GNAV

<u>**The solar system:**</u>

1st law Kepler: Planets move in elliptical orbits with the sun **at one of the foci**
2nd law Kepler: Radius vector sun-earth sweeps out equal areas in equal time
Sun's declination:

- Angle between earth's equator & sun rays
- Northerly: Daylight in S hemisphere shorter
- Angular distance of the sun N/S of the celestial equator
- Sun's position relative to the plane of the Equator

Plane of ecliptic:

- Plane of which the earth travels around the sun, the earth's **axis is 23.5° tilted** tangent to ecliptic plane
- **Polar axis** with a **66.5° inclination** with the ecliptic plane
- Yearly apparent path of the **SUN** around the **EARTH**
- Inclination is the main reason for occurrence of the **seasons**

Apparent sun: Visible sun, always in the **plane of ecliptic**
Mean sun: **Fictitious sun** coinciding each year at **spring equinox** & travelling **along celestial equator** at **uniform/constant speed**
Difference between mean sun & apparent sun highest in **February & November**
Midnight sun: Sun visible for 24 hours
Perihelion: Closest, beginning of **January [Highest speed** of earth's orbit]
Aphelion: Furthest, beginning of **July**
Cancer/Capricorn: 23.5N/S [**Highest altitude** sun reaches **90° above horizon, occurs once a year]**
Polar circles: 66.5N/S
Equinoxes: Length of day/night & rate of change of declination of the sun highest

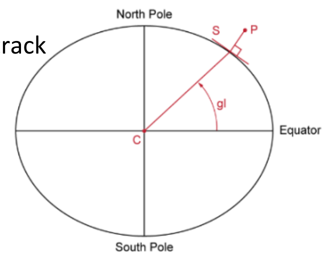
- Spring: Declination = 0
- Autumn: Declination = 0

Earth's rotation: Viewed from above North Pole = Counter clockwise
Solstice: Summer/winter, point when sun reaches its highest/lowest declination
Sidereal day: Describe a relationship concerning the stars
Apparent solar day: Varies continuously due to tilt of Earth's axis & elliptical orbit around the sun
Solar system doesn't include stars

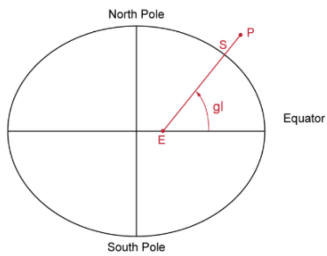
<u>**The earth:**</u>

1NM = 1.852km
Circumference = π x d
1 in 60 rule used for small angles ONLY

Convergence = Change in longitude x sin latitude
Convergence = Great circle initial true track – great circle final true track
Conversion angle = ½ Change in longitude x sin latitude
Departure (NM) = 60 x cos latitude
One degree on equator =60NM
One degree **near** equator = Less than 60NM
Track error = (Distance off track x 60) ÷ 150



gl = Geocentric Latitude



gl = Geographic (or Geodetic) Latitude

Earth is an oblate spheroid. Diameter = 12700km
Circumference: 21600NM
Halfway between two points, GCT = RLT
Convergence of meridians: **Angular difference** between meridians
Convergence angle: **Angular difference** between RLT & GCT
Great circle track (Orthodrome, radio bearings)

- Rhumb line closer to equator
- GC run through area of higher latitude
- GC shorter than RL

Small circle: Does not pass earth's axis. Unlimited number can be drawn between 2 points on the earth
Highest value of longitude: Greenwich anti-meridian
Following rhumb line track (Non-cardinal directions) you will fly a spiral to North Pole
Meridians:

- Parallel only at the equator
- All meridians run **south to north**

Vertex:

- Point on the great circle which has the highest latitude
- True direction either **90^o or 180^o**

Geodetic & geocentric:
- Latitudes only coincide at **equator & poles**
- Maximum difference occurs at **45^o**

Semi minor axis = Semi major axis ÷ 297
Initial rhumb line track = Reciprocal of final rhumb line track & vice versa

<u>Time:</u>
UTC = LMT +/- (longitude x 4)
Make sure to note if there is <u>daylight saving</u>
Know the difference between LMT & ST
Read question AND answers first
Earth rotates at 15^o/hour (UTC)

"Equation of time": The difference in time of transit of the mean sun & the apparent sun any particular day
"Sunset": The time when the observer at sea level sees the last part of the Sun disappear below the horizon
"Apparent solar day"
- Is the period between two successive transits of the **true sun** through the same meridian
- Earth's speed of revolution in its orbit varies continuously, due to orbit being elliptical

"Apparent time": Based on the time of transit of the apparent sun
"Transit": The body is passing the meridian of the observer or another specified meridian
"Apparent sun" if used for time reference, length of day will vary with course of the year
Mean sun: Constant measurement of time, independent of the daily variations in the movement of the sun as observed from the earth

Day and night throughout the year has different duration due to **inclination of ecliptic** to the equator
A day starts when the mean sun transits the anti-meridian of the place
A day is defined as: The period elapsed between **two successive transits of a heavenly body**
Sidereal day is constant
Close to the equinoxes the influence of latitude on duration of daylight is at its smallest
Solar day lasts longer than sidereal day as both the direction of rotation of the earth around its axis & its orbital rotation around the sun are the same

0000 LMT: Mean sun in transit with observer's anti-meridian
1200 LMT: Mean sun in transit with observer's meridian

Time interval between sunrise & sunset/civil twilight depends on **declination of the sun** & the **latitude of the observer**
The sun sets at different times at the same longitude
The sun rises at same LMT for places with same latitude

Twilight: Periods before sunrise & after sunset when the light is lower than when the sun is above the horizon
Duration of twilight is longer at high latitudes
Morning civil twilight:
- Centre of the sun 6^o below of celestial horizon
- Period from centre of sun 6^o below horizon until upper limb of the sun appears at the horizon

ST = Standard time determined by governments
UTC is slightly more accurate than GMT but the difference is too small
Daylight saving time: Used in some countries, used to extend the period of evening, is introduced by setting the standard time by one hour
Standard time: Time set by legal authorities
Countries slow on UTC: Western longitudes
Crossing International Date Line: W – E = -24 hours (Gain one day)/E – W = +24 hours (Lose one day)

Hour angle: Mean sun at 1200 LMT is 000^o

Air almanac:
Time is given in **LMT**
Highest time difference = 13 hours
One set of values given in air almanac:

- Enough to be used for all longitudes, when determining daylight conditions
- May need to be adjusted for observers at high altitudes
- Only for positions situated along the Greenwich meridian

Atmospheric refraction: Sunrise earlier and sunset later

S.E.A - September Equinox Autumn
M.E.S- March Equinox Spring
Solstice – winter (Dec) & summer (June)
During September & spring the inclination of the earth (23.5deg) has the least effect on the amount of daylight with latitude change

<u>Directions:</u>

	NH	SH
PW	E	W
PE	W	E

First convert reference meridian to 000 prime meridian (Grid track + reference)
Convergency east true least, convergency west true best
True track increase NH, decreases SH

Grid convergence = Difference in direction between Grid North & True North
Grid convergence westerly: TN west of GN/for positions East of the grid datum meridian on NH
Grid convergence easterly: TN east of GN

Wind correction: R is (+) & L is (-)

True north: Direction of **observer's meridian** to the North Pole, orientation of local meridian
Magnetic North moves **1^{o} in 5 years**
Earth is a magnet with the blue pole at the North Pole **(North Canada)** and direction of magnetic force straight down to earth's surface
Field direction is from magnet's red pole to the magnet's blue pole
Magnetic compass most effective **midway between magnetic poles**
Force acting on a needle of a DRC is directly proportional to horizontal component of the earth's magnetic field
Total magnetic force strongest at the poles
Directive force: Resultant magnetic force in the horizontal plane in the position where the compass is installed
Increasing magnetic latitude = Increasing inclination & vertical component of the field
Horizontal component of the Earth's magnetic field:
- Maximum at magnetic equator
- Very small at the poles
- Approximately the same at 50^{o}N & 50^{o}S
- Equals to total strength at magnetic equator

Magnetic variation is max at 180^{o}
Magnetic variation **westerly** is **negative (-), easterly** is **positive (+)**
Variation is east when MN is east of TN
Magnetic equator: Horizontal & total strength of magnetic field are the same
Magnetic meridian: Horizontal direction of the Earth's magnetic field in that position, toward the magnetic north pole

Deviation changes because the **undesired magnetic pole is moved** relative to the **direction of the earth's magnetic field**
Compass deviation is a force in direction **perpendicular** to the **compass needle**
Compass **deviation applied to compass heading** to get **magnetic heading** [Important]
Compass deviation affected by: Magnetic **latitude**, aircraft **heading** & aircraft **electronic equipment**
Compass deviation **decrease** as latitude decrease as horizontal component becomes stronger
Compass **free** from extraneous magnetic influence: Magnetic heading
Compass **affected** by extraneous magnetic influence: Compass heading

Compass needle marked **red** is **north seeking pole**
Compass needle will align itself with the direction of the **magnetic lines of force**

Purpose of GRID: Provide a system for directions where a **great circle has a constant direction** even if true direction varies
Grid lines are all parallel to the reference meridian

GRIVATION: Grid convergence + variation/ difference between GH & MH

Agonic line:
- Follows separate paths out of the North Polar Regions, one running through Western Europe, & another through US
- Positions that have 0^{o} **variation**
- Positions where magnetic & true meridians are parallel

Isogonals:
- Lines of equal magnetic variation
- Converge at N & S geographic & magnetic poles

Isoclinals: Lines of equal magnetic **dip**
Aclinic: Line of zero magnetic dip
Isogrives: Lines of equal grivation

Strength of horizontal component: Tesla x cos (dip)
Dip angle = $\cos^{-1}$(H/T)

Magnetic track angle: Direction of a line referenced to Magnetic North

<u>Distances:</u>
1NM = 1.852km
1SM = **5280ft**
1m = 3.28ft
1 inch = **2.54cm**
1ft = **12 inch**

1 min = 1NM
Conversion angle = RLT – GCT
Change in longitude = Conversion angle x 2 ÷ sin latitude
Meeting time of aircraft: Total distance/total speed

1km = 1/10000 part of the meridian length from equator to pole

Heights & altitudes in international aviation: Metre & foot
Horizontal distances: Metres, kilometres & nautical miles
Departure = Change in longitude x cos mean latitude

One minute of arc along a meridian equal to one NM at **45^{o}**

Oblate spheroid: 1 min of arc along equator is greater than 1 min of arc at lat **45^{o}**

<u>Magnetism:</u>
CS-25 standby compass instruments accuracy of magnetic heading is 10^{o}
Red pole RB 70^{o} from the compass, westerly deviation maximum at heading 20

Deviation is dependent on aircraft heading
Compass calibration: Deviation on any heading

DRMC made deadbeat (Aperiodic) by keeping the magnetic assembly mass close to the compass point & by using damping wires
Turning ADF on will not affect DRMC
DRMC does not require power from the aircraft systems to indicate direction

Undershoot north: At first compass indicates a left hand turn, turn has to be broken off before the compass indicates the desired heading, the compass indication will lag during the first 90^{o} of the turn
UN: Undershoot & liquid swirl increase effect
OS: Overshoot & liquid swirl decreases effect
ANDS & UNOS are reversed in Southern Hemisphere

Pre-flight inspection:
- Comparing compass indication to another reference for example the runway direction
- From main compass indication

Turning errors: N/S heading, acceleration errors: E/W heading

Compass swing made when a period of one year has passed during which the aircraft has remained stationary on the ground
General properties of miscellaneous types of projections:
1 inch = 2.54cm
General:

- Aeronautical charts: Exact scale vary within the chart
- "Scale": The ratio of chart length compared to the Earth's distance that it represents

Mercator chart:

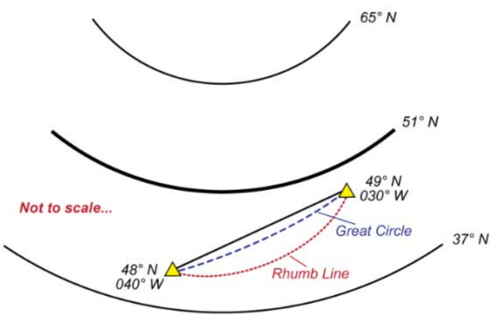
- Scale varies with 1/cosine latitude (secant)
- Expands with **secant** of latitude
- Based on a **cylindrical** projection
- It's a cylindrical projection but it is in fact mathematically produced
- Convergency is **0^o**
- Not possible to represent N/S poles
- Scale increases with increasing distance from the equator
- Chart convergence = earth convergence **at equator**

Lamberts:

- Chart convergence is constant & does not change with latitude
- Chart convergence depends on latitude of parallel of origin & difference in longitude between the positions
- Standard parallels: The latitudes where the cone cuts the reduced earth
- Earth convergence is most accurate at the parallel of origin
- Convergence of meridians at the parallel of origin = earth convergence
- Scale: Correct **along** the two standard parallels
- Scale is constant **along** a parallel of latitude (Parallel of origin)
- Scale reaches its **minimum value** at the parallel of origin
- Scale **contracts** between standard parallels, scale between differs only by **less than 1%** from stated scale
- Scale is **only correct at standard parallels**
- Chart convergency = Change of longitude x constant of cone
- Chart convergency = Change of longitude x sin parallel of origin
- Chart convergency = Change of longitude x chart convergence factor
- Chart convergence = Angular difference between initial true track & final true track
- Lamberts chart has to be processed mathematically to **obtain conformity**

Polar stereographic chart:

- Scale reaches its minimum value at the North pole
- It is a **plane projection**
- **Convergence factor = 1**



Distance = Change of longitude x cos latitude

Track decreasing in easterly direction = Northern hemisphere
Track decreasing in easterly direction = Southern hemisphere

ABBA

Conformal meaning:

- At any point the scale over a short distance in the direction of the parallel is equal to the scale in the direction of the meridian & the meridians are **perpendicular** to the parallels
- Scale is constant along a parallel of latitude

Bearings are great circles

A small scale map shows more area represented & less detail
Small scale = Large area in bad detail
Large scale = Small area in good detail

Basics of dead reckoning
1SM = 1.609km
1 IMP gallon = 1.2 US gallons = 4.546 litres
1lb = 0.454kg
Specific gravity = Mass ÷ volume

Above FL360, ISA temp is -56.5^{o}C

ETA: Estimated time of arrival at destination

Accuracy of the manually calculated DR-position of an aircraft is affected by:
- **Accuracy of forecasted wind**
- **The flight time since the last position update**

Drift is always **FROM** heading **TO** track
Drift is **opposite** of WCA
Radials are **magnetic tracks**

TA = PA + [(QNH -1013) x 30] + [ISA deviation x 0.4% x (PA + pressure correction – station altitude)]

Density altitude: 120ft per 1^{o} ISA deviation
Density altitude = PA + density correction

Calculating heading & ground speed:
XWC = sin (wind angle) x wind speed
Drift = XWC x 60 ÷ TAS
Heading = Track +/- drift
HWC = cos (wind angle) x wind speed
Effective TAS = TAS x cos WCA
GS = Effective TAS +/- headwind/tailwind
***Effective TAS has to be considered for WCA > 10^{o}

Finding W/V
True index to track
Hole on GS
Line to WCA & TAS
Align dot to middle (Left = clockwise, right CCW)
Be careful to see (M) or (T) wind
Be careful to see CAS or TAS

Finding W/V by using TAS: Align index to HEADING & DOT to TAS

Finding GS
Set wind direction
Mark velocity to a reference (Above dot: Tailwind, below dot: headwind)
Turn to track, move mark over TAS arc

Compressibility factor 0.95 at FL290

$GS^2 = TAS^2 + W/V^2 – (2 \times TAS \times W/V \times \cos(\text{wind angle}))$

DR position is estimated position taking account of estimated TAS & wind condition
DR position is found on the **desired track**
Line connecting last known position with DR position: **Estimated track**

Air position: Shows where the aircraft would be as a result if its TAS & true heading were not affected by wind

GD = (AD x GS) ÷ TAS

MH + RB = MB
TH + RB = TB

<u>In-flight navigation:</u>
Transferring position line can be done with radials, DME, QDM/QDR
Transferring range position lines: Transfer the origin & plot the range position lines from the transferred origin
Transferring position lines: LOP are transferred at ground speed
LOP are transferred along track lines

To establish a track plot: At least two pinpoints or fixes
Position line (e.g. canal): More or less perpendicular to track
Track plot: Path of the aircraft relative to the ground
Uncertainty in aircraft's position: Set heading towards a line feature such as coastline, motorway, river or railway
"Whiteout": When the terrain is covered with snow & horizon blends with the sky, visual determination of height become difficult
Two parallel roads crossed at right angles can be used to determine groundspeed
After heavy snowfall: High tension lines/power lines
Coastline = line of position

Hypsometric charts: Lines of altitude

Be aware of **from or to the aircraft** when calculating MB/TB

<u>Navigation in climb & descent:</u>
Only when the say <u>approximate</u> use 1 in 60 rule
1 in 60 rule:
Angle = (Height x 60) ÷ distance

Only when finding TAS, average altitude:
- Climb: 2/3 of altitude climbed + initial altitude
- Descent: ½ of cruising altitude

W/V for climb use wind 2/3 of cruising altitude
W/V for descent use ½ of cruising altitude

Gradient (%) = Altitude difference (feet) x 100 ÷ ground difference (feet) = ROD ÷ ground speed
Gradient (^{o}) = Arctg [Altitude difference (feet) ÷ ground difference (feet)]
ROD = Gradient (%) x groundspeed
ROD = Groundspeed (kt) x gradient (feet/NM) ÷ 60

3^o glideslope: GS x 5

Slant range = hypotenuse

Pick middle value when descending through a level

TAS = IAS + 2%/1000ft [STANDARD CONDITIONS]

Converting CAS to TAS
1) Altitude correction = 1% for each 600ft
2) 0.2% for each 1^oC deviation
3) Find average altitude
   ½ cruising altitude + remaining altitude
   2/3 cruising altitude + initial altitude
4) Correction % = Altitude correction + temperature correction
5) Total correction = (1 + correction/100)
6) TAS = CAS x total correction

<u>Navigation in cruising flight:</u>
Total track correction = TKE angle along track + TKE angle to go

TKE = Planned track TO Current track
TKE = WCA