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1. The Shape of the Earth

What This Section Covers

Why the Earth is not a perfect sphere; the concept of the geoid; geodetic models; why ICAO adopted WGS 84; and the simplifications used in DGCA examinations.

The Earth's shape is commonly described as an **oblate spheroid** — a sphere slightly flattened at its poles. The flattening (called *compression*) is approximately **0.3% (1/300th)**, meaning the Earth's polar diameter is **23 NM (43 km)** less than its equatorial diameter. Recent satellite surveys also show a slight pear-shape, with maximum diameter south of the Equator (measured in tens of metres — far smaller than the polar compression).

Because the Earth is not a perfect ellipse, the only accurate descriptor is "**geoid**" (from Greek — Earth-shaped). Different agencies have modelled the geoid for their own regions; the main ones are:

- UK Ordnance Survey — **OS36**
- France — **NTF 1970**
- Europe — **ED50**
- USA / World — **WGS 84**

Exam Trap — Geoid Differences

Different geoids can give positions differing by **up to ~200 metres** for the same physical point. This was tolerable before GPS/FMS but is now significant. GPS accuracy is of the order of tens of metres, so geoid choice matters operationally.

Why ICAO Adopted WGS 84

Two developments forced standardisation:

1. **GPS** — global, ~tens-of-metres accuracy; adopted WGS 84 from the outset.
2. **FMS/DME position updating** — the FMS data base stores DME station positions in lat/long. Mixing geoids (UK DMEs in OS36, French DMEs in NTF70) would cause large discontinuities when crossing the English Channel.

ICAO therefore mandated **WGS 84** as the world standard. Modern navigation computers automatically correct for Earth-shape distortions.

DGCA Exam Simplification

For any exam calculation, treat the Earth as a **perfect sphere** with:

- Circumference = **21 600 NM** ($= 360^\circ \times 60 \text{ NM}/^\circ$)
- Circumference = **40 000 km**

The Poles

The Poles are the extremities of the Earth's spin axis. The polar axis is inclined to the plane of the Earth's orbit at **$23\frac{1}{2}^\circ$** . For this chapter, the polar axis is drawn upright (the seasonal effects are covered in the chapter on Time).

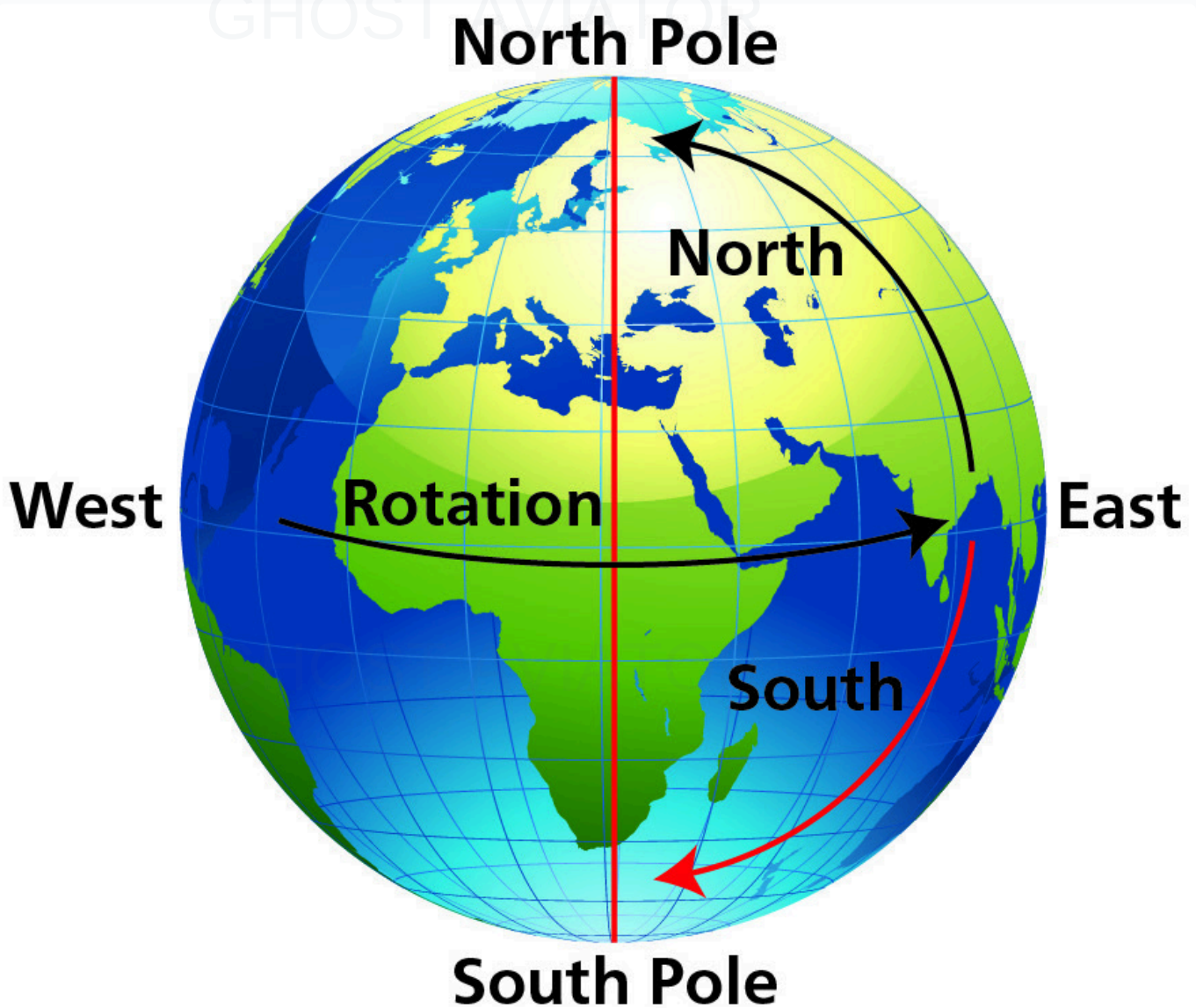


Figure 1 — Earth's rotation shown in elevation — the axis is tilted $23\frac{1}{2}^\circ$ to the orbital plane

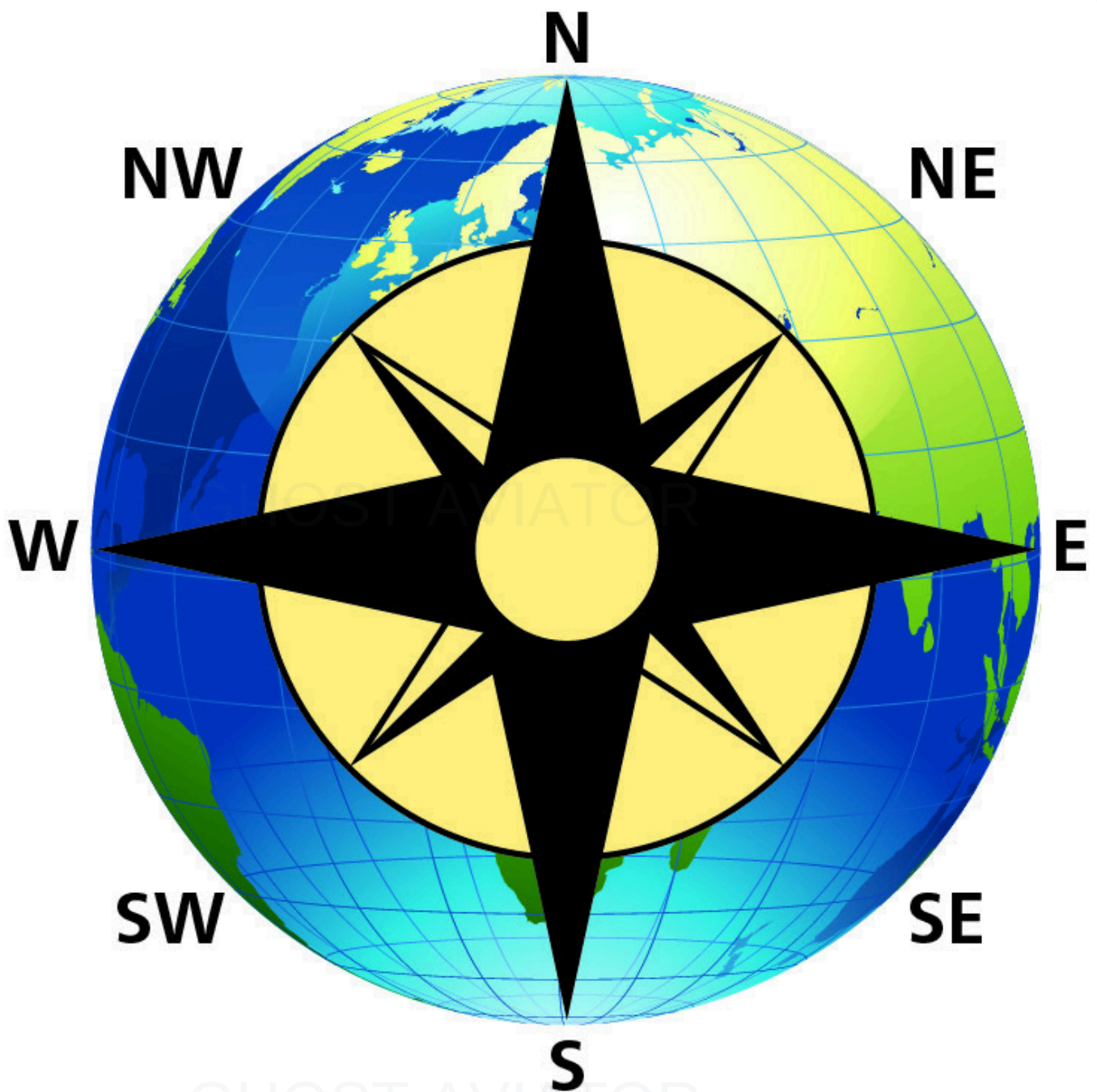


Figure 2 — Cardinal and quadrantal compass points

➤ Operational Relevance

The Earth's compression is negligible for most flight navigation. However, it becomes significant for:

- GPS position accuracy (geoid vs ellipsoid height)
- FMS data base consistency across different country systems
- Precise instrument calibration (ILS localizer, ARP positions)

2. Basic Direction on the Earth

What This Section Covers

How compass directions are defined; the Sexagesimal system; True directions; 3-figure groups; reciprocal directions; viewing Earth from the poles.

Cardinal and Quadrantal Points

The primary datum for direction is the Earth's spin direction (East = sunrise). From this:

- **North** — direction of the North Pole
- **South** — opposite of North
- **East** — direction of Earth's spin
- **West** — opposite of East

Midway between these are the *Quadrantal* directions: NE, SE, SW, NW.

Viewing from the Poles

A frequent exam question — when viewed from *above the North Pole*, the Earth rotates **anticlockwise**. Viewed from above the *South Pole*, it rotates **clockwise**. The direction of East and West does NOT change — it is always the direction of (and opposite to) the Earth's rotation.

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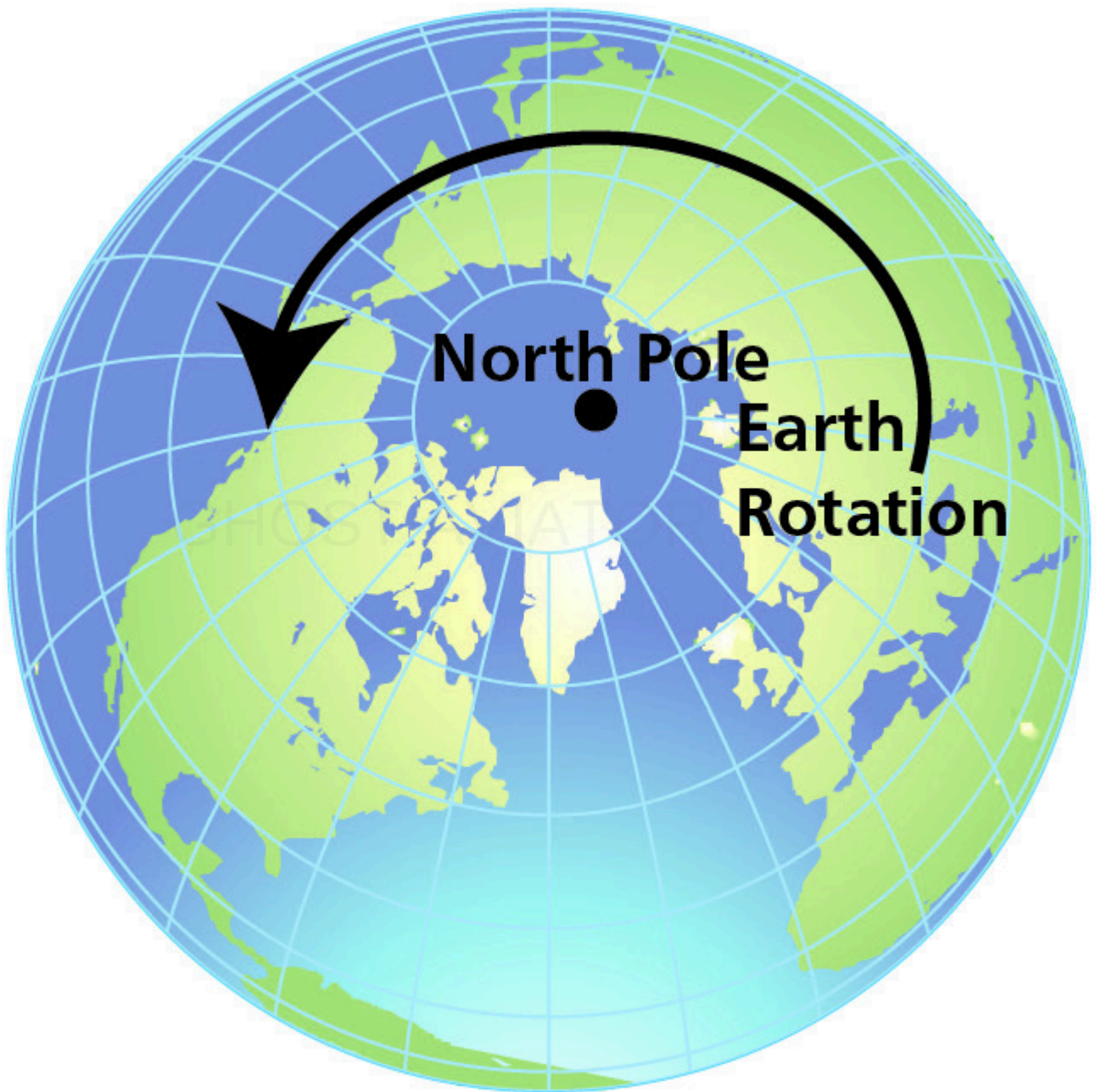


Figure 3 — Earth's rotation viewed from above the North Pole — anticlockwise rotation

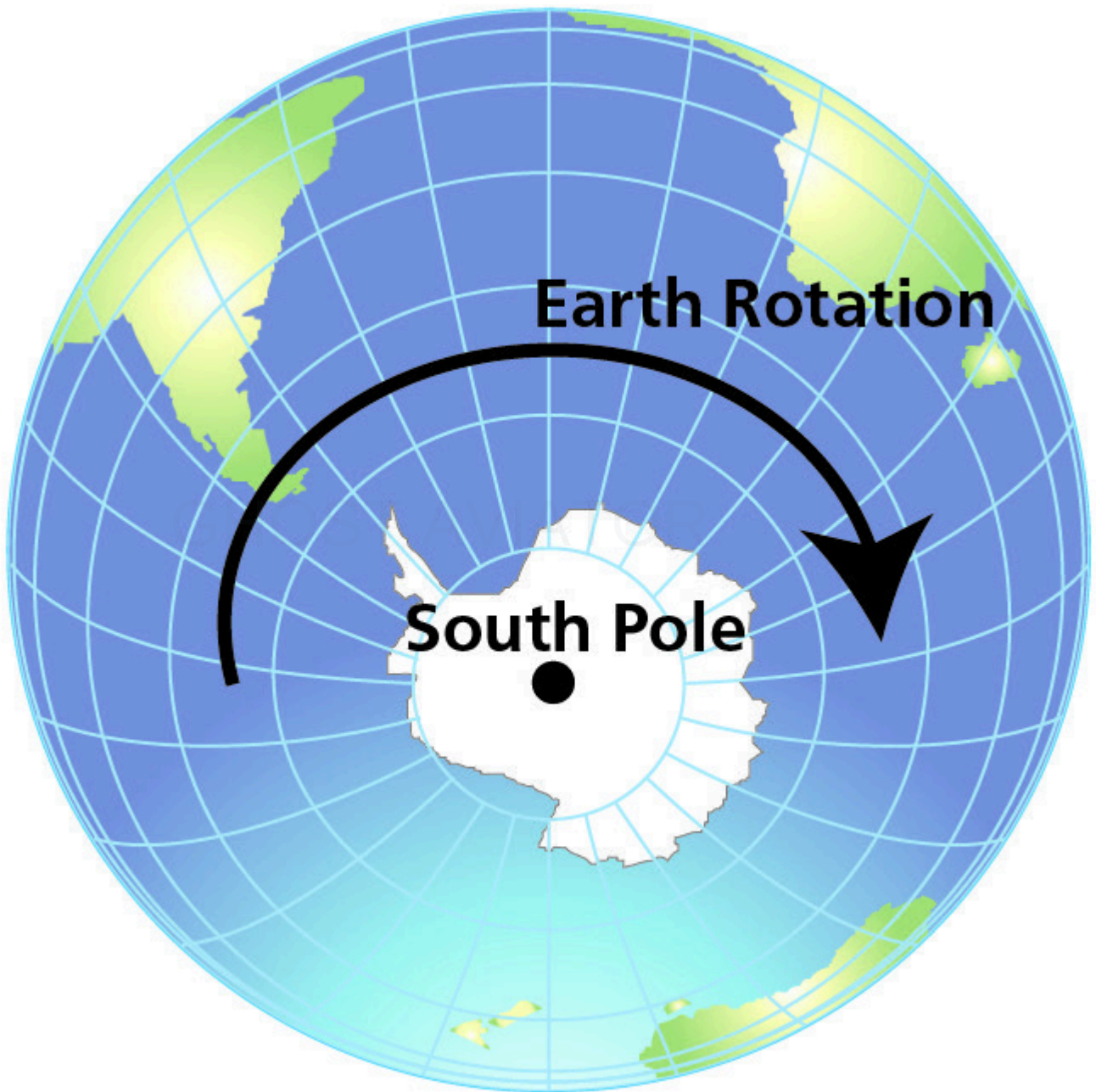


Figure 4 — Earth's rotation viewed from above the South Pole — clockwise rotation

The Sexagesimal System / True Direction

Air navigation uses the **Sexagesimal system**: direction measured in degrees clockwise from North (000° to 360°).

- North = **000°(T)** or 360°(T)
- East = **090°(T)**
- South = **180°(T)**
- West = **270°(T)**

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When the North datum is the geographic North Pole, the direction is **True direction**, written with the suffix (T).



Figure 5 — The sexagesimal compass — 360° clockwise from North

⚠ 3-Figure Group Rule — Never Omit Leading Zeros

Always use 3-figure groups for directions: 027°, not 27°; 090°, not 90°. Ambiguity example: 27° could be corrupted from 027°, 270°, 127°, 227°, 327°, 271°, 272° etc.

Exception — Runway designations: given to nearest 10°, e.g. RWY 27 for 273°(T), RWY 08 for 078°(T). Note: runway directions normally reference Magnetic North, not True North.

Reciprocal Directions

The **reciprocal** of a direction is direction ± 180°.

🔧 Worked Examples

Reciprocal of 060° = 060 + 180 = 240°

Reciprocal of 353° = 353 - 180 = 173°

Rule: if the direction is ≥ 180°, subtract 180; if < 180°, add 180.

3. Position Reference Systems & Circles on the Earth

🔍 What This Section Covers

Why Cartesian coordinates don't work on a sphere; the spherical equivalents (lat/long); Great Circles and Small Circles; Equator; Meridians; Prime Meridian; Parallels of Latitude.

Navigation requires a **Position Reference System** to define location unambiguously on the Earth's surface. On a flat surface, Cartesian coordinates (±x, ±y) work perfectly. On a sphere, *angular* coordinates replace linear ones: **Longitude** (Y-axis equivalent) and **Latitude** (X-axis equivalent).

Great Circle

A **Great Circle** is a circle on the Earth's surface whose centre and radius are those of the Earth itself. It divides the Earth into two equal hemispheres. Key property:

➔ Operational Importance

The **shortest distance** between any two points on the Earth's surface is the shorter arc of the **Great Circle** joining them. This is why long-haul routes fly Great Circle tracks. Given two non-antipodal points, only **one** Great Circle joins them.

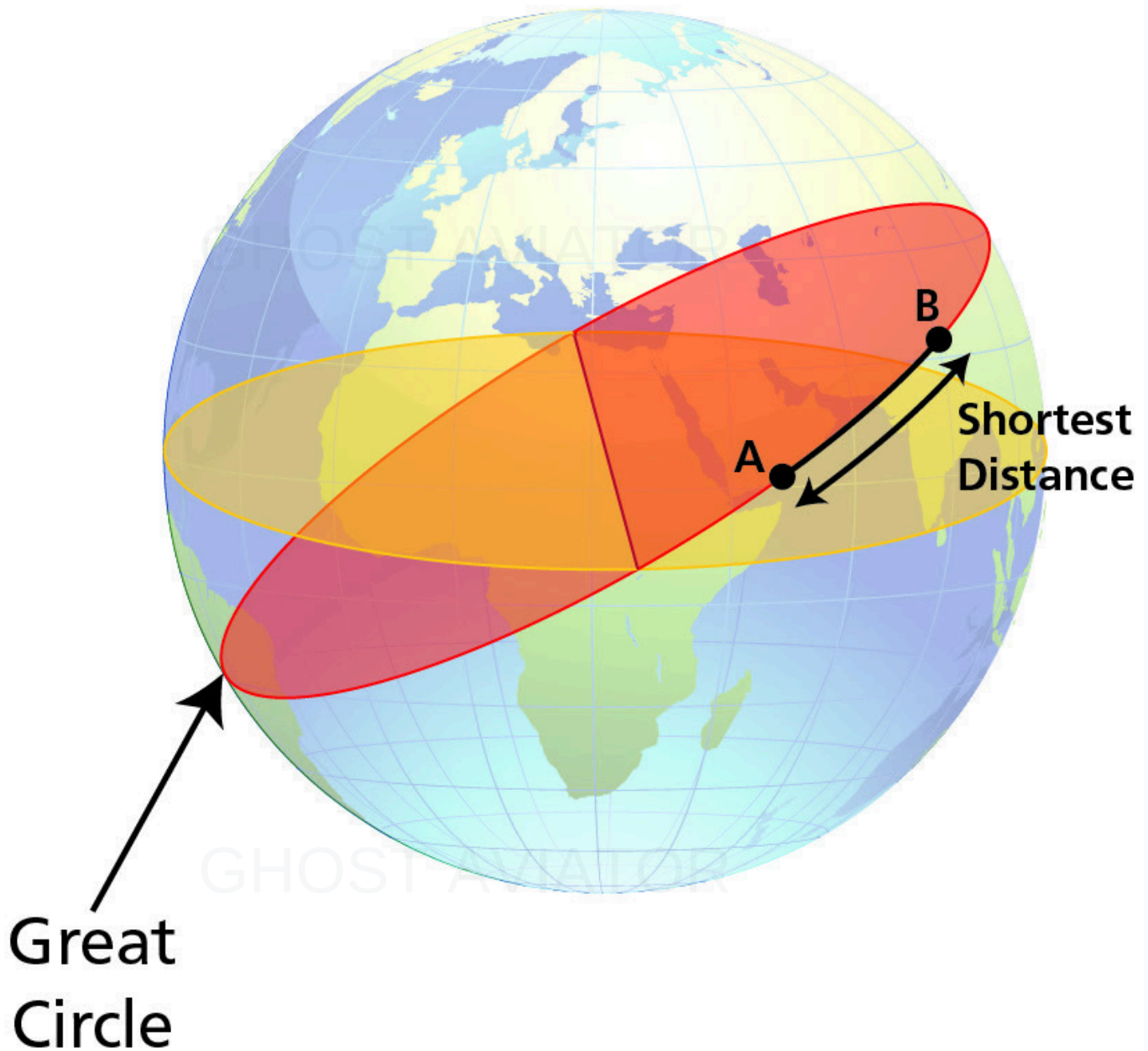


Figure 6 — A Great Circle — its centre and radius are those of the Earth itself

The Equator

The Great Circle whose plane is **perpendicular (90°) to the Earth's polar axis**. It divides the Earth into Northern and Southern Hemispheres and is the **datum for Latitude** (equivalent to the X-axis).

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Meridians

Meridians are semi-Great Circles joining North and South poles. Every Great Circle through the poles forms a *meridian* and its *anti-meridian*. All meridians indicate True North–South direction and cross the Equator at 90° .

The Prime (Greenwich) Meridian

The meridian through Greenwich is the **Prime Meridian** — the datum for Longitude (equivalent to the Y-axis).

Small Circles & Parallels of Latitude

A **Small Circle** is a circle on the Earth's surface whose centre and radius are *not* those of the Earth.

Parallels of Latitude are the most important small circles: they are parallel to the Equator, lie in an East–West direction, and indicate position North or South of the Equator.

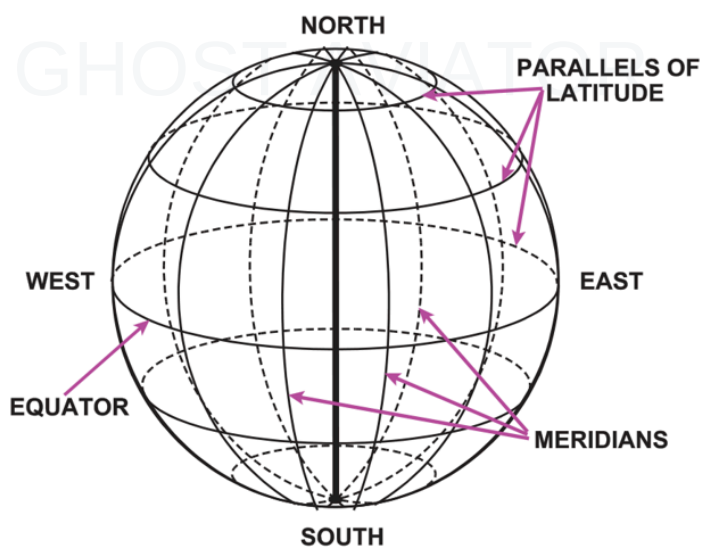
4. The Graticule & Angular Measurements

The Graticule

The **Graticule** is the network formed by the Prime Meridian, all meridians, the Equator, and all parallels of latitude — the spherical equivalent of a Cartesian x–y grid.

Direction, Latitude and Longitude

1



1

Direction, Latitude and Longitude

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Angular Measurements

Position in the Graticule is expressed in *angular* rather than linear units:

Unit	Subdivision	Use
Degree (°)	1/360th of a circle	Primary unit for lat/long and direction
Minute (')	1/60th of a degree	Position accuracy to ~1 NM
Second (")	1/60th of a minute	High-precision positions (charts, ILS)

For *direction*, degrees and decimal degrees are used. For *position*, degrees, minutes (and seconds where needed) are standard.

5. Latitude — Definition & Types

Definition of Latitude

The **latitude** of a point is the arc along the meridian through the point, measured from the Equator to the point. Expressed in degrees, minutes (and seconds) of arc, annotated N or S.

- Equator = **0°**
- North Pole = **90°N**
- South Pole = **90°S**

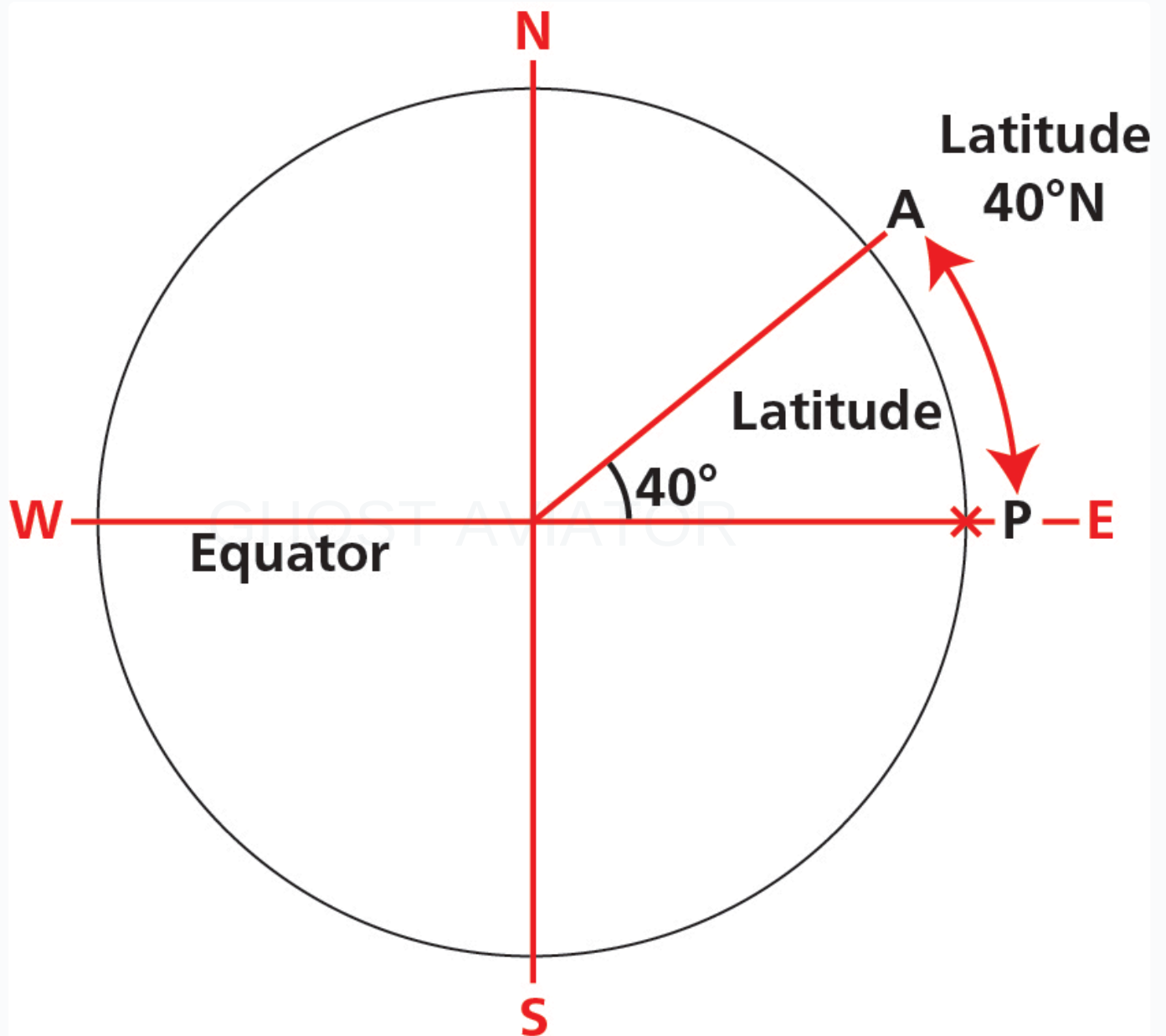


Figure 8 — Latitude — angular arc measured along the meridian from the Equator

Geocentric vs Geodetic (Geographic) Latitude

Because the Earth is an oblate spheroid (not a perfect sphere), two definitions of latitude exist:

- **Geocentric Latitude** — angle between the line from the point to the Earth's *centre* and the Equatorial plane.
- **Geodetic (Geographic) Latitude** — angle between the *normal* (*perpendicular*) to the spheroid *surface* at the point and the Equatorial plane. This normal does *not* necessarily pass through the Earth's centre.

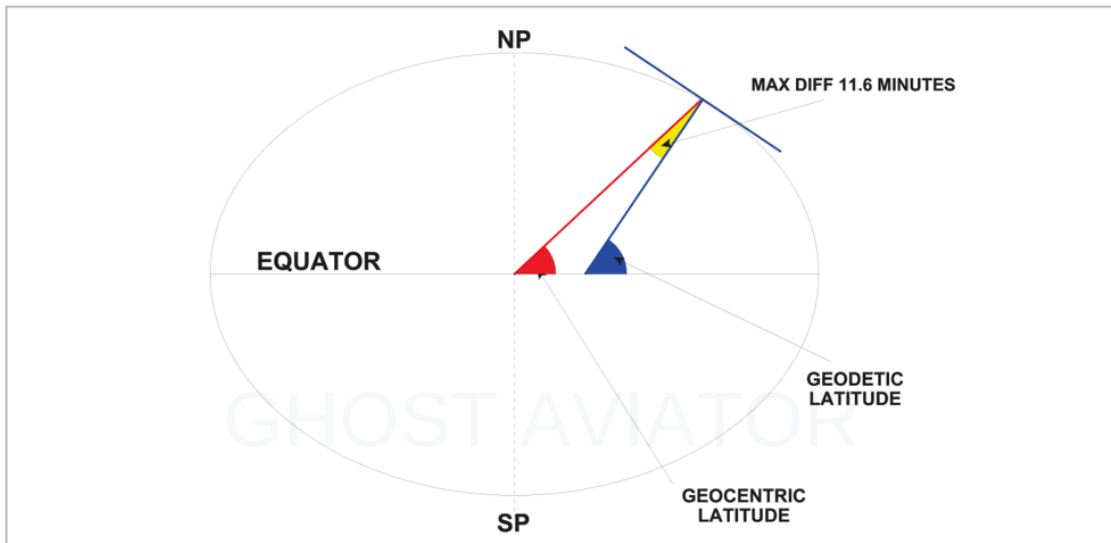


Figure 9 — Geocentric vs Geodetic latitude — the normal to the spheroid does not pass through the Earth's centre

Exam Tip

Navigation charts use **Geodetic (Geographic) Latitude**. The maximum difference between Geocentric and Geodetic latitudes occurs at approximately **45°N/S** and is about **11.6 minutes of arc**.

6. Special Parallels of Latitude

What This Section Covers

Four named parallels related to the Earth's axial tilt of $23\frac{1}{2}^\circ$ — important in the chapter on Time.

Parallel	Latitude	Significance
Arctic Circle	$66\frac{1}{2}^{\circ}\text{N}$	Boundary of midnight sun / polar night
Antarctic Circle	$66\frac{1}{2}^{\circ}\text{S}$	Same in Southern Hemisphere
Tropic of Cancer	$23\frac{1}{2}^{\circ}\text{N}$	Sun directly overhead at Northern summer solstice
Tropic of Capricorn	$23\frac{1}{2}^{\circ}\text{S}$	Sun directly overhead at Northern winter solstice

Mnemonic

The value $23\frac{1}{2}^{\circ}$ = the Earth's axial tilt. The complement is $66\frac{1}{2}^{\circ} = 90^{\circ} - 23\frac{1}{2}^{\circ}$. Cancer is **North** (Northern summer). Capricorn is **South**.

7. Longitude, Difference in Longitude & the Anti-Meridian

Definition of Longitude

The **longitude** of a point is the shorter arc along the Equator between the Prime Meridian and the meridian through the point. Annotated East (E) or West (W), measured up to 180°E or 180°W .

Giving position: Latitude is always quoted first, longitude second — e.g. New York $41^{\circ}\text{N } 074^{\circ}\text{W}$.

1

Direction, Latitude and Longitude

1

Direction, Latitude and Longitude

Longitude

The longitude of any point is the shorter distance in the arc along the Prime Meridian and the meridian through the point. Longitude is measured in minutes of arc and is annotated East (E) or West (W) depending whether it is East or West of the Prime Meridian (Greenwich). In [Figure 1.10](#), you are looking down at the North Pole from a point out in space. The meridian of point B crosses the Equator at 40° of arc to the East of the Prime Meridian. Point B is said to be at long

Difference in Longitude

When calculating the difference between the longitude of two positions, if both are the same East or West longitude then the one is subtracted from the other to give the difference or sometimes called change of longitude (ch long). If they are East and West then the two are added together i.e. $020^\circ\text{W} + 010^\circ\text{E} = 30^\circ$ ch long. One anomaly might occur when the two longitudes are East and West of the Greenwich Anti Meridian.

Example. What is the difference in longitude between 163°E and 152°W ? If you followed the two would be added together to give 315° however we take the 'shortest' value of difference. In this case if you take the 315° away from 360° you get 45° ch long.

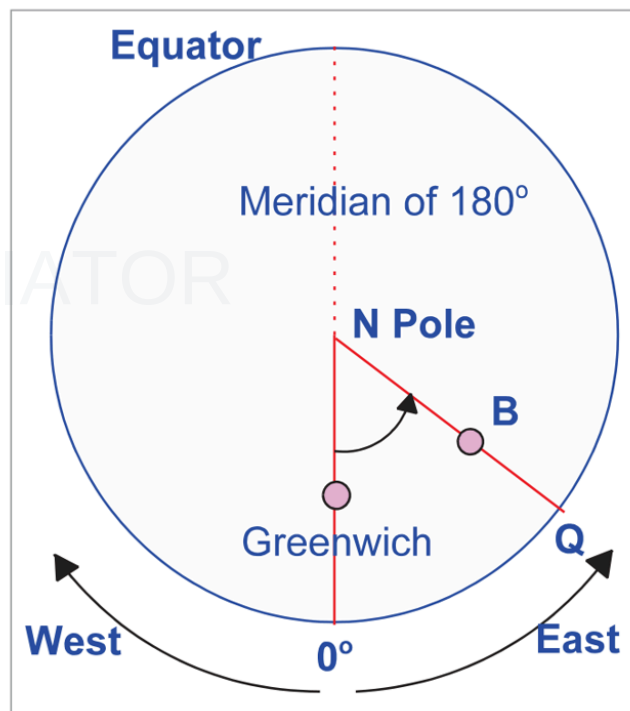


Figure 10 — Longitude — angular arc measured along the Equator from the Prime (Greenwich) Meridian

Difference in Longitude (Ch Long)

✂ Worked Examples

Same side (both E or both W): subtract. $100^{\circ}\text{W} - 080^{\circ}\text{W} = \underline{20^{\circ} \text{ ch long}}$

Opposite sides (one E, one W): add. $020^{\circ}\text{W} + 010^{\circ}\text{E} = \underline{30^{\circ} \text{ ch long}}$

Near Anti-Meridian — take the shorter value:

163°E and 152°W : $163 + 152 = 315^{\circ}$. Since $315^{\circ} > 180^{\circ}$, take $360^{\circ} - 315^{\circ} = \underline{45^{\circ} \text{ ch long}}$

The Greenwich Anti-Meridian (180°E/W)

The 180°E and 180°W meridians are coincident — known as the **Greenwich Anti-Meridian**. A famous source of exam confusion: at 180° longitude, the Eastern Hemisphere is to your *West* and the Western Hemisphere is to your *East*. The direction of East and West has not changed — only which hemisphere is in each direction relative to where you stand.

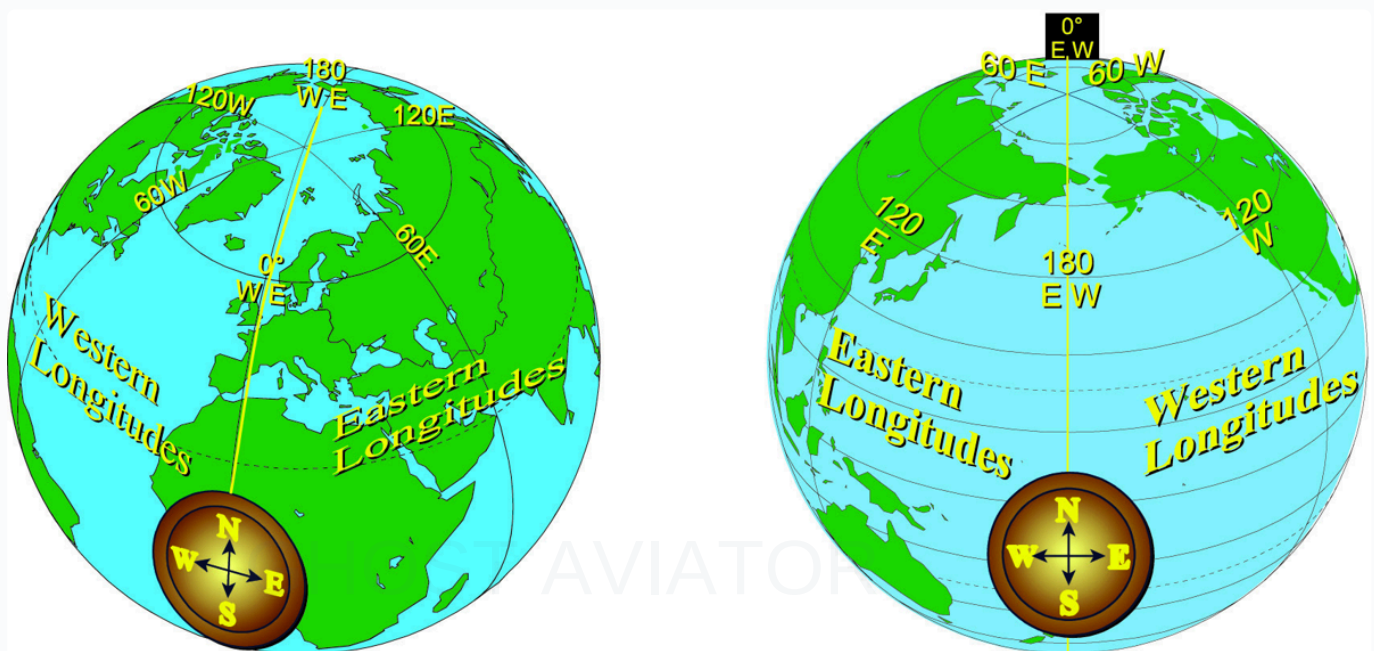


Figure 11 — The Greenwich Anti-Meridian — at 180° the sense of E/W longitudes appears reversed

Latitude vs Longitude — Key Difference

- **Parallels of latitude** — always parallel to each other (like slicing a pineapple)
- **Meridians of longitude** — emanate from the North Pole, reach maximum separation at the Equator, converge to the South Pole (like orange segments)

8. Converting Lat/Long to Distance & Resolution Accuracy

The Nautical Mile — Defined by Arc

The **nautical mile** is defined so that **1 minute of arc on a Great Circle = 1 NM**. The mean Earth radius gives 6 080 ft per minute. ICAO definition: **1 NM = 1 852 metres**.

✈ Operational Use

All meridians are Great Circles, so **change in latitude always converts directly to distance**: 1 minute of latitude = 1 NM. For example, positions 50°00'N and 50°05'N on the same meridian are exactly **5 NM** apart.

Change in longitude does NOT convert at the same rate — only at the Equator (the only parallel that is a Great Circle).

Resolution Accuracy — Summary Table

Direction, Latitude and Longitude

1

(Instrument Landing System) localizer. Accuracy at this level would certainly be needed for section and flight calibration of an ILS.

much for the flexibility of this system of position reference that, whilst for most of the flight we are interested in our position accuracy only to the nearest mile or so, and can write our position as 5150N 00119W - a total of 11 fairly simple numbers or letters, we can use the system to establish a position to within half a metre by writing 515000.28N 00119.45W, which is really not too long-winded considering the level of accuracy achieved.

Summary of accuracy resolution is given in the following table:

How Written	Level of Accuracy	Typical Application

Figure 12 — Position resolution accuracy — how the format of a quoted position determines its precision

1
Direction, Latitude and Longitude

How Written	Level of Accuracy	Typical Application
5321N	1 NM (6 080 ft)	En-route navigation
5321.3N	600 ft / 185 m	INS, IRS, FMS, GPS displays
53°21'17"N	100 ft / 30 m	Airfield diagram chart
53°21'17.3"N	10 ft / 3 m	Location of precision navaid (ILS)
53°21'17.32"N	1 ft / 30 cm	Calibration of precision navaid

Exam Tip — Two ways to go beyond 1 NM resolution

1. **Decimal minutes** — e.g. 5321.3N (nearest 0.1 NM = 600 ft). Used in INS/FMS/GPS entry.
2. **DMS (degrees, minutes, seconds)** — used on large-scale charts and for precision navaids. One second of arc $\approx$ **100 ft (30 m)**.

9. Great Circle Vertices

What This Section Covers

Vertices of a Great Circle; their relationship to equator crossings; how to calculate crossing longitudes and track angles — a common calculation-type exam question.

Definition

The **Northern vertex** is the most northerly point on a Great Circle; the **Southern vertex** is the most southerly point. Key properties:

- Vertices are **antipodal** — directly opposite each other on the Earth, on a common meridian/anti-meridian
- Their latitudes are equal in magnitude but opposite in sign
- GC distance between them = **10 800 NM** ($= 180^\circ \times 60 \text{ NM}$)
- At either vertex the GC direction is exactly **090°(T)** (East) or **270°(T)** (West)

Vertex Longitude — Finding the South Vertex

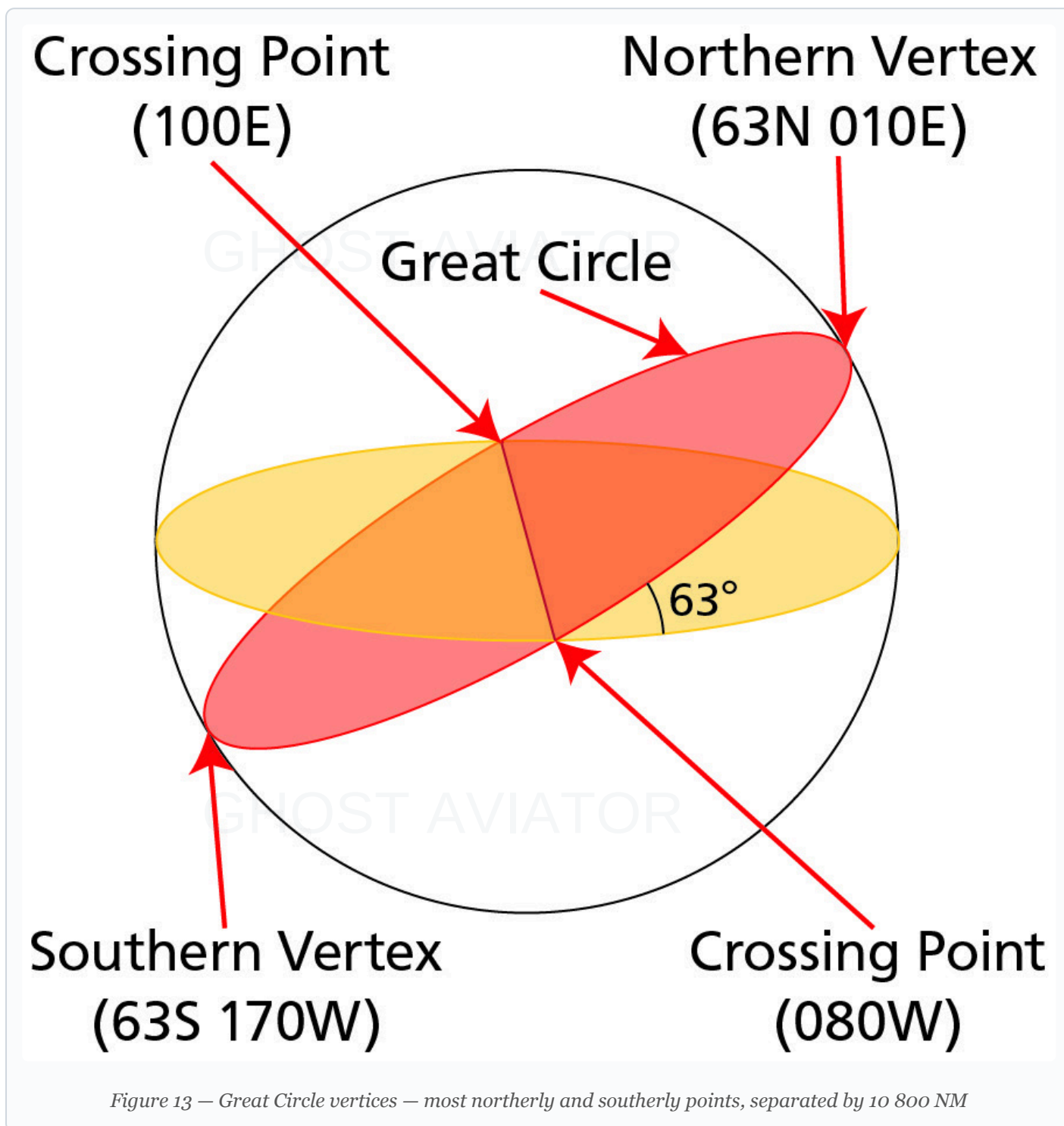
South vertex longitude = North vertex longitude **$\pm 180^\circ$** (take the value ≤ 180).

✂ **Example: North vertex 70°N 130°E → South vertex?**

Latitude: **70°S** (same magnitude, opposite sign)

Longitude: $130^\circ\text{E} + 180^\circ = 310^\circ\text{E} = \mathbf{050^\circ\text{W}}$

South vertex: 70°S 050°W



Equator Crossings — Longitudes

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The GC crosses the Equator at **two points**, each **90° of longitude** from either vertex:

✂ **Example (continued): Vertex 70°N 130°E**

Crossing 1: $130^\circ\text{E} - 90^\circ = \mathbf{040^\circ\text{E}}$

Crossing 2: $130^\circ\text{E} + 90^\circ = 220^\circ\text{E} = \mathbf{140^\circ\text{W}}$

Equator Crossings — Track Angles

The track angle at each equator crossing depends on the vertex latitude and the direction of travel:

- **First crossing eastbound** (from north vertex going East): track = **$90^\circ + \text{vertex latitude}$**
- **Second crossing eastbound** (after south vertex, still East): track = **$90^\circ - \text{vertex latitude}$**
- **Westbound crossings**: take the reciprocals of the eastbound values

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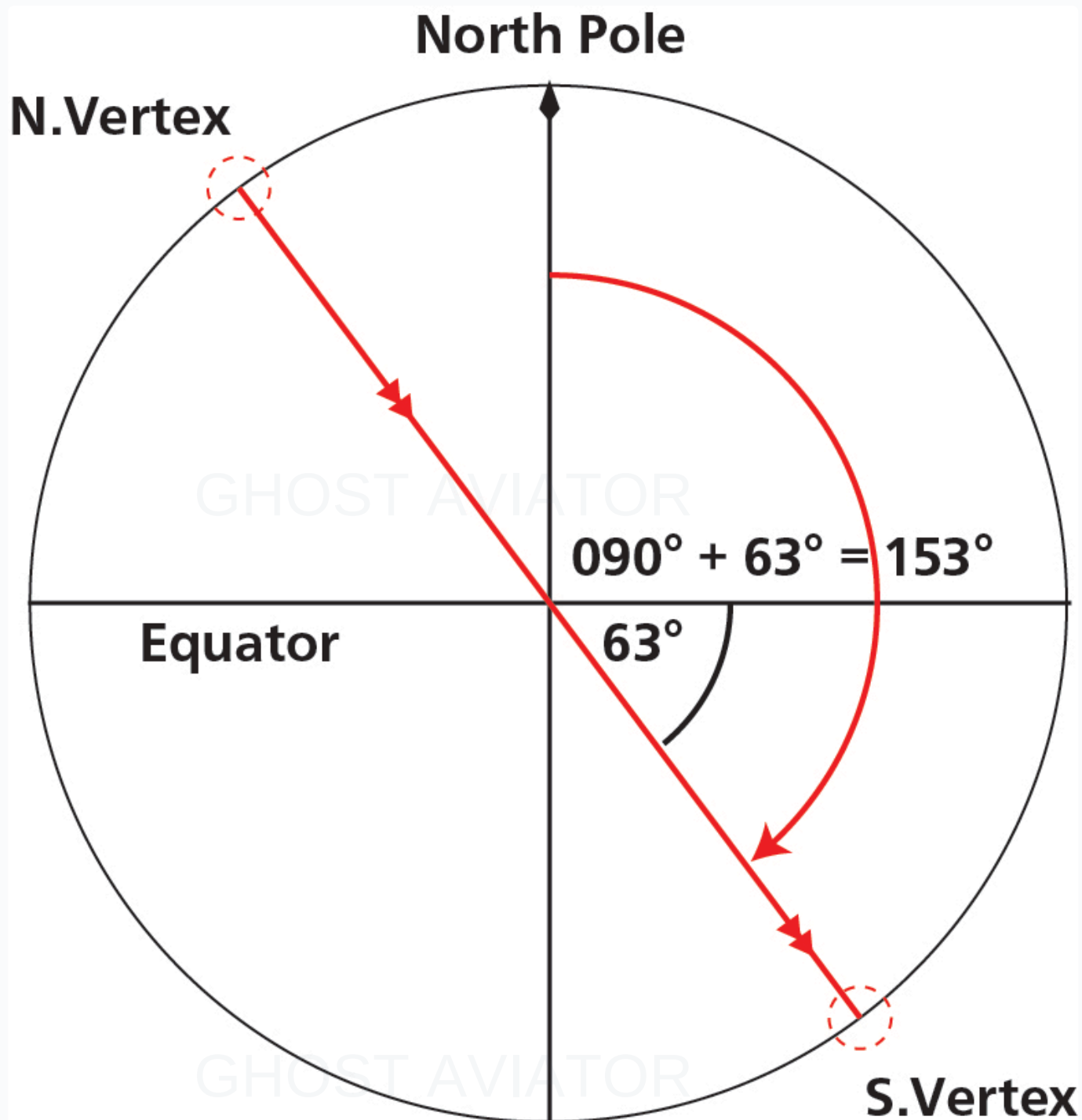


Figure 14 — First equator crossing when tracking East from the northern vertex — track angle = $90^\circ + \text{vertex latitude}$

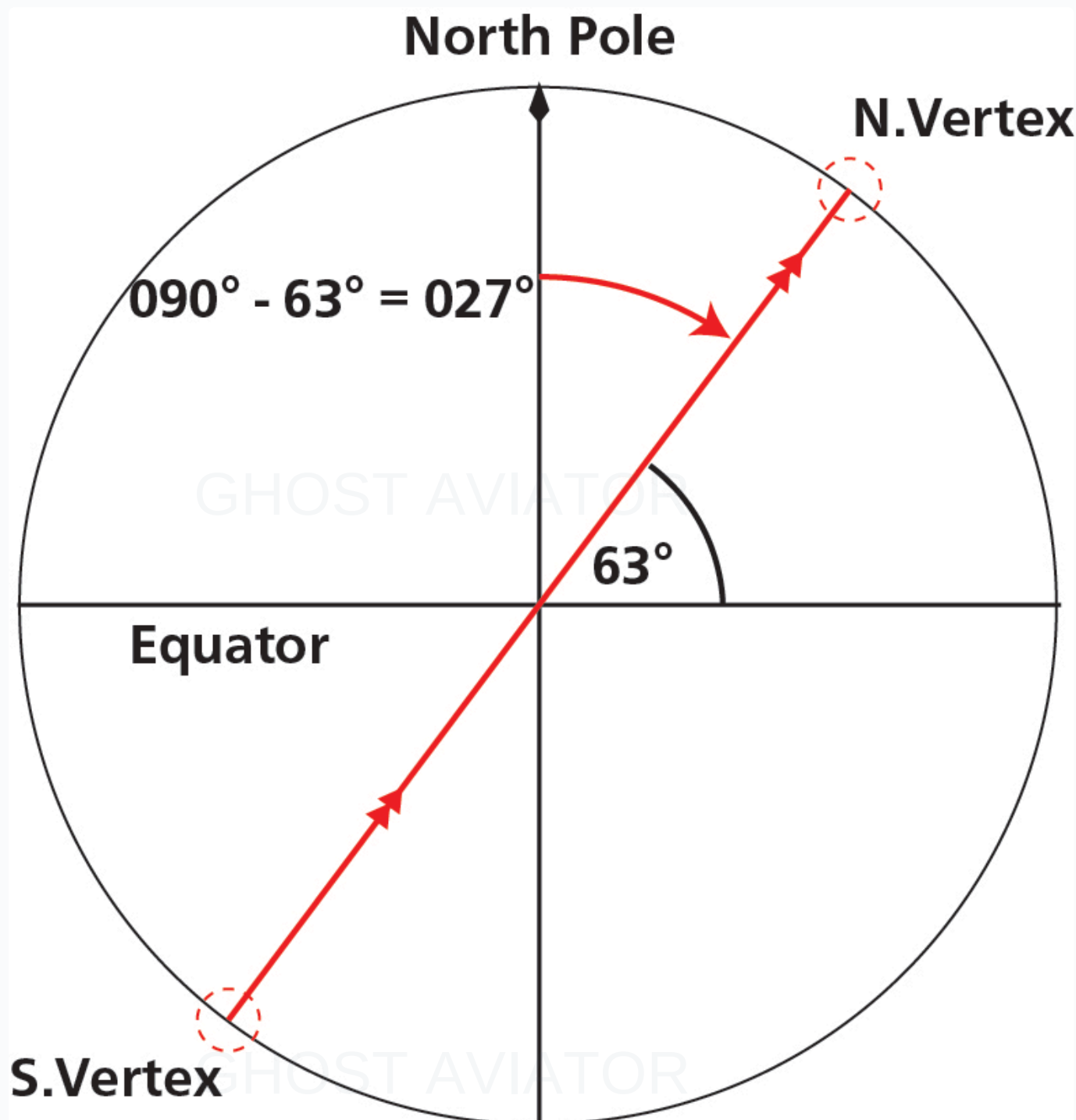


Figure 15 — Second equator crossing when tracking East (after the southern vertex) — track angle = $90^\circ - \text{vertex latitude}$

✍ Full Worked Example: vertex 70°N 130°E, going East

Crossings at: 140°W and 040°E

First crossing (140°W), going East: $90^\circ + 70^\circ = \underline{160^\circ(T)}$

Second crossing (040°E), going East: $90^\circ - 70^\circ = \underline{020^\circ(T)}$

Going West from north vertex: reciprocals → first crossing (040°E): 200°(T), second crossing (140°W): 340°(T)

Special Cases

- A meridian (vertices at 90°N/S) crosses the Equator at 000°(T) or 180°(T)
- The Equator itself (vertices at 0°N/S) has direction 090°(T) or 270°(T)

📖 Quick Revision Summary — Chapter 1

- Earth = oblate spheroid; compression $\approx \underline{0.3\%}$; polar diameter shorter by 23 NM
- Geoid = Earth-shaped; ICAO standard = WGS 84
- DGCA exam: treat Earth as sphere, circumference = 21 600 NM / 40 000 km
- True direction: clockwise from True North, 3-figure groups always
- Reciprocal = direction $\pm \underline{180^\circ}$
- North Pole view = anticlockwise rotation; South Pole view = clockwise
- Great Circle = shortest path; centre = Earth's centre
- Equator = only parallel that is a Great Circle
- Latitude: $0^\circ \rightarrow \pm 90^\circ$; Longitude: $0^\circ \rightarrow \pm 180^\circ$; latitude given **first**
- 1 minute of latitude = 1 NM (everywhere); 1 minute of longitude $\neq$ 1 NM (except at Equator)
- Geodetic latitude on charts; max difference from geocentric $\approx \underline{11.6'}$ at 45°N/S
- Vertex latitude = latitude of vertex; equator crossings 90° of longitude from vertex
- Track at first eastbound equator crossing = 90° + vertex lat

Practice Questions & Detailed Answers

5 questions • All sourced from end-of-chapter material • Full answer key, explanations & distractor analysis

Q1. What is the approximate compression of the Earth?

Anchor: [Section 1 – Shape of the Earth](#)

- (a) 3%
- (b) 0.03%
- (c) 0.3% ✓**
- (d) 1/3 000

Correct Answer: (c) 0.3% (= 1/300th)

The Earth's polar diameter is approximately **23 NM (43 km) shorter** than its equatorial diameter. This flattening is called *compression* and equals approximately **0.3%** or **1/300th**. The precise ICAO value (WGS 84) is 1/297, but 0.3% / 1/300 is the standard exam answer.

Distractor Analysis:

- (a) 3% — ten times too large; would imply 230 NM difference, implying the Earth is almost a flat disc at the poles.
- (b) 0.03% — ten times too small; would be almost imperceptible and navigationally irrelevant.
- (d) 1/3 000 — this is 0.033%, a factor of ~10 too small; confusable with 1/300 if misread.

Instructor's Note: The compression value of **1/297** appears in precise geodetic work (WGS 84). For the DGCA exam, 0.3% = 1/300 is the expected answer. No discrepancy with source key — answer (c) is unambiguous.

Q2. A Graticule is the name given to:

Anchor: [Section 4 – The Graticule](#)

- (a) a series of lines drawn on a chart
- (b) a series of Latitude and Longitude lines drawn on a chart or map ✓**
- (c) a selection of small circles as you get nearer to either pole

Correct Answer: (b) A series of Latitude and Longitude lines drawn on a chart or map

The **Graticule** is the complete network formed by the Prime Meridian, all meridians, the Equator, and all parallels of latitude — specifically *both* the latitude and longitude systems together. It is the spherical equivalent of a Cartesian x-y grid and allows any point to be defined unambiguously.

Distractor Analysis:

(a) Too vague — any set of lines on a chart could be called "a series of lines." The graticule is specifically the lat/long grid.

(c) Inverts the relationship — parallels of latitude become *closer together* towards the poles (on the globe), not more numerous. This option misrepresents both the definition and the geometry.

Instructor's Note: Answer consistent with source key. Note that on a Mercator chart the parallels appear equally spaced (scale expands with latitude), but on the globe they converge at the poles. Answer (b) is unambiguous.

Q3. A Great Circle has its North vertex at $70^{\circ}\text{N } 130^{\circ}\text{E}$. What is the position of its South vertex?

Anchor: [Section 9 – Great Circle Vertices](#)

(Answer) $70^{\circ}\text{S } 050^{\circ}\text{W}$ ✓

South vertex: $70^{\circ}\text{S } 050^{\circ}\text{W}$

Step 1 — Latitude: Vertices are antipodal and equal in magnitude but opposite in sign. North vertex = 70°N → South vertex = **70°S** .

Step 2 — Longitude: Vertices lie on a common meridian/anti-meridian. Anti-meridian of 130°E = $130^{\circ}\text{E} - 180^{\circ}$... no, apply the correct method:

$130 + 180 = 310^{\circ}\text{E}$. Since $310^{\circ} > 180^{\circ}$, convert: $360^{\circ} - 310^{\circ} = \mathbf{050^{\circ}\text{W}}$.

Alternatively: the south vertex longitude is simply 180° away from the north vertex. Starting at 130°E , move 180° East → $310^{\circ}\text{E} = 050^{\circ}\text{W}$.

Common Errors:

Subtracting 180° instead of adding: $130^{\circ} - 180^{\circ} = -50^{\circ} = 050^{\circ}\text{W}$ (happens to give same answer in this case — coincidence of numbers). Always use: N vertex lon + 180° , convert to $\leq 180^{\circ}$ E or W.

Wrong latitude sign: writing 70°N for south vertex — vertices are always opposite N/S.

Instructor's Note: Short-answer question (no MCQ options). Source key: **70°S 050°W**. Calculation verified. No discrepancy.

Q4(a). For the Great Circle in Q3 (North vertex 70°N 130°E): at what longitude and in what direction does the Great Circle cross the Equator when the initial direction from the northern vertex is *East*?

Anchor: [Section 9 – Great Circle Vertices](#)

(Answer) 140°W at track 160°(T) ✓

First eastbound equator crossing: 140°W at 160°(T)

Step 1 – Crossing longitudes: The GC crosses the Equator at two longitudes, each 90° of longitude from the vertex (130°E):

Crossing A: $130^\circ\text{E} + 90^\circ = 220^\circ\text{E} = \mathbf{140^\circ\text{W}}$

Crossing B: $130^\circ\text{E} - 90^\circ = \mathbf{040^\circ\text{E}}$

Step 2 – Direction at first eastbound crossing (140°W):

Track = $90^\circ + \text{vertex latitude} = 90^\circ + 70^\circ = \mathbf{160^\circ(T)}$

Step 3 – Direction at second eastbound crossing (040°E):

Track = $90^\circ - \text{vertex latitude} = 90^\circ - 70^\circ = \mathbf{020^\circ(T)}$

(Note: the source key only provides the first crossing – 140°W at 160°(T). The second crossing at 040°E at 020°(T) is the complete picture.)

Common Errors:

Mixing up + and – for the track formula: using $90^\circ - 70^\circ = 20^\circ$ for the first crossing gives the second crossing answer.

Wrong longitude: subtracting 90° for "east" instead of adding (going east from 130°E reaches 140°W after +90°, not –90°).

Instructor's Note: Source key gives **140°W 160°(T)** for Q4a – this is the first crossing only. The second crossing (040°E, 020°(T)) is equally valid and completing the full picture is good exam practice. No discrepancy with source key for the stated answer.

Q4(b). Same Great Circle – at what longitude and in what direction when the initial direction from the northern vertex is *West*?

Anchor: [Section 9 – Great Circle Vertices](#)

(Answer) 040°E at track 200°(T) ✓

First westbound equator crossing: 040°E at 200°(T)

Going *West* from the north vertex at 130°E, the GC first reaches the crossing at 040°E (90° west of the vertex).

Track direction at 040°E going West:

Eastbound direction at 040°E (second crossing going east) = 020°(T).

Reciprocal (westbound) = $020^\circ + 180^\circ = \mathbf{200^\circ(T)}$.

Alternatively, use the formula directly:

First westbound crossing direction = $180^\circ + (90^\circ - \text{vertex lat}) = 180^\circ + 20^\circ = \mathbf{200^\circ(T)}$

Common Errors:

Applying the eastbound formula ($90^\circ + 70^\circ = 160^\circ$) to westbound direction — gives the reciprocal of the correct westbound answer at the OTHER crossing.

Getting longitude wrong: going West from 130°E by 90° reaches 040°E, not 140°W.

Instructor's Note: Source key gives **040°E 200°(T)**. Verified — consistent with the methodology in the text. No discrepancy.

Q5. Given that the compression value of the Earth is $1/297$ and the semi-major axis (equatorial radius) is 6 378.4 km, what is the semi-minor axis (polar radius)?

Anchor: [Section 1 — Shape of the Earth](#)

(a) 6 399.9 km

(b) 6 356.9 km ✓

(c) 6 378.4 km

(d) 6 367.0 km

Correct Answer: (b) 6 356.9 km

Formula: Compression = (semi-major – semi-minor) / semi-major

Rearranging: semi-minor = semi-major $\times$ (1 – compression)

Calculation:

Compression = $1/297 \approx 0.003367$

$$\begin{aligned}\text{semi-minor} &= 6\,378.4 \times (1 - 1/297) = 6\,378.4 \times (296/297) \\ &= 6\,378.4 \times 0.99664 = \mathbf{6\,356.9\text{ km}}\end{aligned}$$

Distractor Analysis:

- (a) 6 399.9 km — larger than the equatorial radius; impossible (polar radius must be *smaller*).
- (c) 6 378.4 km — same as equatorial radius; this would mean a perfect sphere (compression = 0).
- (d) 6 367.0 km — close but incorrect; this is approximately the mean Earth radius, not the polar radius.

Instructor's Note: WGS 84 actual value: semi-minor = 6 356.752 km. Source key answer (b) is correct. Calculation verified numerically. No discrepancy.

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Master Reference Tables — Chapter 1

All Key Numerical Values

Parameter	Value	Unit	Section
Earth compression (approx)	0.3% (1/300)	—	§1
Earth compression (WGS 84)	1/297	—	§1
Polar diameter shorter than equatorial	23 NM / 43 km	—	§1
Earth circumference (exam)	21 600 NM / 40 000 km	—	§1
Polar axis tilt to orbital plane	23½°	degrees	§1
North Pole latitude	90°N	—	§5
South Pole latitude	90°S	—	§5
Max longitude	180°E / 180°W	—	§7
Geodetic vs Geocentric lat max difference	11.6' at 45°N/S	arc-min	§5
1 minute of arc on Great Circle	1 NM (1 852 m)	—	§8
Decimal minute resolution	600 ft / 185 m	—	§8
1 arc-second resolution	100 ft / 30 m	—	§8
Arctic / Antarctic Circle	66½°N / 66½°S	—	§6
Tropic of Cancer / Capricorn	23½°N / 23½°S	—	§6
GC vertex to vertex distance	10 800 NM	NM	§9
GC track at vertex (direction)	090°(T) or 270°(T)	—	§9
Equator crossings from vertex	±90° longitude	—	§9
Track at 1st eastbound equator crossing	90° + vertex lat	°(T)	§9
Track at 2nd eastbound equator crossing	90° – vertex lat	°(T)	§9

Mnemonics

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Concept	Mnemonic / Rule
Reciprocal direction	If $< 180^\circ$, add 180. If $\geq 180^\circ$, subtract 180.
North Pole view	N orth = a nticlockwise
Latitude order	L at before L ong (alphabetical)
Great Circle = shortest	G reat = G oes shortest
South vertex longitude	North lon $\pm 180^\circ$ (take value ≤ 180)
Tropic values	Earth's tilt = $23\frac{1}{2}^\circ \rightarrow$ Tropics at $23\frac{1}{2}^\circ$; complement = $66\frac{1}{2}^\circ \rightarrow$ Circles
Eastbound track formula	F irst = $90 + \text{lat}$ (going deeper); S econd = $90 - \text{lat}$ (flattening out)

Answer Key Summary

Q	Answer	Flag
1	(c) 0.3%	—
2	(b) Series of lat/long lines on chart/map	—
3	70°S 050°W	—
4(a)	140°W at 160°(T) [first crossing; second = 040°E at 020°(T)]	—
4(b)	040°E at 200°(T)	—
5	(b) 6 356.9 km	—

No 🚩 flags — all source key answers verified as correct.

DGCA CPL/ATPL General Navigation Study Notes

Chapter 1 — Direction, Latitude & Longitude

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