

CHAPTER 15 · GENERAL NAVIGATION

Departure

E-W distance in nautical miles · The cosine formula · Latitude variation · Worked examples

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Definition of Departure

Departure is the distance between two meridians measured along a specified parallel of latitude, expressed in nautical miles.

This may sound simple, but the key insight is that the *same change of longitude* does *not* represent the same east-west distance at every latitude. The closer you are to the poles, the shorter the E-W distance for a given change of longitude — because the meridians converge.



Figure 1 — Two meridians separated by the same change of longitude — the east-west distance between them varies with latitude



Figure 2 — Effect of latitude: the same ch.long gives shorter departure as latitude increases toward the poles

Think of it this way: 360 degrees of longitude span the full circumference of the Earth. At the Equator, the circumference is about 21 600 NM. At 60°N the circumference of the parallel is only about 10 800 NM — exactly half. One degree of longitude at 60°N is therefore half of one degree of longitude at the Equator.

Why Departure Varies with Latitude

The key observation is about the two extreme cases:

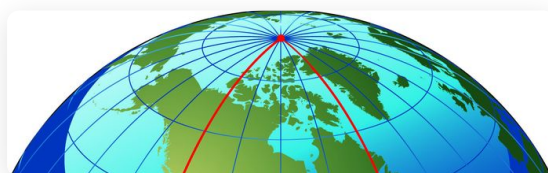


Figure 4 — At the poles meridians converge to a single point — departure is zero regardless

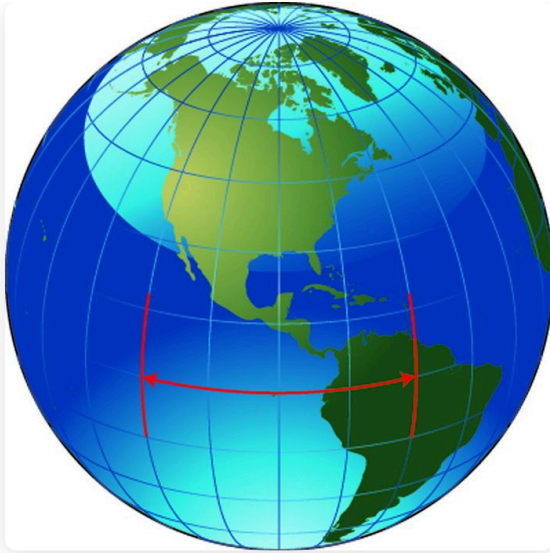


Figure 3 — At the Equator the meridians are at their maximum separation — departure is greatest here

- **At the Equator (lat = 0°):** The parallels of latitude are great circles. One minute of arc of longitude = one minute of arc of a great circle = **1 NM**. Departure is maximum here.
- **At the Poles (lat = 90°):** All meridians meet at a single point. Departure = 0 regardless of how far apart the meridians are in longitude.
- **At intermediate latitudes:** Departure is proportional to **cos(latitude)**. The cosine function has exactly the right behaviour: $\cos(0^\circ) = 1.0$ (full departure at Equator) and $\cos(90^\circ) = 0$ (zero at Poles).

WHY COSINE, NOT SINE?

Because departure depends on the *radius of the parallel*, and the radius of any parallel at latitude $\phi = R \times \cos(\phi)$, where R is the Earth's radius. The circumference at any latitude is $2\pi \times R \times \cos(\phi)$ — it shrinks by the cosine factor as you move toward the poles.

The Departure Formula

$$\text{Departure (NM)} = \text{ch.long (minutes)} \times \cos(\text{latitude})$$

ch.long must be in minutes of arc (multiply degrees by 60)

Derivation

At the Equator, 1 minute of longitude = 1 NM. At latitude ϕ , the parallel has a circumference equal to $\cos(\phi)$ of the Equatorial circumference. Therefore:

$$\text{departure} = \text{ch.long (in minutes)} \times \cos(\text{latitude})$$

Units to Remember

Item	Unit	Conversion
Change of Longitude	Minutes of arc	degrees $\times$ 60
Departure	Nautical Miles	—
Latitude	Degrees	used directly in $\cos()$
Kilometres to NM	$\div 1.852$	1 NM = 1.852 km
NM to km	$\times 1.852$	—



Figure 5 — Two meridians joined by a parallel of latitude — the east-west measurement is departure

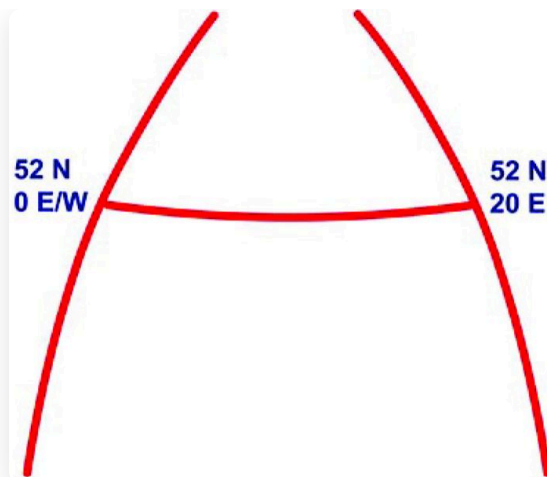


Figure 6 — Departure sketch for the 52°N example: $ch.long = 20^\circ = 1200'$; departure = $1200 \times \cos(52^\circ) = 739 \text{ NM}$

The 52°N Example

WORKED CALCULATION

Change of longitude = $20^\circ = 20 \times 60 = 1200$ minutes of longitude

Latitude = 52°N ; $\cos(52^\circ) = 0.6157$

Departure = $1200 \times 0.6157 = 738.8 \text{ NM}$

Three Rearrangements

The one formula has three uses depending on what is unknown:

Unknown	Formula
Departure	$Dep = ch.long(min) \times \cos(lat)$
Change of Longitude	$ch.long(min) = Dep \div \cos(lat)$

Latitude

$$\cos(\text{lat}) = \text{Dep} \div \text{ch.long}(\text{min}) \rightarrow \text{lat} = \arccos(\dots)$$

Types of Departure Questions

Exam questions on departure fall into two categories:

Type 1: Variations on the Basic Formula

These questions give you two of the three variables (ch.long, lat, departure) and ask you to find the third. The steps are always:

1. Convert all units (km to NM, degrees to minutes if needed)
2. Identify which variable is unknown
3. Rearrange the formula and solve
4. Convert the answer back if needed (minutes of longitude to degrees + minutes)

Type 1, Example A — Find New Position

Aircraft at $60^{\circ}00'N$ $005^{\circ}22'W$ flies 165 km due East. New position?

Convert: $165 \text{ km} \div 1.852 = 89.1 \text{ NM departure}$.

Apply: $\text{Dep} = \text{ch.long}(\text{min}) \times \cos(\text{lat})$

$$89.1 = \text{ch.long} \times \cos(60^{\circ}) = \text{ch.long} \times 0.5$$

$$\text{ch.long} = 89.1 / 0.5 = 178.2 \text{ minutes} = 2^{\circ}58.2'E$$

New position: $60^{\circ}00'N$ $002^{\circ}24'W$ (i.e. $005^{\circ}22'W - 2^{\circ}58'$)

Type 1, Example B — Find Latitude

In which latitude does a difference of $44^{\circ}11'$ of longitude = 2 000 NM departure?

$$44^{\circ}11' = 44 \times 60 + 11 = 2651 \text{ minutes of arc.}$$

$$\cos(\text{lat}) = \text{Dep} / \text{ch.long} = 2000 / 2651 = 0.7544$$

$$\text{lat} = \arccos(0.7544) = 41^{\circ}\text{N or S}$$

Latitude: 41°N or 41°S (cosine gives ambiguous N/S — check context)

Type 2: Departure at One Latitude → Find It at Another

When a flight goes south then east then north (or vice versa), the departure flown is at a different latitude from the starting point. You need to find the departure at the *original* latitude that corresponds to the same change of longitude.

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The Latitude Ratio Formula

When you know departure at latitude B and need to find departure at a different latitude A (where both A and B share the same meridian spacing), use:

$$\text{Dep at Lat A} / \text{Dep at Lat B} = \cos A / \cos B$$

$$\text{Rearranged: Dep at A} = \text{Dep at B} \times (\cos A / \cos B)$$

This formula saves a step of working out the change of longitude explicitly. You simply divide the departure at the known latitude by the cosine of the known latitude, then multiply by the cosine of the target latitude.

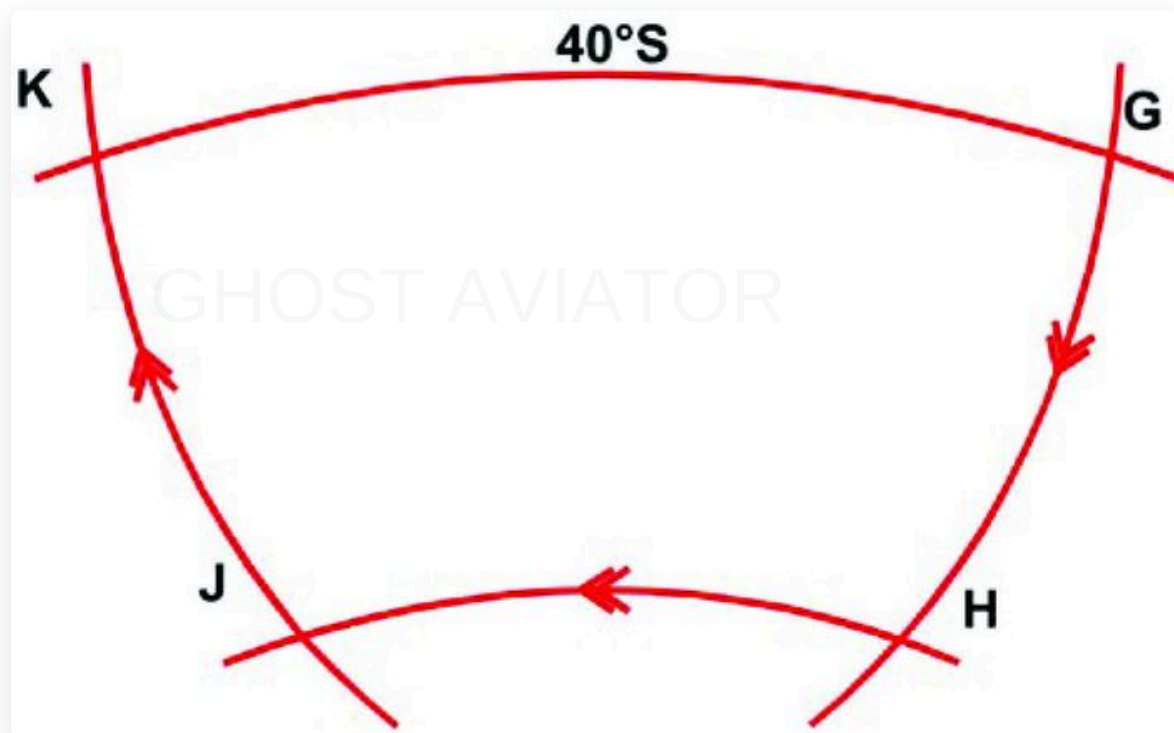


Figure 7 — Departure problem with multiple legs — example 3 diagram showing tracks and the key is that the N-S legs cancel, leaving only the E-W leg as the net answer

Ratio Formula Example — Example 3

Start G (40°S) → H: 180° 240 NM → J: 270° 240 NM → K: 000° 240 NM

Find RL bearing and distance K from G.

The 240 NM south takes G (40°S) to H (44°S).

The 240 NM west from H is at **44°S**.

The 240 NM north takes J (44°S) back to K (40°S).

So K is at the same latitude as G (40°S) but directly west.

The E-W displacement = departure of leg H→J (at 44°S) converted to departure at 40°S.

Dep at 40°S = Dep(44°S) × cos(40°)/cos(44°) = 240 × 0.7660/0.7193 = **255.6 NM**

**K is 255.6 NM due West of G. RL bearing = 270°(T),
distance = 255.6 NM.**

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Inspection of Answers — A Time-Saving Technique

For MCQ examinations, it is often not necessary to calculate the exact answer. By understanding the *direction* of the effect, you can eliminate impossible options and identify the correct one without arithmetic.

Example — The North/South/East/West Box

Aircraft at 27°00'N 170°00'W travels 3000 km S, 3000 km E, 3000 km N, 3000 km W. Final position?

Key insight: The southward leg takes the aircraft to a lower latitude (more toward the equator). At that lower latitude, the eastward leg covers *fewer* degrees of longitude. When the northward leg returns to the original latitude, the westward leg at that higher latitude covers *more* degrees. Net result: same latitude as start, but displaced **west**.

Answer immediately: final position is at $27^{\circ}00'N$, west of start ($170^{\circ}00'W$). Only option (c) $2700N\ 17318W$ fits. No calculation needed.

GENERAL RULE FOR THE "BOX" PROBLEM

$S \rightarrow E \rightarrow N \rightarrow W$ starting in the Northern Hemisphere: net displacement is **west** (eastward leg at lower lat covers less longitude than westward leg at higher lat).

$N \rightarrow E \rightarrow S \rightarrow W$: net displacement is **east**.

In the Southern Hemisphere, the directions reverse.

Practice Questions

Questions 1–10 require calculation; Q11–15 are multiple-choice. All solutions are shown.

Q1 A flight is to be made along the parallel of latitude from A ($48^{\circ}00'N\ 04^{\circ}00'W$) to B ($48^{\circ}00'N\ 02^{\circ}27'E$). Calculate the distance.

ANSWER: 259 NM

Change of longitude = $04^{\circ}00'W$ to $02^{\circ}27'E = 6^{\circ}27' = 387$ minutes.

Departure = $387 \times \cos(48^{\circ}) = 387 \times 0.6691 = \mathbf{259\ NM}$

Q2 An aircraft flies 1000 NM along a rhumb line track of $090^{\circ}(T)$ from C ($36^{\circ}00'N\ 174^{\circ}45'E$) to D. What is the longitude of D?

ANSWER: $164^{\circ}39'W$

$\text{Dep} = \text{ch.long}(\text{min}) \times \cos(36^\circ) \rightarrow \text{ch.long}(\text{min}) = 1000 / \cos(36^\circ) = 1000 / 0.809 = 1236 \text{ min.}$
 $1236 \text{ min} = 20^\circ 36'$ of longitude eastward from $174^\circ 45' \text{E}$.
 $174^\circ 45' \text{E} + 20^\circ 36' \text{E} = 195^\circ 21' \text{E} = 360^\circ - 195^\circ 21' = \mathbf{164^\circ 39' \text{W}}$

Q3 Starting from E (50°N): E $\rightarrow$ F $000^\circ (\text{T})$ 300 NM; F $\rightarrow$ G $090^\circ (\text{T})$ 300 NM; G $\rightarrow$ H $180^\circ (\text{T})$ 300 NM. What is the RL bearing and distance of H from E?

ANSWER: $090^\circ (\text{T})$ AT 336 NM

E to F = 300 NM north $\rightarrow$ lat of F = 55°N ($300/60=5^\circ$ north).
 F to G = 300 NM east at 55°N : $\text{ch.long} = 300/\cos 55^\circ = 300/0.5736 = 523 \text{ min} = 8^\circ 43'$.
 G to H = 300 NM south $\rightarrow$ lat of H = 50°N (same as E).
 E and H are both at 50°N , H is $8^\circ 43'$ east of E.
 Departure at $50^\circ \text{N} = 523 \times \cos 50^\circ = 523 \times 0.6428 = 336 \text{ NM}$.
 Bearing of H from E = $090^\circ (\text{T})$ (due east). **Distance = 336 NM.**

Q4 What is the track and distance along the parallel of 80°S from $176^\circ 15' \text{W}$ to $179^\circ 45' \text{E}$?

ANSWER: $270^\circ (\text{T})$ AT 41.7 NM

$176^\circ 15' \text{W}$ to $179^\circ 45' \text{E}$ going west: $176^\circ 15' \text{W} + (180^\circ - 179^\circ 45') = 176^\circ 15' + 0^\circ 15' = 176^\circ 30'$ remaining to 180° . Wait — going west: $176^\circ 15' \text{W}$ to $180^\circ = 3^\circ 45'$; then 180° to $179^\circ 45' \text{E} = 0^\circ 15'$. Total = $4^\circ 00' = 240 \text{ min}$.
 Departure = $240 \times \cos(80^\circ) = 240 \times 0.1736 = \mathbf{41.7 \text{ NM}}$. Track = $270^\circ (\text{T})$.

Q5 In which latitude is a difference of longitude of $44^\circ 10'$ equivalent to a departure of 2295 NM?

ANSWER: 30°N OR 30°S

$44^\circ 10' = 44 \times 60 + 10 = 2650 \text{ minutes of arc}$.
 $\cos(\text{lat}) = 2295 / 2650 = 0.8660$

$$\text{lat} = \arccos(0.866) = \mathbf{30^\circ\text{N or S}} \quad (\sin 30^\circ = 0.5; \cos 30^\circ = 0.866 \checkmark)$$

Q6 Aircraft departs J ($36^\circ 00'S$ $130^\circ 14'E$) at 0946 UTC, flying RL track 270° at FL100, temp 0°C , Mach 0.81, wind component 35 kt tail. Position at 1004 UTC?

ANSWER: $36^\circ 00'S$ $126^\circ 48'E$

Speed of sound at 0°C : $38.95 \times \sqrt{273} = 38.95 \times 16.52 \approx 643$ kts.

TAS = $0.81 \times 643 = \mathbf{521 \text{ kts}}$ (use 520 kts).

GS = $520 + 35 = 555$ kts.

Time = $1004 - 0946 = 18$ min. Distance = $555 \times 18/60 = 166.5$ NM.

Heading west at 36°S : ch.long(min) = $166.5 / \cos(36^\circ) = 166.5 / 0.809 = 205.8$ min ≈ 206 min = $3^\circ 26'$.

New longitude = $130^\circ 14'E - 3^\circ 26' = \mathbf{126^\circ 48'E}$.

Position: $36^\circ 00'S$ $126^\circ 48'E$.

Q7 (a) At which latitude is the departure in NM between two points equal to:
(i) their difference in longitude in minutes? (ii) half their difference in longitude in minutes? (b) At 52°N : (i) departure between $136^\circ 16'W$ and $43^\circ 44'E$? (ii) shortest distance between those same points?

ANSWER: (A)(I) EQUATOR (A)(II) 60°N OR S (B)(I) 6 653 NM (B)(II) 4 560 NM

(a)(i) Dep = ch.long $\times \cos(\text{lat})$. For Dep(NM) = ch.long(min): $\cos(\text{lat}) = 1.0 \rightarrow \text{lat} = 0^\circ = \mathbf{\text{Equator}}$.

(a)(ii) For Dep = $\frac{1}{2}$ ch.long: $\cos(\text{lat}) = 0.5 \rightarrow \text{lat} = \mathbf{60^\circ\text{N or S}}$.

(b)(i) $136^\circ 16'W$ to $43^\circ 44'E = 180^\circ = 10\,800$ minutes. Dep = $10\,800 \times \cos(52^\circ) = 10\,800 \times 0.6157 = \mathbf{6\,653 \text{ NM}}$.

(b)(ii) Shortest distance from 52°N 136°W to 52°N 044°E goes over the North Pole. Route = $(90^\circ - 52^\circ) \times 2 = 76^\circ$ of latitude change $\times 60 \text{ NM}/^\circ = \mathbf{4\,560 \text{ NM}}$.

Q8 Aircraft leaves L (37°S) flying L→M $270^\circ(\text{T})$ at 310 kt for 80 min; M→N $180^\circ(\text{T})$ at 280 kt; N→P $090^\circ(\text{T})$ at 250 kt. P is due south of L. N reached 93.5 min after leaving N. Calculate distance and time M to N.

ANSWER: DISTANCE = 240 NM, TIME = 51.25 MIN

L to M: $310 \times 80/60 = 413.3$ NM at 37°S going west.

ch.long = $413.3/\cos(37^\circ) = 413.3/0.7986 = 517$ min = $8^\circ 37'$ west.

P is due south of L, so N→P must cover the same $8^\circ 37'$ going east.

N to P: 93.5 min at 250 kt = 389.6 NM (east).

ch.long for N→P: 517 min → lat of N/P: $\cos(\text{lat}) = 389.6/517 = 0.7537 \rightarrow \text{lat} \approx 41^\circ\text{S}$.

Distance M to N = difference in latitude $\times 60$: $41^\circ\text{S} - 37^\circ\text{S} = 4^\circ = \mathbf{240\text{ NM}}$.

Time M to N = $240/280 = 0.857$ hr = **51.25 min**.

Q9 Aircraft Q (GS 301 kt) flies parallel 46°N through 10° of longitude. Aircraft R (GS 364 kt) takes the same time. At what latitude does R fly?

ANSWER: 33°N OR S

Q at 46°N : ch.long = $10^\circ = 600$ min; Dep = $600 \times \cos(46^\circ) = 600 \times 0.6947 = 417$ NM.

Time Q = $417/301 = 1.385$ hr = 83 min.

R in 83 min at 364 kts covers $364 \times 83/60 = 503.5$ NM.

$\cos(\text{lat}_R) = 503.5/600 = 0.8392 \rightarrow \text{lat} = \arccos(0.8392) = \mathbf{33^\circ\text{N or S}}$.

Q10 S ($36^\circ\text{N } 10^\circ\text{E}$, GS 470 kt, RL 090°) and T ($30^\circ\text{N } 10^\circ\text{E}$, GS 150 kt, RL 090°) depart 1522Z. S turns onto 180° at 13°E . Which reaches $30^\circ\text{N } 13^\circ\text{E}$ first, and when? Where is the other aircraft at that time?

ANSWER: T ARRIVES FIRST AT 1624Z; S IS AT $30^\circ 27'\text{N } 13^\circ\text{E}$

S (36°N , 470 kt): $10^\circ\text{E} \rightarrow 13^\circ\text{E}$ at $36^\circ\text{N} = 180$ min longitude.

Dep S leg 1 = $180 \times \cos(36^\circ) = 145.6$ NM at 470 kt = 18.5 min.

Then $36^\circ\text{N} \rightarrow 30^\circ\text{N} = 6^\circ = 360$ NM at 460 kt = 47.0 min. Total S = 65.5 min.

T (30°N , 150 kt): $10^\circ\text{E} \rightarrow 13^\circ\text{E}$ at $30^\circ\text{N} = 180 \times \cos(30^\circ) = 155.9$ NM at 150 kt = 62.0 min.

T arrives first (62.0 min vs 65.5 min — 3.5 min earlier → $1522 + 62$ min = 1624Z).

When T arrives, S is $65.5 - 62.0 = 3.5$ min short. At 460 kt: $3.5 \times 460/60 =$

26.8 NM $\approx$ 27 NM $\approx$ 27 min lat.

S position: 30°27'N 13°E.

Q11 Aircraft starts 0410S 17822W, heads true north 2950 NM, then 90° left for 314 km RL. Final position?

a. 5500N 17422W

b. 4500N 17422W

c. 5500N 17738E

d. 4500N 17738E

ANSWER: D

2950 NM north from 04°10'S: $2950/60 = 49.17^\circ \rightarrow$ final lat = $49.17^\circ - 4.17^\circ = 45^\circ 00'N$.

90° left from north heading = west. $314 \text{ km} \div 1.852 = 169.5 \text{ NM}$.

ch.long = $169.5/\cos(45^\circ) = 169.5/0.7071 = 239.7 \text{ min} = 3^\circ 59.7' \approx 4^\circ$ west.

$17822W + 4^\circ = 17^\circ 82' + 240' = 178^\circ + 60' + 22' + 60' \rightarrow 17822W + 0400 = 18222W = 360^\circ - 182^\circ 22' = 177^\circ 38'E$.

Answer: 45°00'N 177°38'E $\rightarrow$ **d (4500N 17738E)**.

Q12 Aircraft at 50°N 006°E: 300 NM South, 300 NM East, 300 NM North, 300 NM West. Final position relative to start?

a. North

b. East

c. West

d. South

ANSWER: C

S leg: 50°N $\rightarrow$ 45°N. E leg at 45°N: ch.long = $300/\cos 45^\circ = 424 \text{ min} = 7^\circ 4' E$.

N leg: back to 50°N. W leg at 50°N: ch.long = $300/\cos 50^\circ = 467 \text{ min} = 7^\circ 47' W$.

Net: went 7°4' E then 7°47' W $\rightarrow$ net = 0°43' W. Final position is **west** of

start.

Answer: **c**

Q13 Aircraft departs $04^{\circ}00'N$ $170^{\circ}00'W$: 600 NM south, 600 NM east, 600 NM north, 600 NM west. Final position?

- a. $04^{\circ}00'N$ $170^{\circ}00'W$
- b. $06^{\circ}00'S$ $170^{\circ}00'W$
- c. $04^{\circ}00'N$ $169^{\circ}58.1'W$
- d. $04^{\circ}00'N$ $170^{\circ}01.8'W$

ANSWER: C

S: $04^{\circ}N \rightarrow 06^{\circ}S$. E at $06^{\circ}S$: ch.long = $600 / \cos 6^{\circ} = 600 / 0.9945 = 603.3$ min
= $10^{\circ}3.3'$ E.

N: $06^{\circ}S \rightarrow 04^{\circ}N$. W at $04^{\circ}N$: ch.long = $600 / \cos 4^{\circ} = 600 / 0.9976 = 601.4$ min
= $10^{\circ}1.4'$ W.

Net: $10^{\circ}3.3'$ E – $10^{\circ}1.4'$ W = $1.9'$ E. Start $170^{\circ}00'W - 1.9' = \mathbf{169^{\circ}58.1'W}$.

Answer: **c**

Q14 Aircraft flying eastwards at $60^{\circ}N$ at 240 kts goes once round Earth. At what speed must another fly eastwards along the Equator to take the same time?

- a. 600 kts
- b. 240 kts
- c. 480 kts
- d. 120 kts

ANSWER: C

Circumference at $60^{\circ}N$ = full circumference $\times \cos(60^{\circ}) = 21\,600 \times 0.5 = 10\,800$ NM.

Time = $10\,800 / 240 = 45$ hours.

Equatorial circumference = $360 \times 60 = 21\,600$ NM.

Required speed = $21\,600 / 45 = \mathbf{480\ kts}$. Answer: **c**

Q15 Position $58^{\circ}33'N$ $174^{\circ}00'W$. Fly exactly 6 NM eastwards. New position?

a. $58^{\circ}33'N$ $174^{\circ}11.5'W$

b. $58^{\circ}33'N$ $173^{\circ}55'W$

c. $58^{\circ}33'N$ $173^{\circ}40'W$

d. $58^{\circ}33'N$ $173^{\circ}48.5'W$

ANSWER: D

At $58^{\circ}33'N$: $\cos(58.55^{\circ}) \approx 0.5217$.

ch.long = $6 / 0.5217 = 11.5$ min of longitude.

Going east from $174^{\circ}00'W$: $174^{\circ}00' - 11.5' = 173^{\circ}48.5'W$.

Answer: **d — $58^{\circ}33'N$ $173^{\circ}48.5'W$**

Quick Answer Summary

Q1 259 NM	Q2 $164^{\circ}39'W$	Q3 090° 336NM	Q4 270° 41.7NM	Q5 $30^{\circ}N/S$
Q6 36S 126°48E	Q7 Eq/60°/6653/4540NM	Q8 51.25min	Q9 $33^{\circ}N/S$	Q10 T / $30^{\circ}27'N$ 13E
Q11 d	Q12 c	Q13 c	Q14 c	Q15 d

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