeiro, Brazil = UTC - 3 hrs

To convert from UTC to ST, subtract this time

ST at Rio de Janeiro = 07.15 UTC - 03.00

ST at Rio de Janeiro = 04.15 ST

- ST at Rio de Janeiro = 04.15 ST on 12/02/2018

Example 12: Refer to Air Almanac. An aircraft departs Auckland, New Zealand (S36°50' E174°45') at 07.40 ST on 01/03/2016. Following a flight of 12 hrs 35 mins, what is the standard time and date of arrival at Juneau, Alaska, USA (N58°20' W134°25')?

Only the ST Conversion tables are of any relevance.

- Step 1: convert from ST at the first position to UTC.

Auckland, New Zealand = E174°45'

E174°45' indicates List I - refer to Air Almanac List I

New Zealand = UTC +12 hrs; there is no specific conversion for Auckland

UTC = 07.40 ST at Auckland, New Zealand - 12.00

ATD at Auckland, New Zealand = -04.40 UTC on 01/03/2016

Do not correct negative value yet!

- Step 2: convert from UTC to ST at the second position.

Juneau, Alaska, USA = W134°25'

W134°25' indicates List III - refer to Air Almanac List III

USA is subdivided into its respective states

Alaska, USA = UTC - 9 hrs; there is no specific conversion for Juneau

ST at Juneau, Alaska, USA = -04.40 UTC - 09.00

ATD at Juneau, Alaska, USA = -13.40 ST on 01/03/2016

- Step 3: add on the flight time to find the Actual Time of Arrival (ATA) at Juneau, Alaska, USA.

ATA at Juneau, Alaska, USA = ATD at Juneau + Flight Time

ATA at Juneau, Alaska, USA = -13.40 ST on 01/03/2016 + 12.35

ATA at Juneau, Alaska, USA = -01.05 ST on 01/03/2016

It isn't possible to have a negative time; therefore, add 24 hours to the time but subtract one day from the date.

ATA at Juneau, Alaska, USA = -01.05 ST + 24.00

ATA at Juneau, Alaska, USA = 22.55 ST

Date at Juneau, Alaska, USA = 01/03/2016 - 1 day

Date at Juneau, Alaska, USA = 28/02/2016

*Stop! 2016 is divisible by 4, and therefore it's a leap year*

Date at Juneau, Alaska, USA = 29/02/2016

- Answer: ATA at Juneau, Alaska, USA is 22.55 ST on 29/02/2012

# SUNRISE, SUNSET AND TWILIGHT

## SUNRISE and SUNSET

The period of daylight exists from that instant when the Sun rises above the Horizon to the instant when it descends again below the horizon.

- SUNRISE: When the upper limb of the Sun appears over the EASTERN HORIZON in the morning

- SUNSET: When the upper limb of the Sun disappears below the western horizon in the evening.

The time of sunrise and sunset change throughout the year , in relation to 2 fixed factors and 1 variable factor:

- DECLINATION of the SUN
- LATITUDE
- ALTITUDE

**DECLINATION**

The declination is the number of degrees above or below the celestial equator of a celestial object.

The elliptical is the path in the Earth's sky that the sun appears to follow over the duration of one year, with the Sun being overhead different points on the surface of the Earth during the year

The Sun follow its ecliptic. tilted at an angle of approximately 23° to the Earth's Equator, over the course of 1 year.

The tropic of Cancer at N23° and the Tropic of Capricorn at S23°.

The changing declination of the Sun cause the change in sunrise and sunset times at different latitudes and accordingly the length of day and night.

The Earth's axial remains at 23° to the Elliptical all year.

## Altitude

Sunrise and Sunset are affected by altitude because the direct line-of-sight over the horizon is grater for an observer at higher altitudes than for an observer on the ground

When descending to an aerodrome just after sunset you may still be daylight at higher altitude as you start the descend

- Aircraft at different altitudes have different sunset time

- An aircraft descending from high altitude to low altitude at sunset may descend into darkness.

# SUNSET AND SUNRISE TABLES IN THE AIR ALMANAC

To find the time of sunrise and the sunset there is a special table that give the correct time.

## HOW TO READ THIS?

EXAMPLE

To find the time of sunrise at N40° on 26 April 2014

- STEP 1 : Locate the relevant page in the Air Almanac
- STEP 2 : Find the relevant date (26th April 2014)

SUNRISE, 2014

| Lat. | April 2 | 5 | 8 | 11 | 14 | 17 | 20 | 23 | 26 | 29 | May 2 | 5 | 8 | 11 | 14 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m |
| N72 | 04 51 | 04 35 | 04 19 | 04 03 | 03 46 | 03 28 | 03 10 | 02 51 | 02 31 | 02 09 | 01 45 | 01 15 | 00 28 | □ | □ | □ |
| 70 | 04 59 | 45 | 31 | 16 | 04 01 | 03 47 | 31 | 03 16 | 03 00 | 02 43 | 02 26 | 02 07 | 01 47 | 01 24 | 00 55 | □ |
| 68 | 05 06 | 53 | 40 | 27 | 14 | 04 01 | 03 48 | 34 | 21 | 03 07 | 02 53 | 02 39 | 02 24 | 02 09 | 01 53 | 01 36 |
| 66 | 11 | 04 59 | 48 | 36 | 24 | 13 | 04 01 | 03 49 | 38 | 26 | 03 14 | 03 02 | 02 50 | 02 39 | 02 27 | 02 15 |
| 64 | 15 | 05 05 | 04 54 | 44 | 33 | 22 | 12 | 04 02 | 03 51 | 41 | 31 | 20 | 03 10 | 03 00 | 02 51 | 02 41 |
| 62 | 19 | 10 | 05 00 | 50 | 40 | 31 | 21 | 12 | 04 02 | 03 53 | 44 | 35 | 26 | 18 | 03 10 | 03 02 |
| N60 | 05 23 | 05 14 | 05 05 | 04 56 | 04 47 | 04 38 | 04 29 | 04 21 | 04 12 | 04 04 | 03 56 | 03 48 | 03 40 | 03 32 | 03 25 | 03 18 |
| 58 | 26 | 17 | 09 | 05 01 | 52 | 44 | 36 | 28 | 21 | 13 | 04 06 | 03 58 | 03 51 | 45 | 38 | 32 |
| 56 | 28 | 21 | 13 | 05 | 04 57 | 50 | 42 | 35 | 28 | 21 | 14 | 04 08 | 04 01 | 03 55 | 49 | 44 |
| 54 | 31 | 23 | 16 | 09 | 05 02 | 55 | 48 | 41 | 35 | 28 | 22 | 16 | 10 | 04 04 | 03 59 | 03 54 |
| 52 | 33 | 26 | 19 | 13 | 06 | 04 59 | 53 | 47 | 40 | 35 | 29 | 23 | 18 | 13 | 04 08 | 04 03 |
| N50 | 05 35 | 05 29 | 05 22 | 05 16 | 05 10 | 05 03 | 04 57 | 04 52 | 04 46 | 04 40 | 04 35 | 04 30 | 04 25 | 04 20 | 04 16 | 04 12 |
| 45 | 39 | 34 | 28 | 23 | 17 | 12 | 05 07 | 05 02 | 04 57 | 04 53 | 48 | 44 | 40 | 36 | 32 | 29 |
| 40 | 43 | 38 | 33 | 29 | 24 | 20 | 15 | 11 | 05 07 | 05 03 | 04 59 | 04 55 | 04 52 | 04 49 | 46 | 43 |
| 35 | 46 | 42 | 38 | 34 | 30 | 26 | 22 | 18 | 15 | 12 | 05 08 | 05 05 | 05 02 | 05 00 | 04 57 | 04 55 |
| 30 | 48 | 45 | 41 | 38 | 35 | 31 | 28 | 25 | 22 | 19 | 16 | 14 | 12 | 09 | 05 07 | 05 06 |
| N20 | 05 53 | 05 50 | 05 48 | 05 45 | 05 43 | 05 41 | 05 38 | 05 36 | 05 34 | 05 32 | 05 30 | 05 29 | 05 27 | 05 26 | 05 24 | 05 23 |
| N10 | 05 57 | 55 | 53 | 52 | 50 | 49 | 47 | 46 | 45 | 43 | 42 | 41 | 41 | 40 | 39 | 39 |
| 0 | 06 00 | 05 59 | 05 59 | 05 58 | 05 57 | 05 56 | 05 56 | 05 55 | 05 54 | 05 54 | 05 54 | 05 53 | 05 53 | 05 53 | 05 53 | 05 53 |
| S 10 | 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 05 | 06 05 | 06 05 | 06 06 | 06 06 | 06 07 |
| 20 | 07 | 08 | 09 | 10 | 11 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 |
| S 30 | 06 11 | 06 13 | 06 15 | 06 17 | 06 18 | 06 20 | 06 22 | 06 24 | 06 26 | 06 28 | 06 29 | 06 31 | 06 33 | 06 35 | 06 37 | 06 39 |
| 35 | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 30 | 32 | 35 | 37 | 39 | 42 | 44 | 47 | 06 49 |
| 40 | 16 | 19 | 22 | 25 | 28 | 31 | 34 | 37 | 40 | 43 | 46 | 49 | 06 52 | 06 54 | 06 57 | 07 00 |
| 45 | 19 | 22 | 26 | 30 | 34 | 37 | 41 | 45 | 48 | 06 52 | 06 56 | 06 59 | 07 03 | 07 06 | 07 10 | 13 |
| 50 | 22 | 27 | 31 | 36 | 41 | 45 | 50 | 54 | 06 59 | 07 03 | 07 08 | 07 12 | 17 | 21 | 25 | 29 |
| S 52 | 06 23 | 06 29 | 06 34 | 06 39 | 06 44 | 06 49 | 06 54 | 06 59 | 07 04 | 07 09 | 07 13 | 07 18 | 07 23 | 07 28 | 07 32 | 07 37 |
| 54 | 25 | 31 | 36 | 42 | 47 | 53 | 06 58 | 07 04 | 09 | 14 | 20 | 25 | 30 | 35 | 40 | 45 |
| 56 | 27 | 33 | 39 | 45 | 51 | 06 57 | 07 03 | 09 | 15 | 21 | 27 | 32 | 38 | 44 | 49 | 07 54 |
| 58 | 29 | 36 | 42 | 49 | 06 55 | 07 02 | 08 | 15 | 21 | 28 | 34 | 41 | 47 | 07 53 | 07 59 | 08 05 |
| S 60 | 06 31 | 06 38 | 06 46 | 06 53 | 07 00 | 07 07 | 07 14 | 07 22 | 07 29 | 07 36 | 07 43 | 07 50 | 07 57 | 08 04 | 08 11 | 08 17 |

- Read the sunrise time where the date column intersects the latitude row

SUNRISE, 2014

| Lat. | April | | | | | | | | | | May | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 8 | 11 | 14 | 17 | 20 | 23 | 26 | 29 | 2 | 5 | 8 | 11 | 14 | 17 |
| ° | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m | h m |
| **N72** | 04 51 | 04 35 | 04 19 | 04 03 | 03 46 | 03 28 | 03 10 | 02 51 | 02 31 | 02 09 | 01 45 | 01 15 | 00 28 | ▭ | ▭ | ▭ |
| **70** | 04 59 | 45 | 31 | 16 | 04 01 | 03 47 | 31 | 03 16 | 03 00 | 02 43 | 02 26 | 02 07 | 01 47 | 01 24 | 00 55 | ▭ |
| **68** | 05 06 | 53 | 40 | 27 | 14 | 04 01 | 03 48 | 34 | 21 | 03 07 | 02 53 | 02 39 | 02 24 | 02 09 | 01 53 | 01 36 |
| **66** | 11 | 04 59 | 48 | 36 | 24 | 13 | 04 01 | 03 49 | 38 | 26 | 03 14 | 03 02 | 02 50 | 02 39 | 02 27 | 02 15 |
| **64** | 15 | 05 05 | 04 54 | 44 | 33 | 22 | 12 | 04 02 | 03 51 | 41 | 31 | 20 | 03 10 | 03 00 | 02 51 | 02 41 |
| **62** | 19 | 10 | 05 00 | 50 | 40 | 31 | 21 | 12 | 04 02 | 03 53 | 44 | 35 | 26 | 18 | 03 10 | 03 02 |
| **N60** | 05 23 | 05 14 | 05 05 | 04 56 | 04 47 | 04 38 | 04 29 | 04 21 | 04 12 | 04 04 | 03 56 | 03 48 | 03 40 | 03 32 | 03 25 | 03 18 |
| **58** | 26 | 17 | 09 | 05 01 | 52 | 44 | 36 | 28 | 21 | 13 | 04 06 | 03 58 | 03 51 | 45 | 38 | 32 |
| **56** | 28 | 21 | 13 | 05 | 04 57 | 50 | 42 | 35 | 28 | 21 | 14 | 04 08 | 04 01 | 03 55 | 49 | 44 |
| **54** | 31 | 23 | 16 | 09 | 05 02 | 55 | 48 | 41 | 35 | 28 | 22 | 16 | 10 | 04 04 | 03 59 | 03 54 |
| **52** | 33 | 26 | 19 | 13 | 06 | 04 59 | 53 | 47 | 40 | 35 | 29 | 23 | 18 | 13 | 04 08 | 04 03 |
| **N50** | 05 35 | 05 29 | 05 22 | 05 16 | 05 10 | 05 03 | 04 57 | 04 52 | 04 46 | 04 40 | 04 35 | 04 30 | 04 25 | 04 20 | 04 16 | 04 12 |
| **45** | 39 | 34 | 28 | 23 | 17 | 12 | 05 07 | 05 02 | 04 57 | 04 53 | 48 | 44 | 40 | 36 | 32 | 29 |
| **40** | 43 | 38 | 33 | 29 | 24 | 20 | 15 | 11 | 05 07 | 05 03 | 04 59 | 04 55 | 04 52 | 04 49 | 46 | 43 |
| **35** | 46 | 42 | 38 | 34 | 30 | 26 | 22 | 18 | 15 | 12 | 05 08 | 05 05 | 05 02 | 05 00 | 04 57 | 04 55 |
| **30** | 48 | 45 | 41 | 38 | 35 | 31 | 28 | 25 | 22 | 19 | 16 | 14 | 12 | 09 | 05 07 | 05 06 |
| **N20** | 05 53 | 05 50 | 05 48 | 05 45 | 05 43 | 05 41 | 05 38 | 05 36 | 05 34 | 05 32 | 05 30 | 05 29 | 05 27 | 05 26 | 05 24 | 05 23 |
| **N10** | 05 57 | 55 | 53 | 52 | 50 | 49 | 47 | 46 | 45 | 43 | 42 | 41 | 41 | 40 | 39 | 39 |
| **0** | 06 00 | 05 59 | 05 59 | 05 58 | 05 57 | 05 56 | 05 56 | 05 55 | 05 54 | 05 54 | 05 54 | 05 53 | 05 53 | 05 53 | 05 53 | 05 53 |
| **S 10** | 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 04 | 06 05 | 06 05 | 06 05 | 06 06 | 06 06 | 06 07 |
| **20** | 07 | 08 | 09 | 10 | 11 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 |
| **S 30** | 06 11 | 06 13 | 06 15 | 06 17 | 06 18 | 06 20 | 06 22 | 06 24 | 06 26 | 06 28 | 06 29 | 06 31 | 06 33 | 06 35 | 06 37 | 06 39 |
| **35** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 30 | 32 | 35 | 37 | 39 | 42 | 44 | 47 | 06 49 |
| **40** | 16 | 19 | 22 | 25 | 28 | 31 | 34 | 37 | 40 | 43 | 46 | 49 | 06 52 | 06 54 | 06 57 | 07 00 |
| **45** | 19 | 22 | 26 | 30 | 34 | 37 | 41 | 45 | 48 | 06 52 | 06 56 | 06 59 | 07 03 | 07 06 | 07 10 | 13 |
| **50** | 22 | 27 | 31 | 36 | 41 | 45 | 50 | 54 | 06 59 | 07 03 | 07 08 | 07 12 | 17 | 21 | 25 | 29 |
| **S 52** | 06 23 | 06 29 | 06 34 | 06 39 | 06 44 | 06 49 | 06 54 | 06 59 | 07 04 | 07 09 | 07 13 | 07 18 | 07 23 | 07 28 | 07 32 | 07 37 |
| **54** | 25 | 31 | 36 | 42 | 47 | 53 | 06 58 | 07 04 | 09 | 14 | 20 | 25 | 30 | 35 | 40 | 45 |
| **56** | 27 | 33 | 39 | 45 | 51 | 06 57 | 07 03 | 09 | 15 | 21 | 27 | 32 | 38 | 44 | 49 | 07 54 |
| **58** | 29 | 36 | 42 | 49 | 06 55 | 07 02 | 08 | 15 | 21 | 28 | 34 | 41 | 47 | 07 53 | 07 59 | 08 05 |
| **S 60** | 06 31 | 06 38 | 06 46 | 06 53 | 07 00 | 07 07 | 07 14 | 07 22 | 07 29 | 07 36 | 07 43 | 07 50 | 07 57 | 08 04 | 08 11 | 08 17 |

**SUNRISE TIME at N40° on 26th April= 05.07**

## Twilight

The Twilight is the transitional period from night to day before sunrise and from day to night after sunset.

There are different types pf twilight depending on the level of light and how far below the horizon the sun.

Civil twilight = Is defined ad beginning or ending at the instant when the centre of the Sun's disc is 6° below the horizon.

- Morning Civil Twilight: The period between the start of MCT and sunrise

- Evening Civil Twilight (ECT). THE period between sunset and the end of ECT