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Principles of Navigation (Dead Reckoning)

You're Probably Asking Yourself Two Questions:

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Is it possible to teach navigation without paper charts, E6B, plotter and NavLog?

YES!

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What do students need to understand about the principles of navigation?

The tools don't matter

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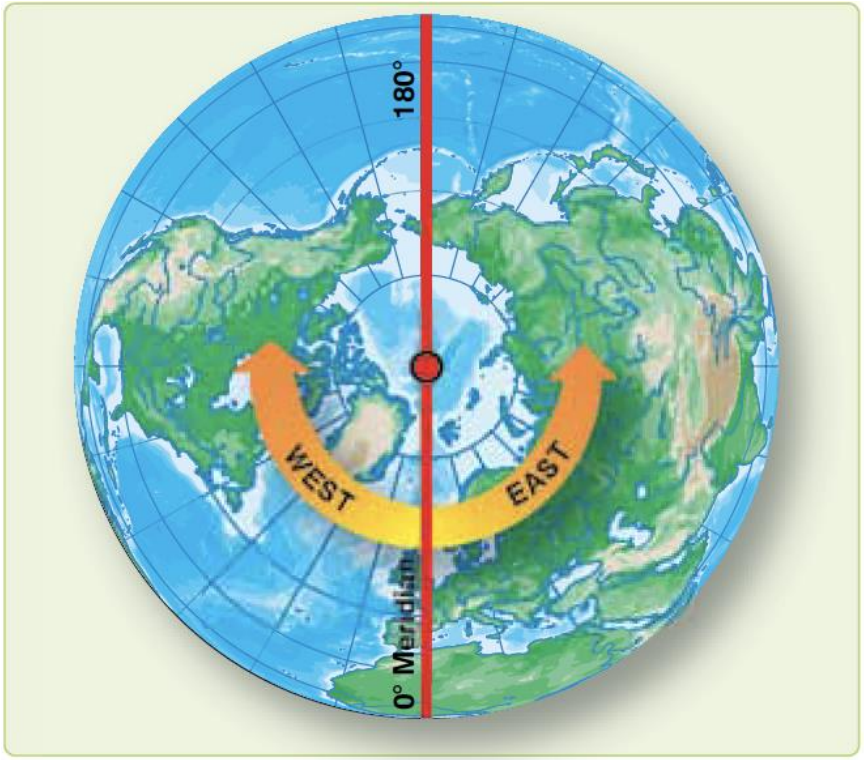
Location

Longitude is an angular measurement E and W

From the prime meridian, 0°

118° 30’W



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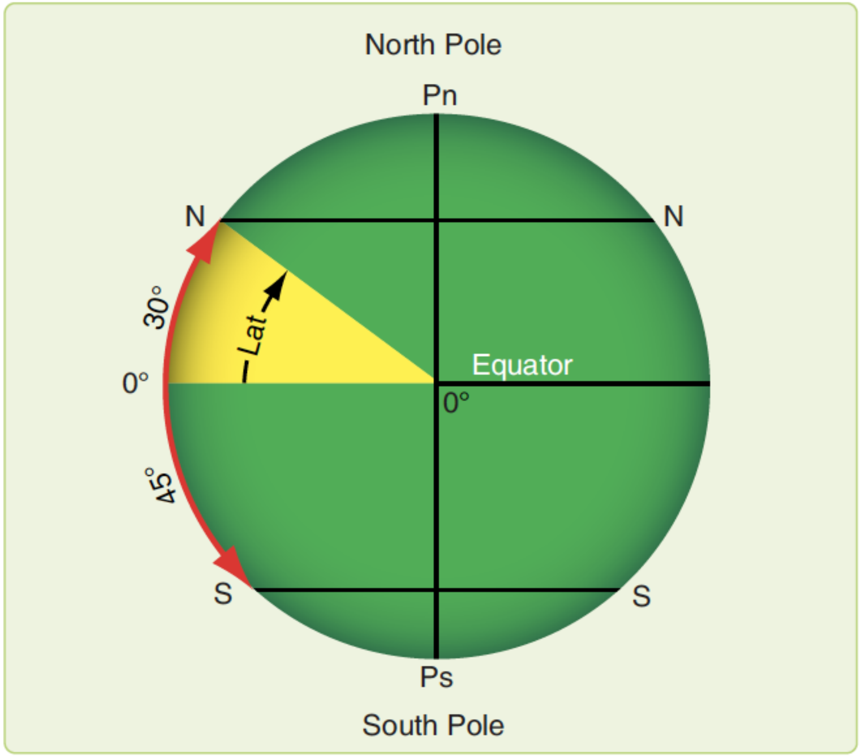
Location

Latitude is an angular measurement N and S

At the equator the latitude is 0°

N above the equator and S below

30° 29'N



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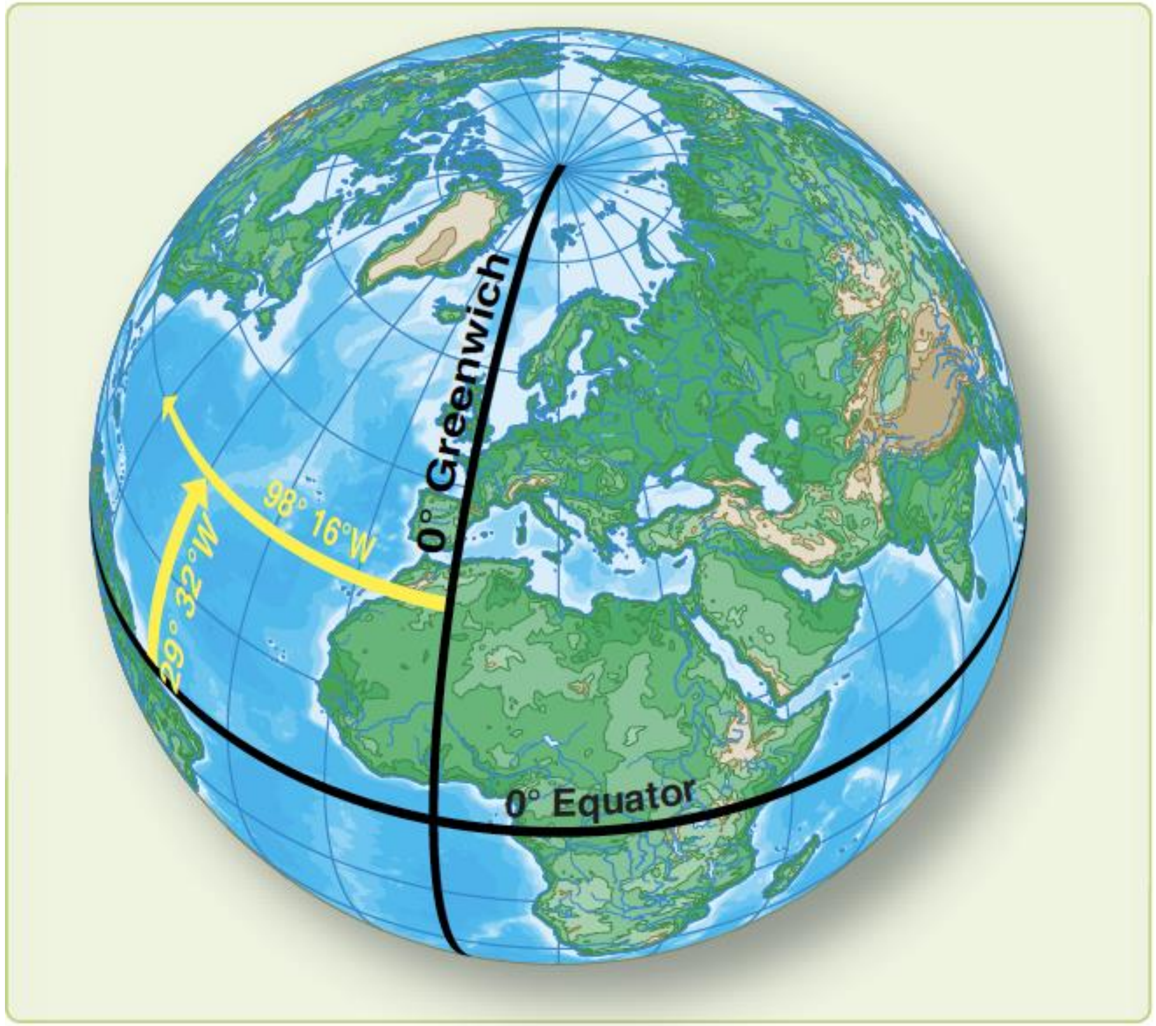
Location

Longitude and latitude

98° 16’W, 29° 32’N



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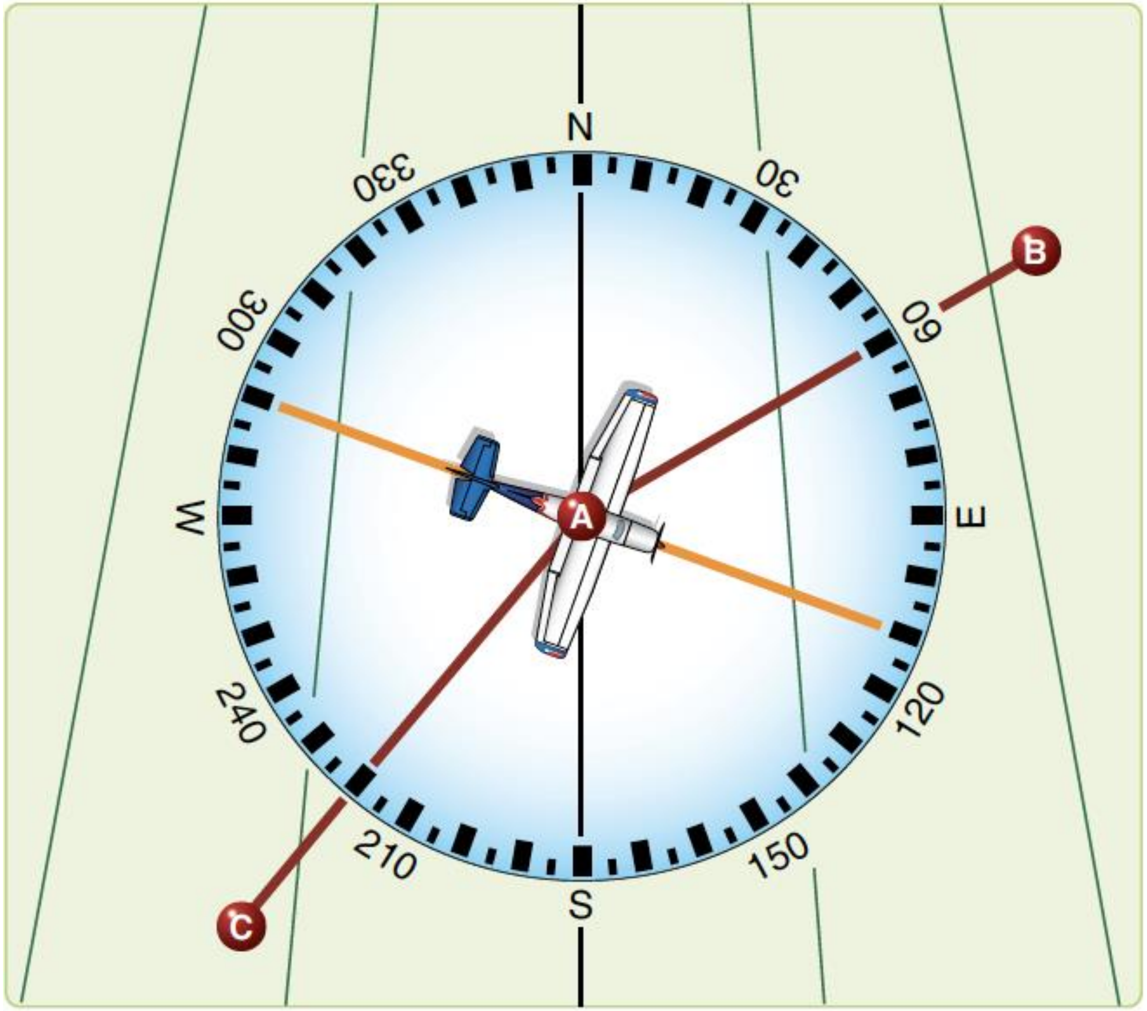
Numerical system in Navigation

Compass Rose

360 degrees



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Terms

Course – Intended direction of travel

Heading – Actual orientation of the longitudinal axis

Bearing – Direction between two points

Direction – position of one object relative to the other

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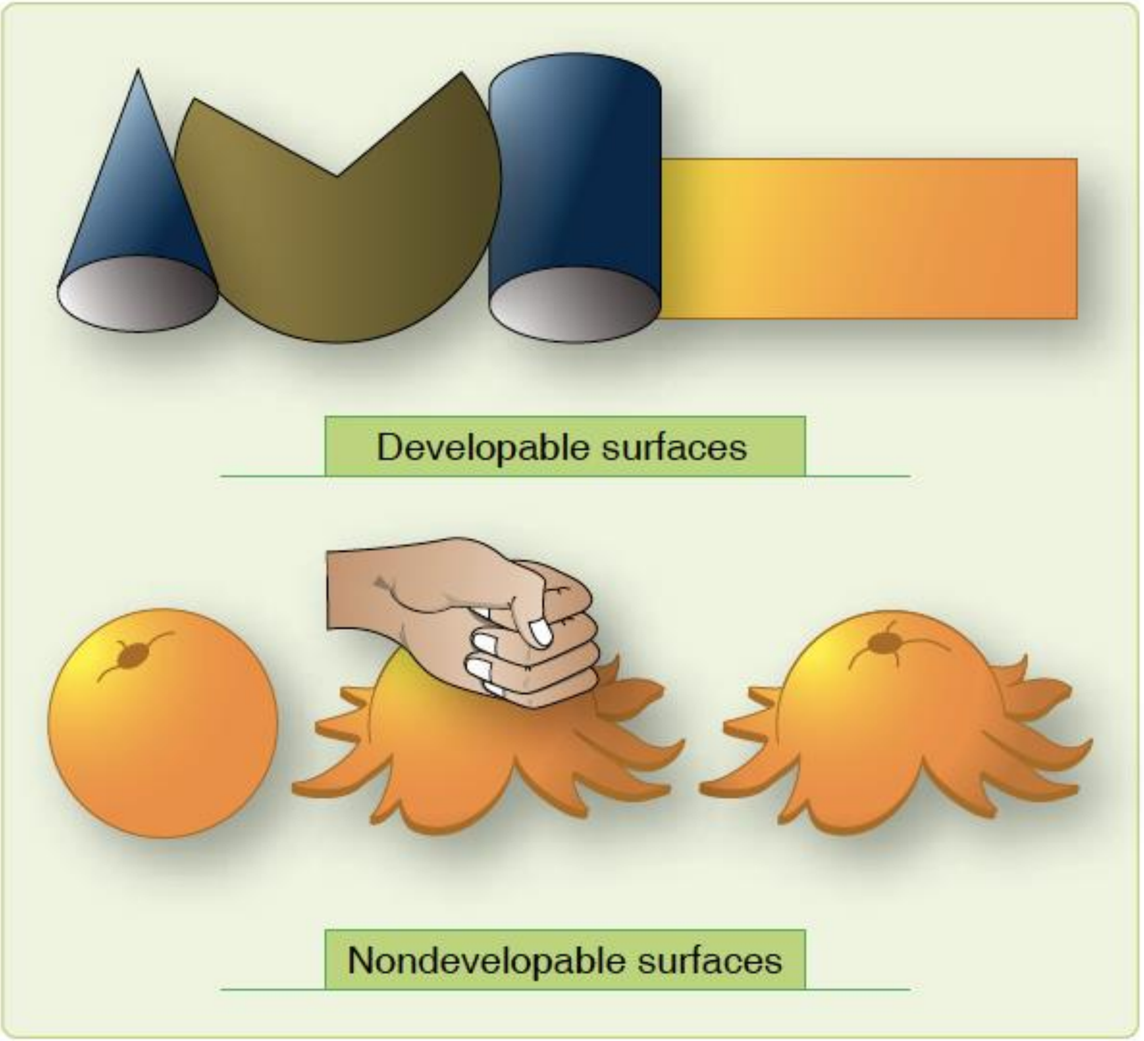
Map Projections

Surfaces

Spheres can't be flattened into a flat map

A projection is needed



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Map Projections

Mercator

Longitude and Latitude are always perpendicular

Landmasses distorted

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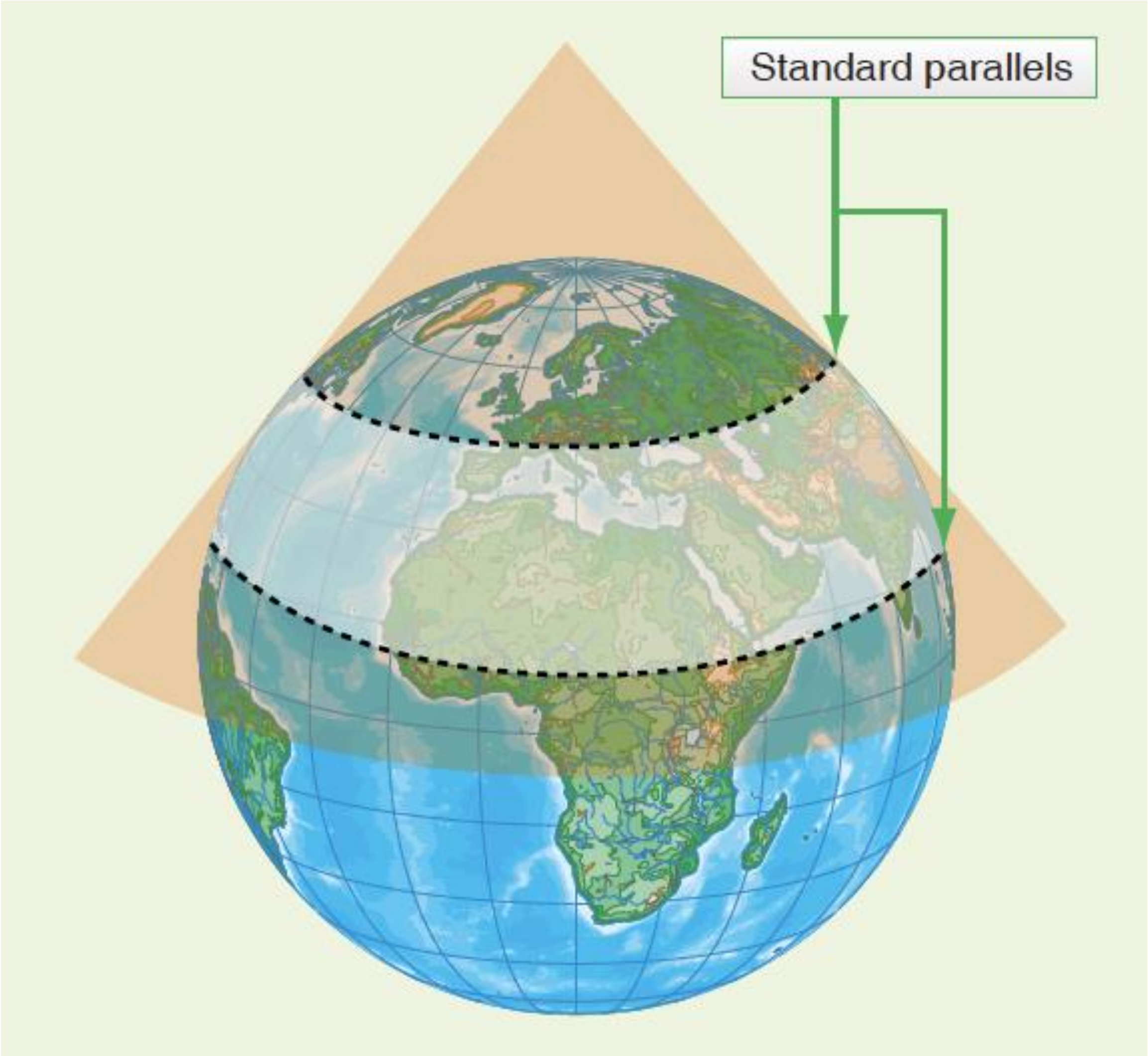
Map Projections

Lambert’s Conic

Accurate over the standard parallels

Longitude lines converge at northern latitudes



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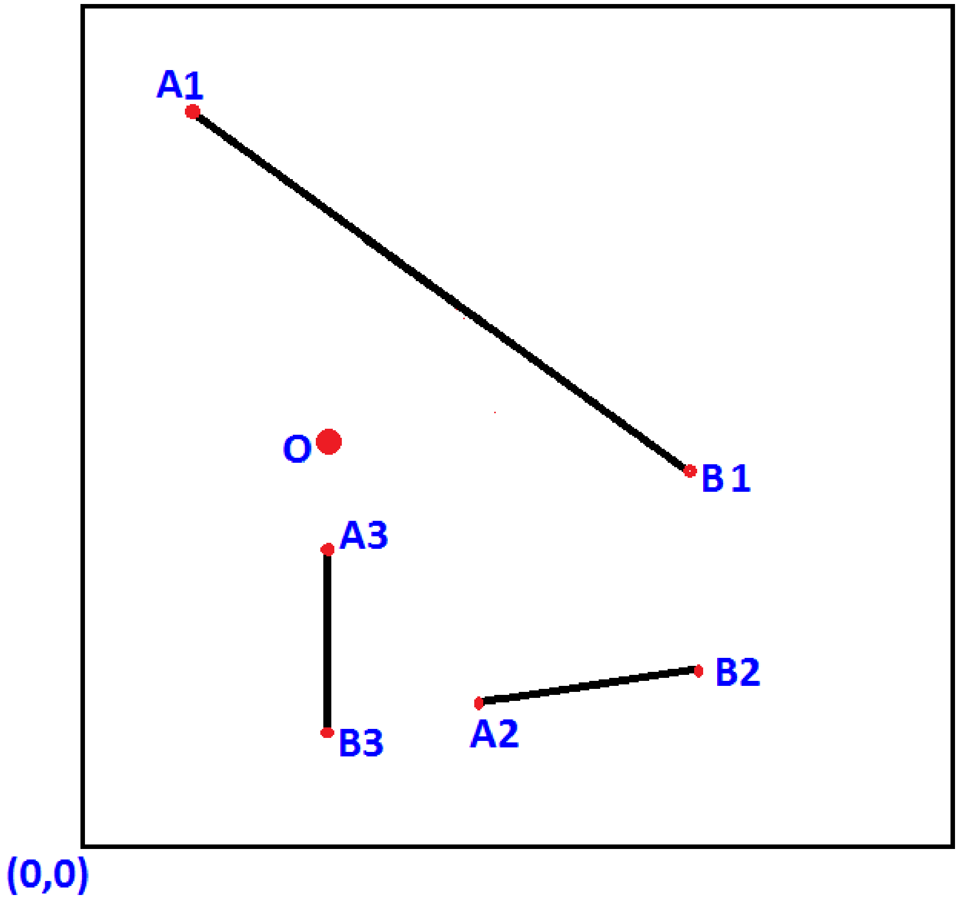
Distance

Flat surface – 2D

Shortest distance A-B is a line



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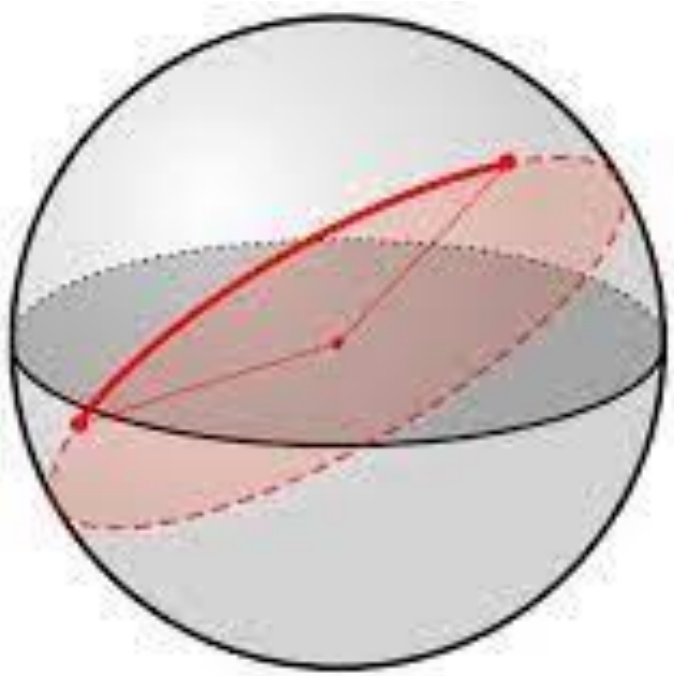
Distance



Sphere

Shortest distance – Great Circle

Great circles divide the earth in two equal halves

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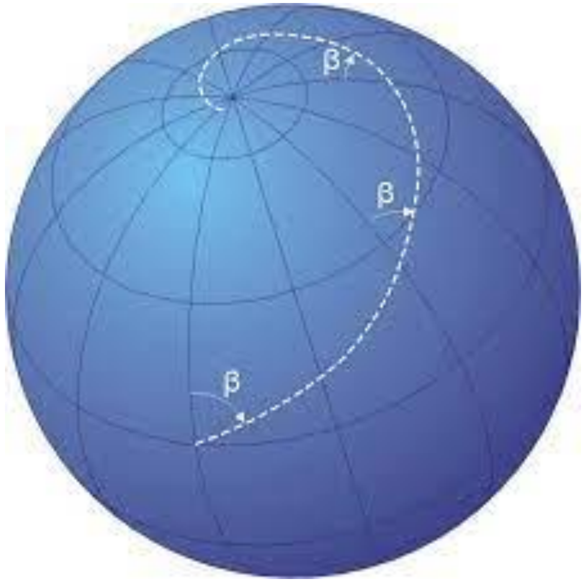
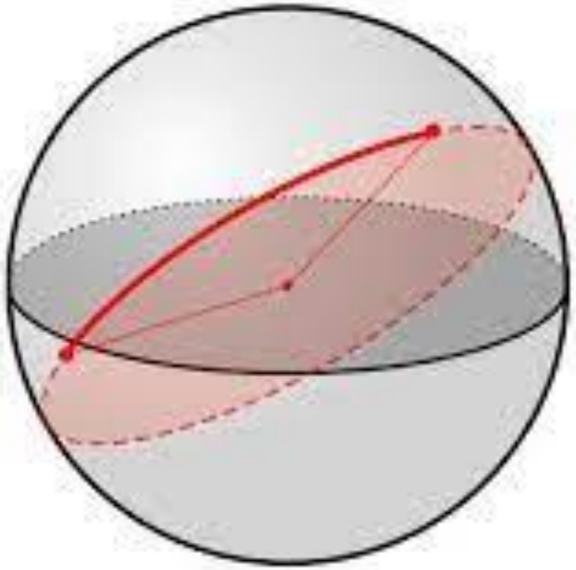
Tracks – Rhumb line vs Great Circle





Great circle tracks always changing

Rhumb line tracks always same angle to the meridians - - track stays fixed

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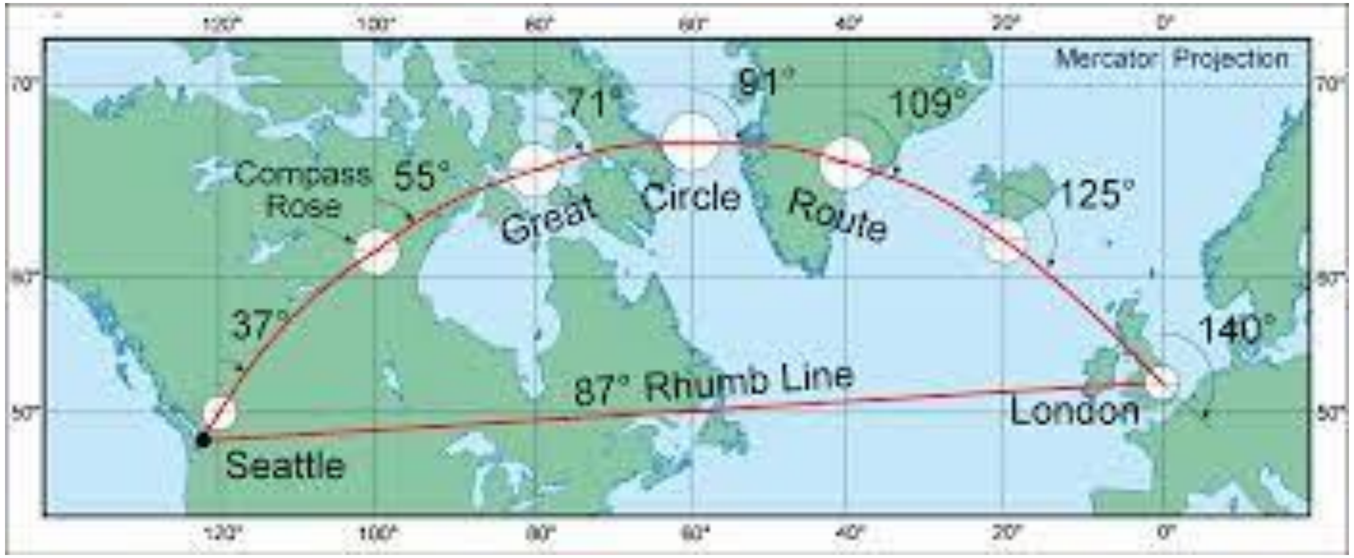
Tracks – Rhumb line vs Great Circle



Great circle shortest – difficult to fly

Rhumb lines easy – longer but same heading

Rhumb lines used in light airplanes

Long Haul - hybrid

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Aeronautical Charts

Lambert’s Conic Projection

Sectional scale is 1:500,000

Terminal Chart scale is 1:250,000

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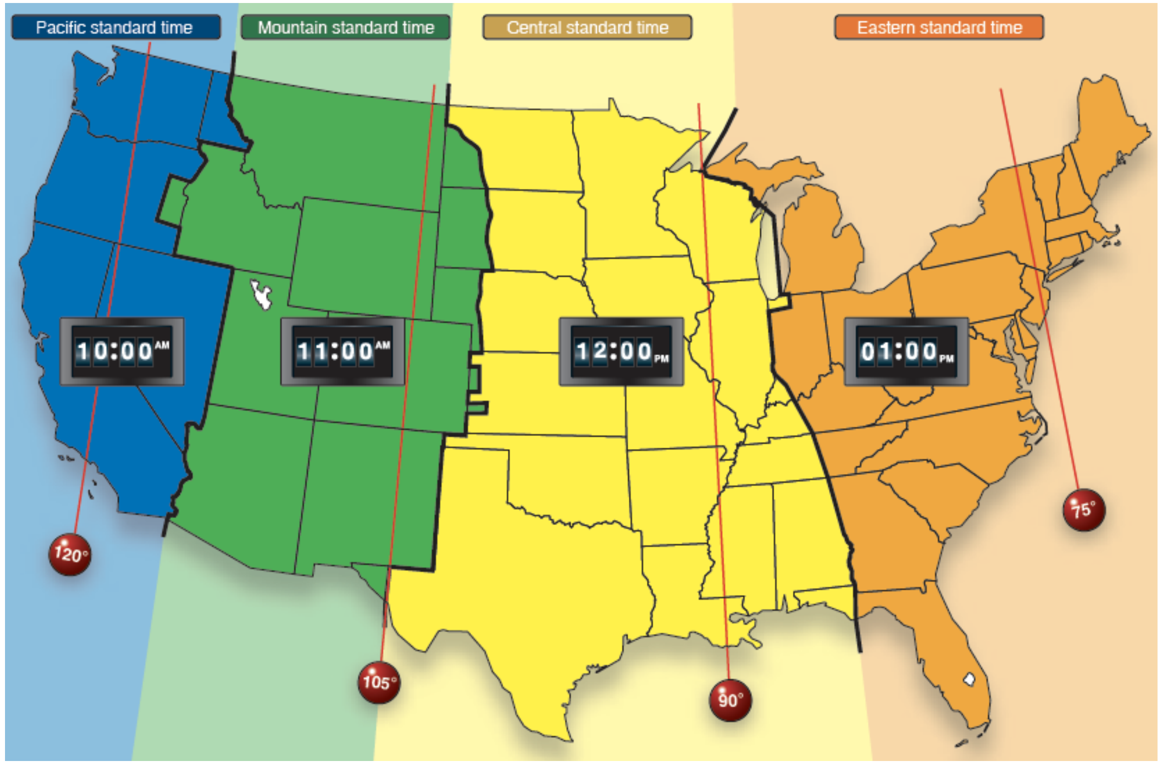
Time Zones

Typically each 15° longitude

15° is one hour

Some countries use other than one-hour increments

Daylight vs Standard time



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Compass Rose

Courses and Bearings

360 degrees

Plotted courses are True Courses

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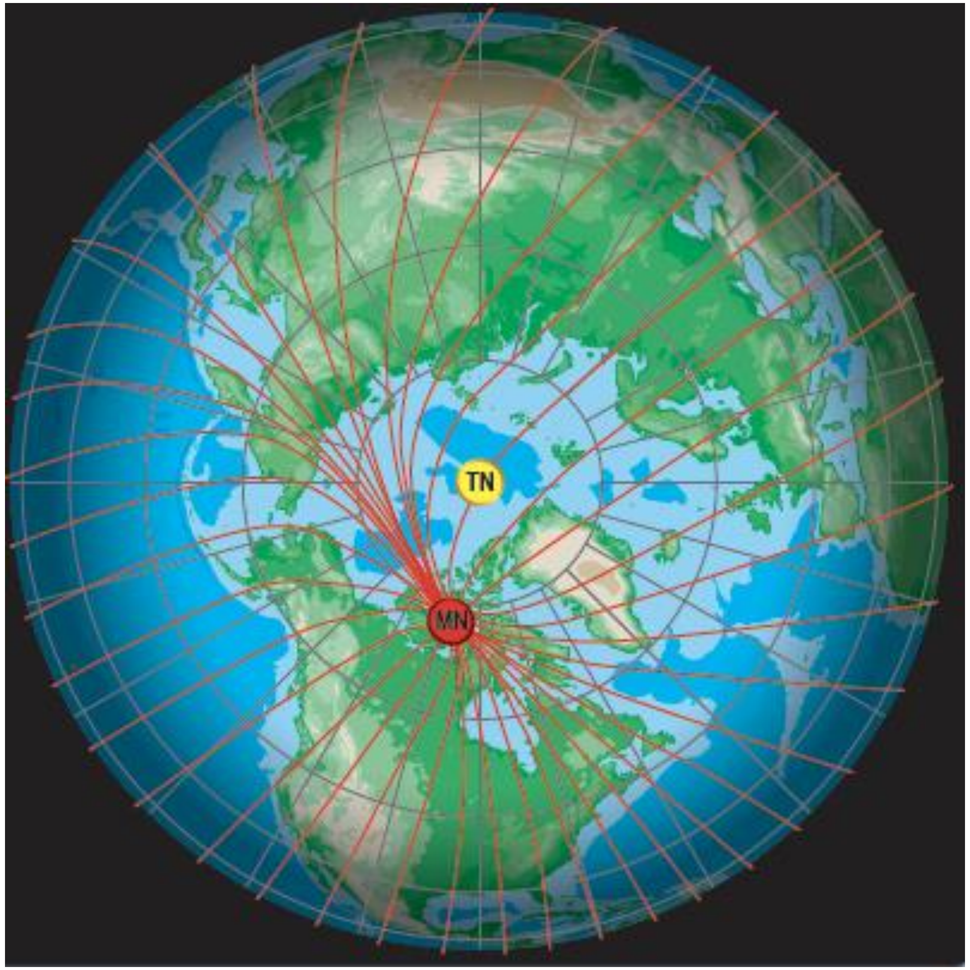
Magnetic Variation

Difference between TN and MN

Maps and terrain follow TN

Compass points to MN

Angular difference is variation



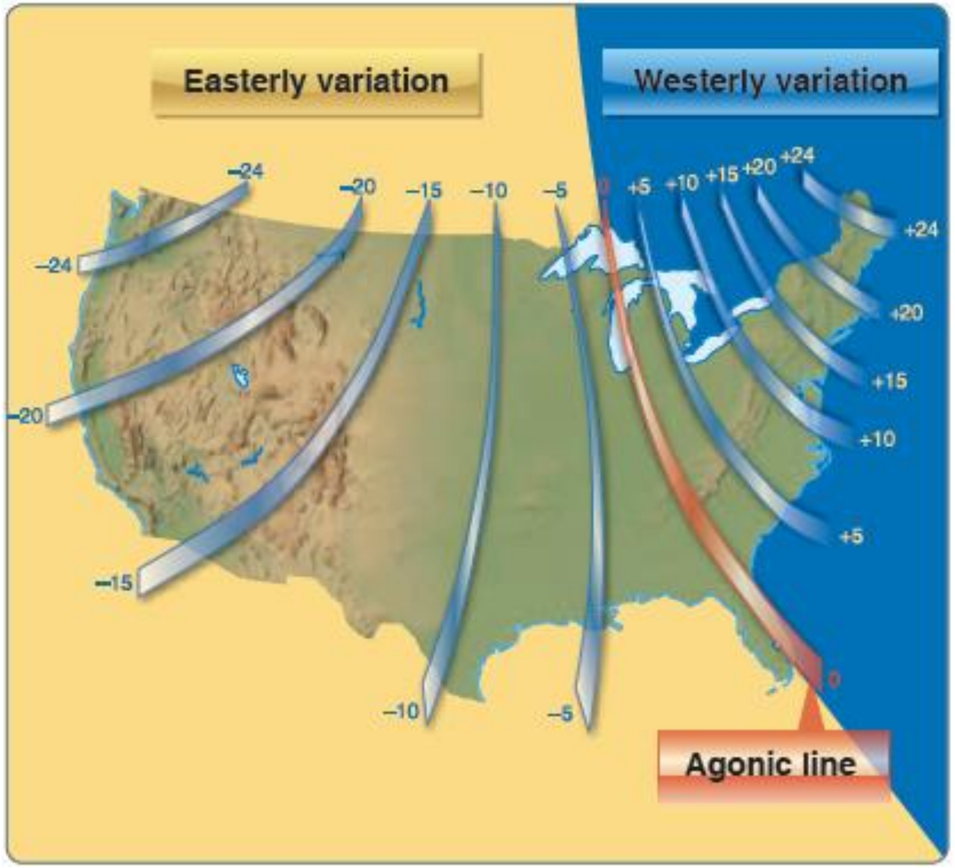
Magnetic Variation

Variation in the US

Louisiana - 0°

San Francisco, CA - 13.5° East

Miami, FL - 6° West



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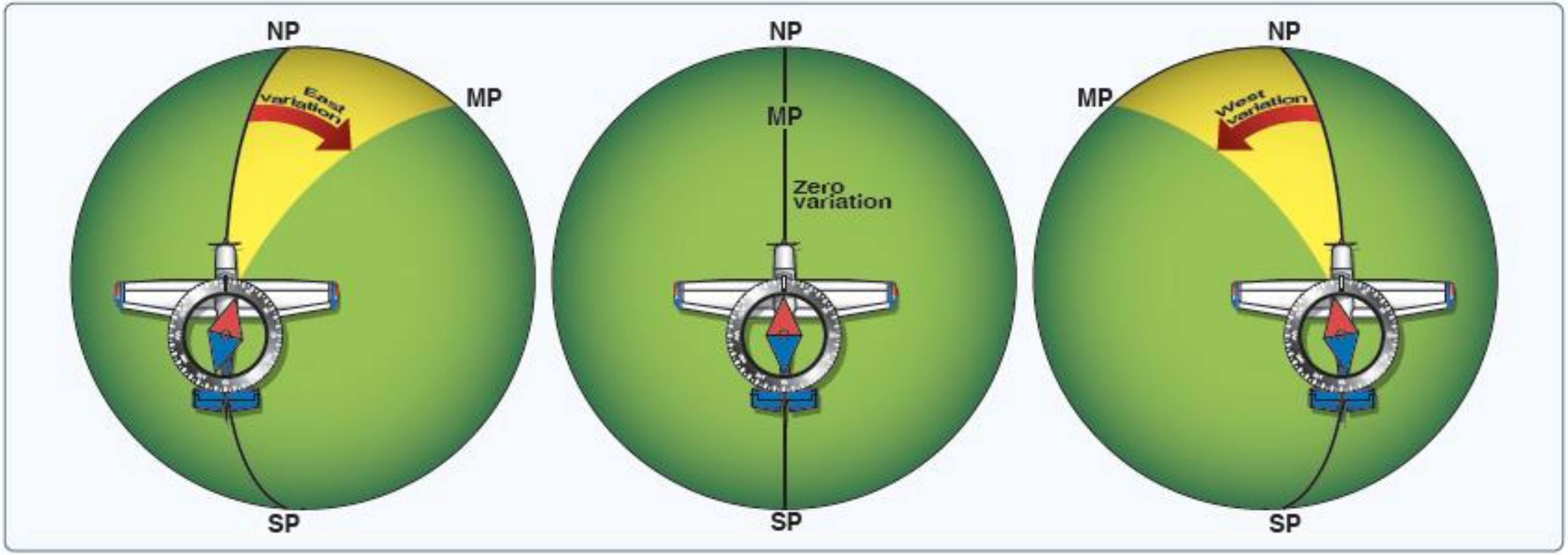
Magnetic Variation Summary

Where the compass points when flying 0° TC



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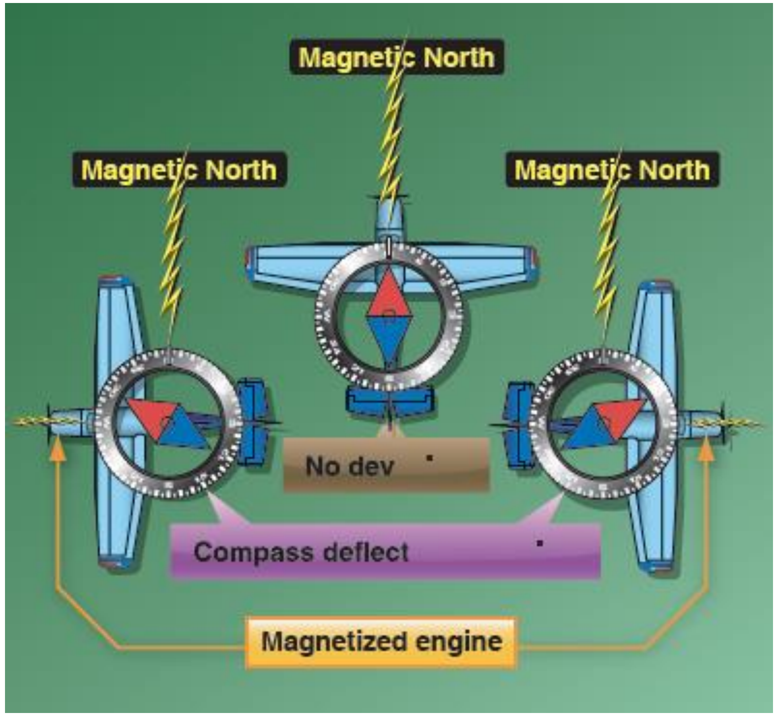
Deviation - CH

Compass affected by the plane's electromagnetism



For (Magnetic)	N	30	60	E	120	150
Steer (Compass)	0	28	57	86	117	148
For (Magnetic	S	210	240	W	300	330
Steer (Compass)	180	212	243	274	303	332

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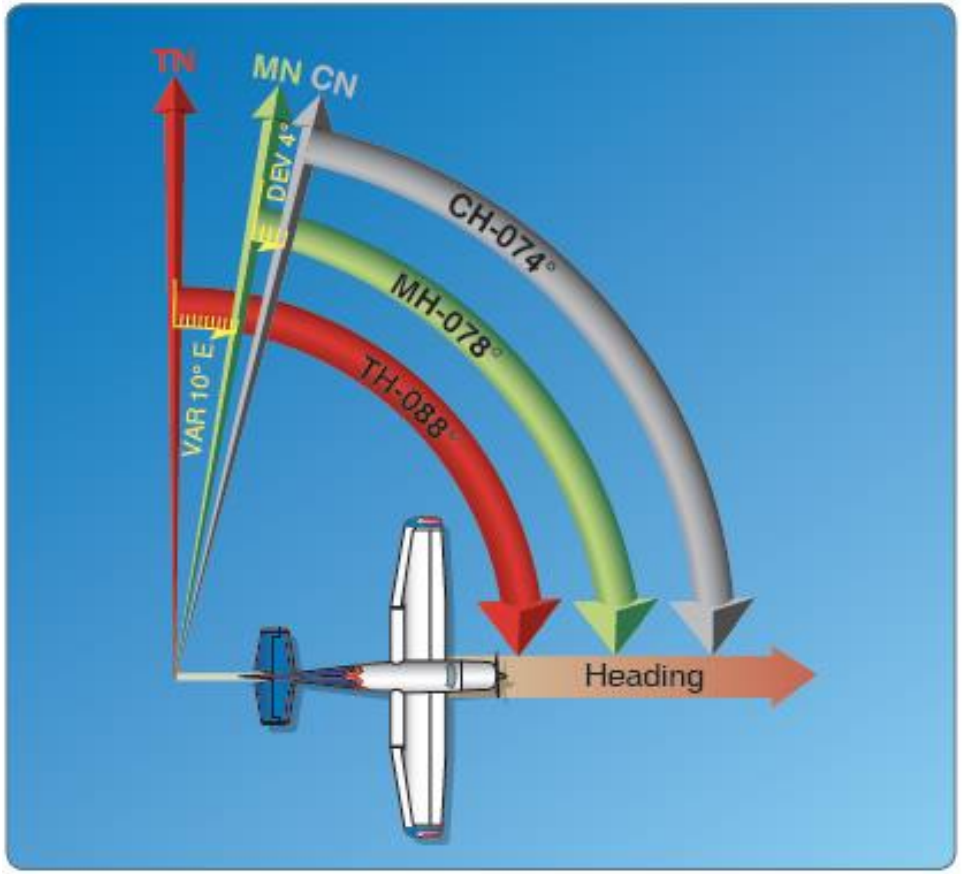
Terminogy

Relationship of True, Magnetic, and Compass Headings

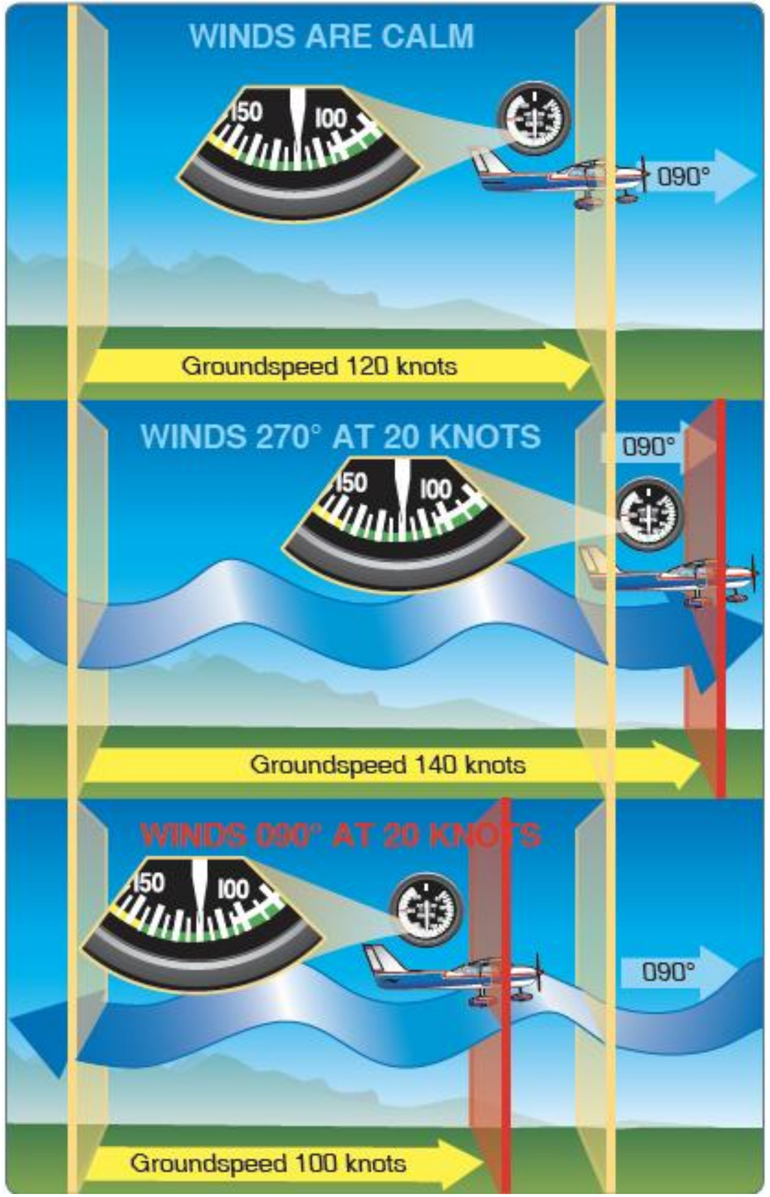


Effect of Wind

Groundspeed

TAS ± Windspeed

Speed over the ground



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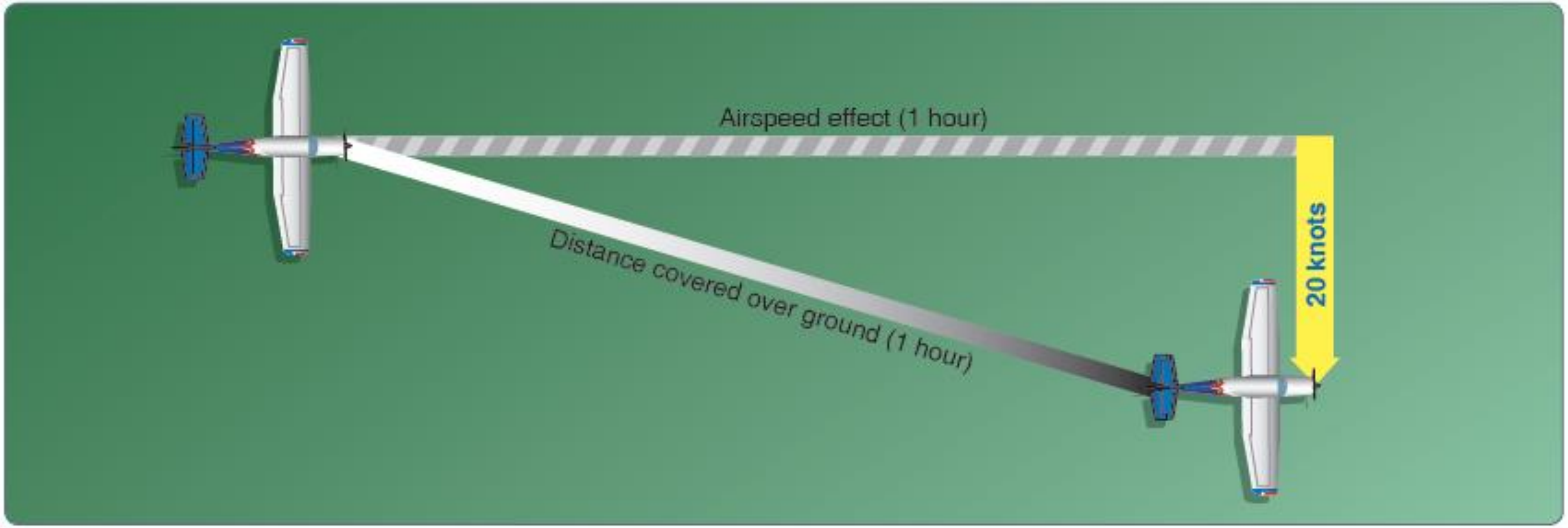
Flight Path

Affected by airplane speed, direction and wind



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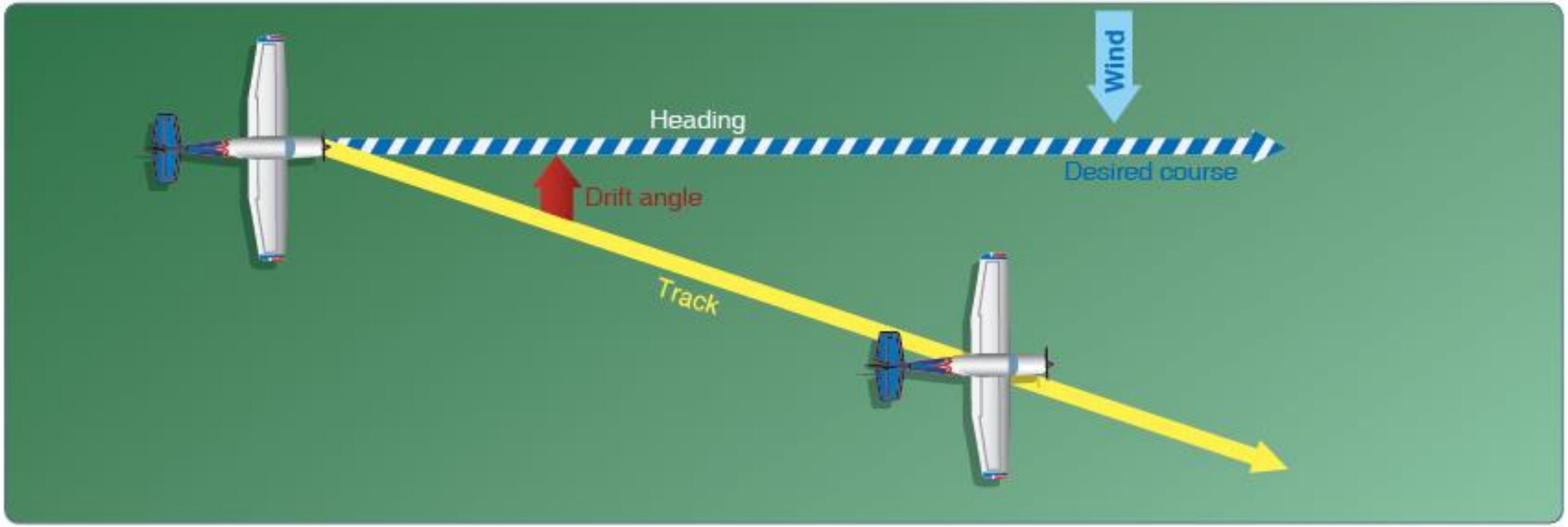
Effect of Wind Drift

Wind drift is affected by speed, direction and wind



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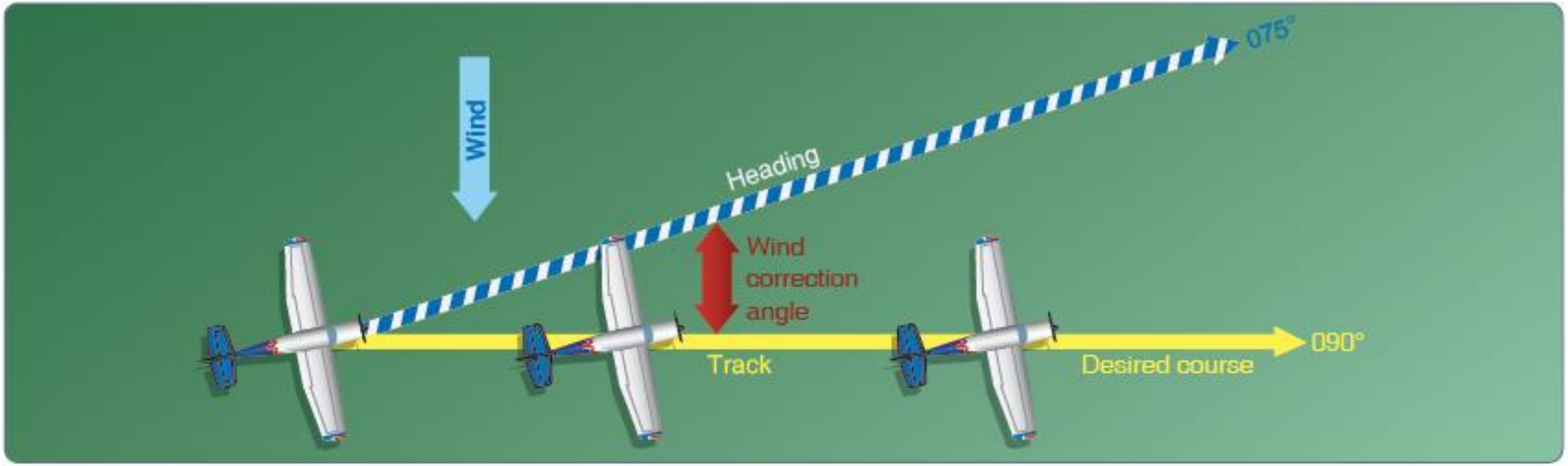
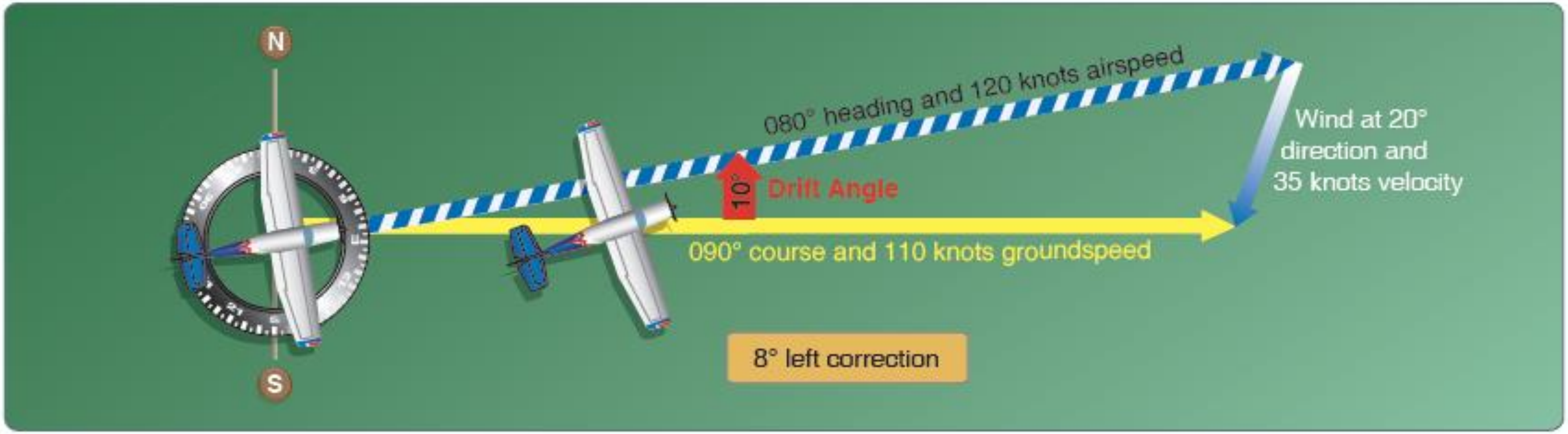
Wind Correction Angle - WCA

The new heading that reduces drift to 0°

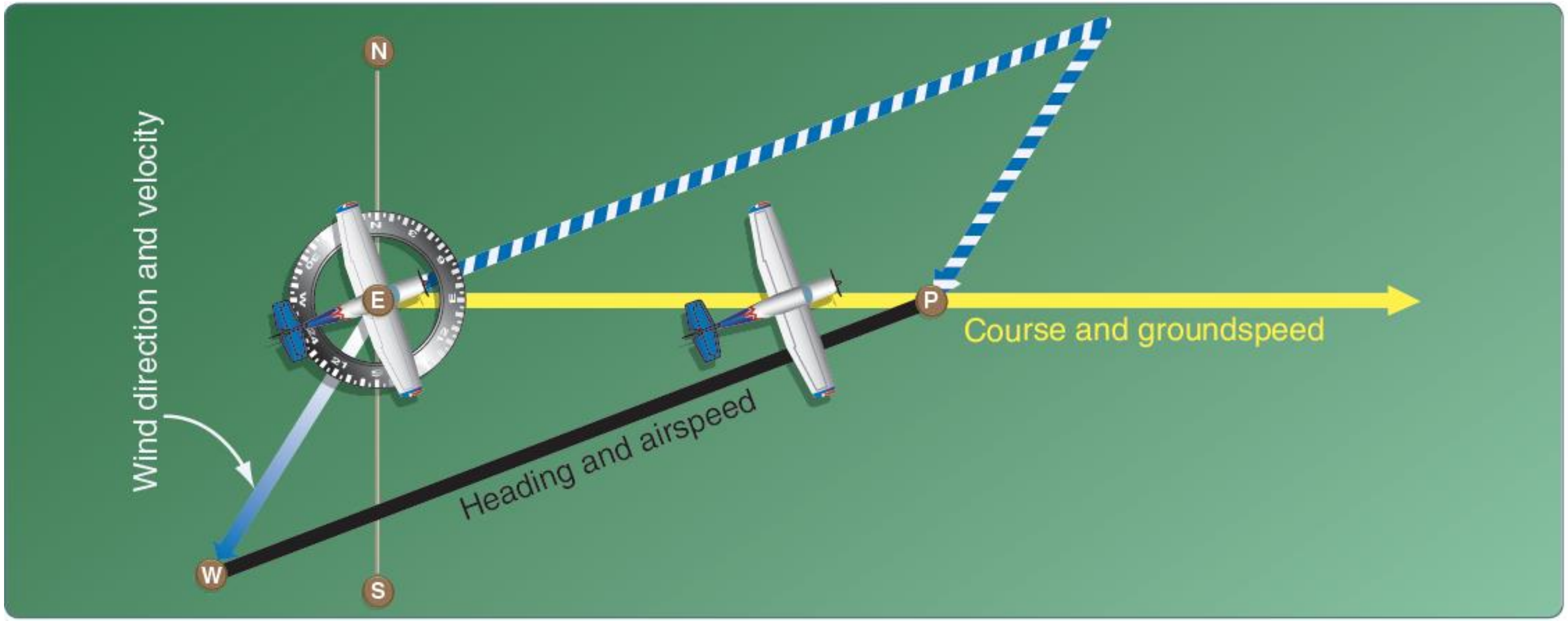


Wind Triangle

Principle of the Wind Triangle



The Wind Triangle as Used in Navigation



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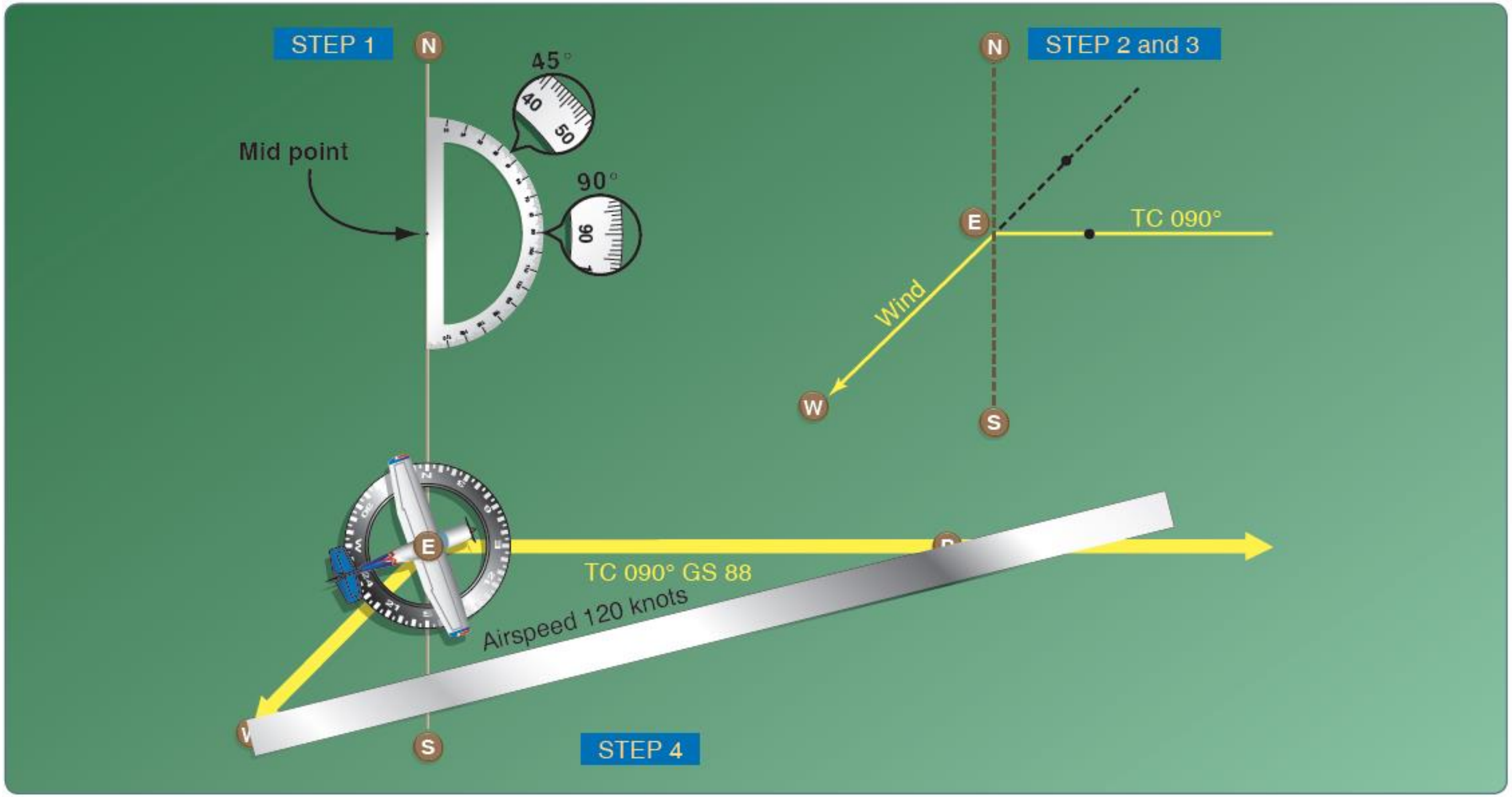
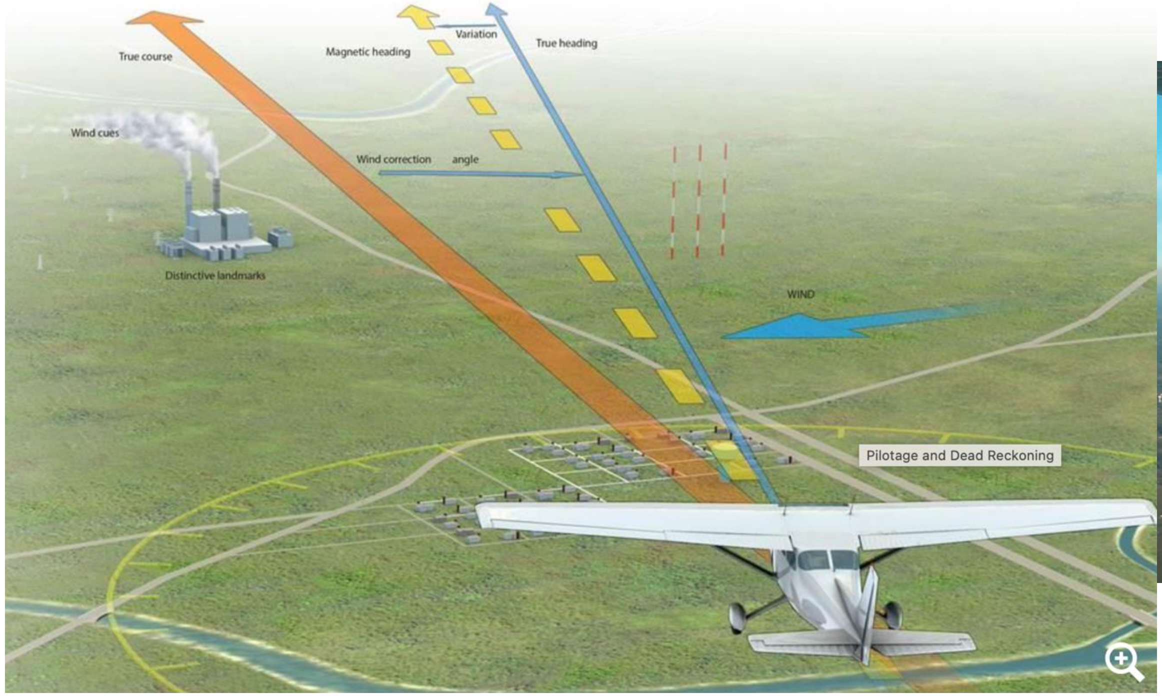
Steps in Drawing a Wind Triangle



Forms of Navigation

Pilotage – Using Outside Visual References



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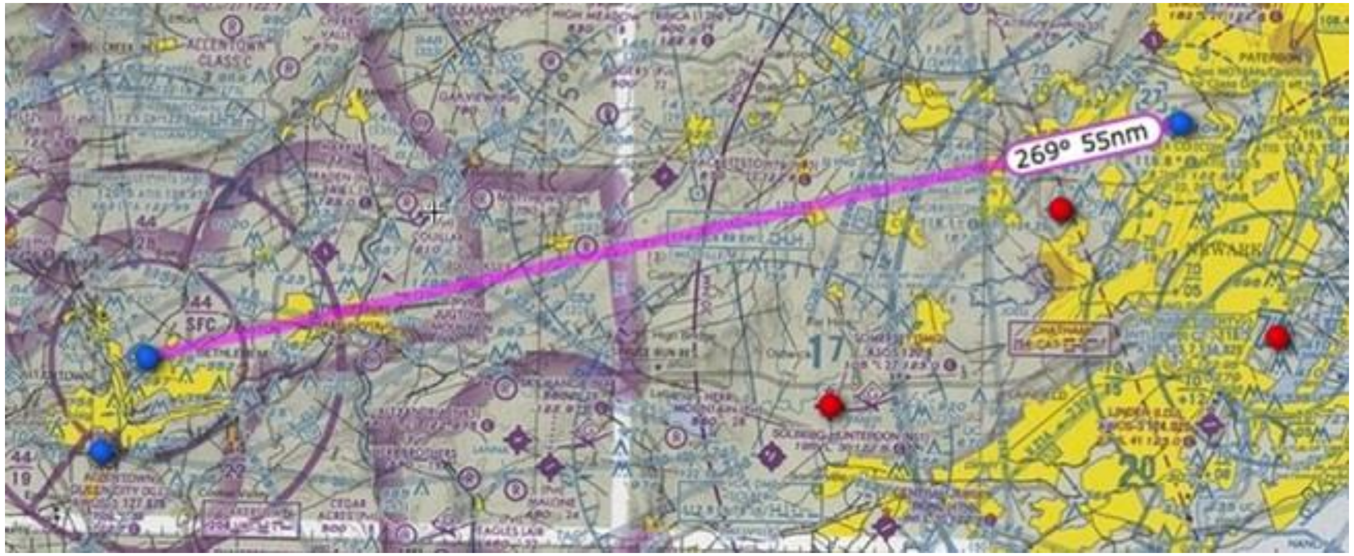
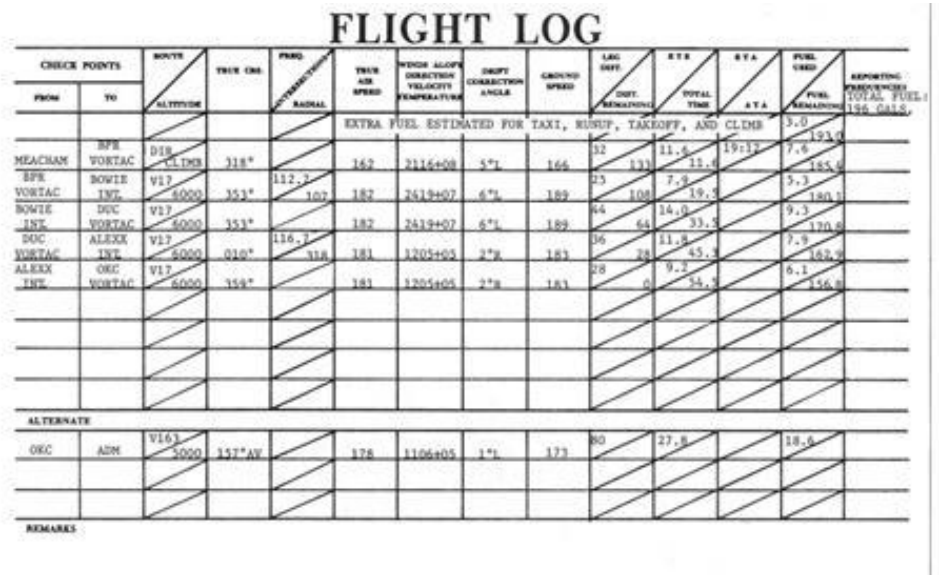
Forms of Navigation

Dead Reckoning – Using Precalculated Headings and GS's





FLIGHT LOG

Check Points: From	Check Points: To	Route / Altitude	True Crs.	Freq. / Radial	True Air Speed	Winds Aloft Direction Velocity Temperature	Drift Correction Angle	Ground Speed	Leg Dist. / Dist. Remaining	ETE / Total Time	ETA / ATA	Fuel Used / Fuel Remaining	Reporting Frequencies
					EXTRA FUEL ESTIMATED FOR TAXI, RUNUP, TAKEOFF, AND CLIMB							3.0 / 193.0	TOTAL FUEL: 196 GALS.
MEACHAM	BPR VORTAC	DIR / CLIMB	318°		162	2116+08	5°L	166	32 / 133	11.6 / 11.6	19:12	7.6 / 185.4	
BPR VORTAC	BOWIE INT.	V17 / 6000	353°	112.7 / 107	182	2419+07	6°L	189	25 / 108	7.9 / 19.5		5.3 / 180.1	
BOWIE INT.	DUC VORTAC	V17 / 6000	353°		182	2419+07	6°L	189	44 / 64	14.0 / 33.5		9.3 / 170.8	
DUC VORTAC	ALEXX INT.	V17 / 6000	010°	116.7 / 318	181	1205+05	2°R	183	36 / 28	11.8 / 45.3		7.9 / 162.9	
ALEXX INT.	OKC VORTAC	V17 / 6000	359°		181	1205+05	2°R	183	28 / 0	9.2 / 54.5		6.1 / 156.8	
ALTERNATE													
OKC	ADM	V163 / 3000	157°AV		178	1106+05	1°L	173	80	27.8		18.6	

REMARKS

Steps in determining the Compass Heading - CH

If planning using a manual method with a flight computer perform the following steps

Step One – Plot the Course - TC

TRUE COURSE (TC) - Plotted Course

Plot the course using a plotter on a chart.
The result is the TRUE COURSE which is
referenced to True North

Step Two – Calculate WCA and GS - TH

TRUE HEADING (TH) - +/- WCA

Using the WINDS ALOFT forecast determine the winds at the altitude you chose to fly. Using the POH determine the TAS for the altitude you will be flying. Now use the Flight Computer to Determine the Wind Correction Angle and the Ground Speed

Step Three – Apply the Variation - MH

MAGENTIC HEADING (MH) - +/- Variation

Using an chart, determine the Magnetic Variation in the area. You can also use the Chart Supplement.

Subtract Easterly Variation or Add Westerly Variation from the TH

Step Four – Apply the Deviation - CH

COMPASS HEADING (CH) - +/- Deviation

Using the Compass Deviation Card determine the deviation for the MH. Apply the deviation to get the Compass Heading (CH)

Where to get what

TAS - POH performance section

Wind – Winds Aloft Forecast (FT)

Variation – Sectional or Chart Supplements

Deviation – Compass card

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Basic Calculations

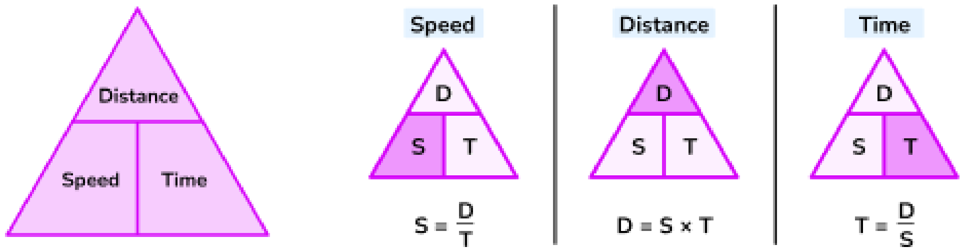
Speed distance time

Speed, distance, time is a topic about the relationship between these three measures as shown by the formula below.

$$Speed = Distance \div Time$$

"Speed equals distance divided by time"

This formula can also be rearranged to calculate distance or calculate time given the other two measures. An easy way to remember the formula and the different rearrangements is to use this speed distance time triangle.



THIRD SPACE LEARNING

Fuel needed = Time(hours)*fuel burned per hr

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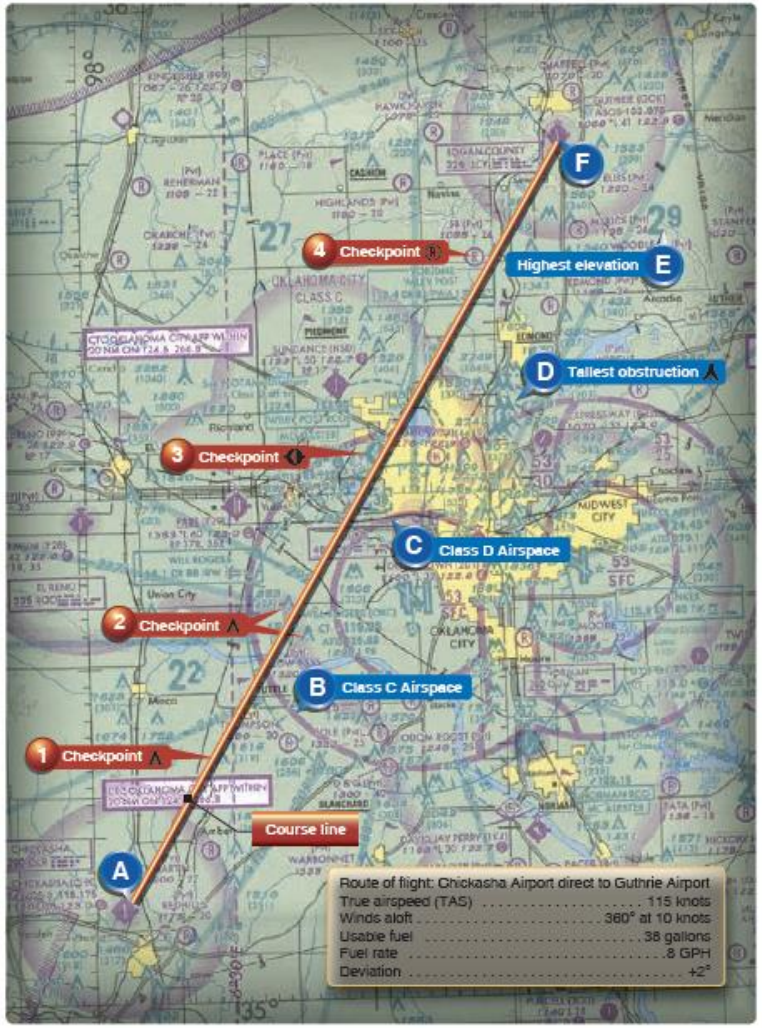
Sectional Chart Example



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Pilot’s Planning Sheet

Example of one leg

PILOT’S PLANNING SHEET

PLANE IDENTIFICATION N123DB DATE

COURSE	TC	WIND		ALTITUDE	WCA R+ L-	TH	MAG VAR W+ E-	MH	DEV	CH	TOTAL MILES	GS	TOTAL TIME	FUEL RATE	TOTAL FUEL
		Knots	From												
From Chickasha To Guthrie	031°	10	360°	8000	3° L	28	7° E	21°	+2°	23	53	106 kts	35 min	8 GPH	38 gal
From To															

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Pilot's Planning Sheet

VISUAL FLIGHT LOG								
TIME OF DEPARTURE	NAVIGATION AIDS	COURSE	ALTITUDE	DISTANCE	ELAPSED TIME	GS	CH	REMARKS
POINT OF DEPARTURE Chickasha Airport	NAVAID IDENT. FREQ.	TO / FROM	TO / FROM	POINT TO POINT / CUMULATIVE	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	WEATHER AIRSPACE ETC.
CHECKPOINT #1			8000 / 10000	11 NM	6 min +5	106 kts	023°	
CHECKPOINT #2			8000 / 10000	10 NM / 21 NM	6 min	106 kts	023°	
CHECKPOINT #3			8000 / 10000	10.5 NM / 31.5 NM	6 min	106 kts	023°	
CHECKPOINT #4			8000 / 10000	13 NM / 44.5 NM	7 min	106 kts	023°	
DESTINATION Guthrie Airport				8.5 NM / 53 NM	5 min			

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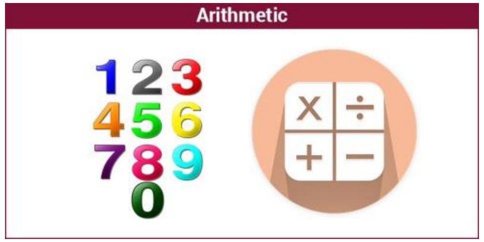
Calculation Methods



Manually -

- Using geometry and arithmetic
- Using a calculator and flight computer

Electronic -

- ForeFlight or another EFB

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What's needed?

Route – Applying risk assessment principles

Aircraft Performance and Abilities

Weather

Departure/Arrival Airport Information

What EFB's can't do

Choose the best route

Apply risk management

Make a Go/No Go decision

Incorporate your personal minimums

Check the plan for TLAR – What's TLAR?

"That looks about right!"

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Getting back on course

The airplane must be allowed to drift on heading

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Getting back on course

You must identify how far off course and distance traveled and remaining

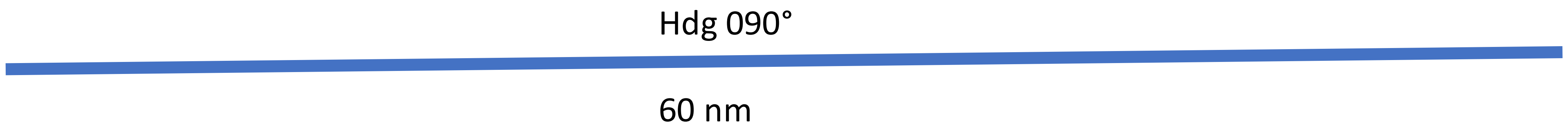
Getting back on course

1:60 Rule

Every mile off course over 60 miles is 1°

Getting back on course

1:60 Rule



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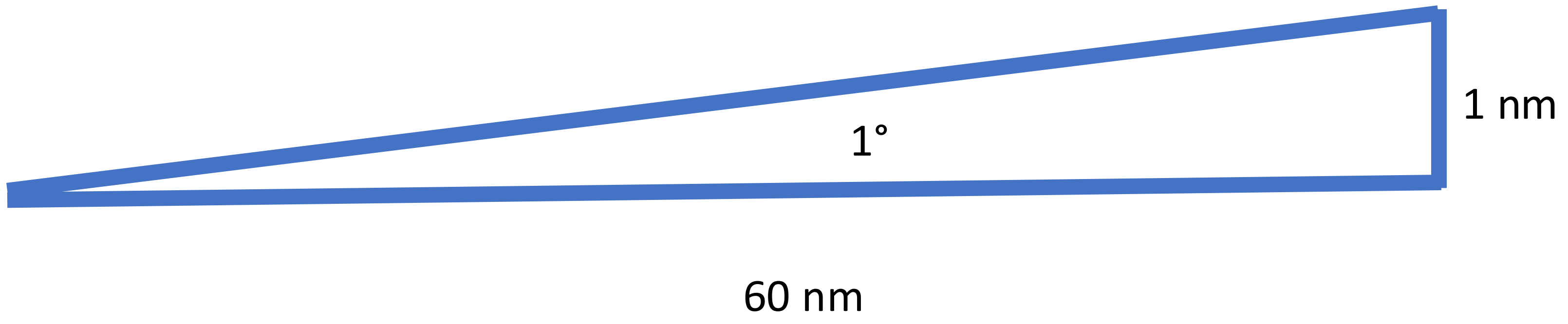
Getting back on course

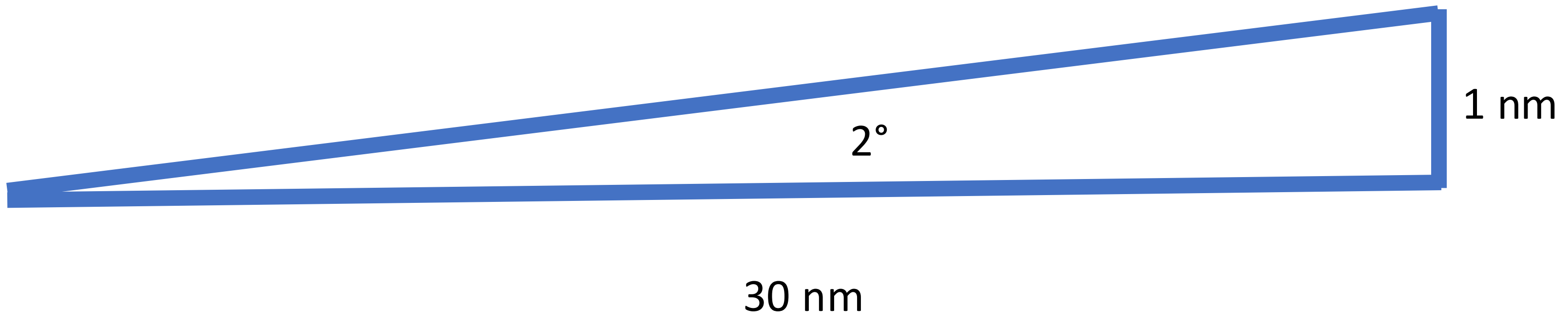
1:60 Rule



Getting back on course

1:60 Rule

Drift angle = Distance off track/(60/Distance Traveled)



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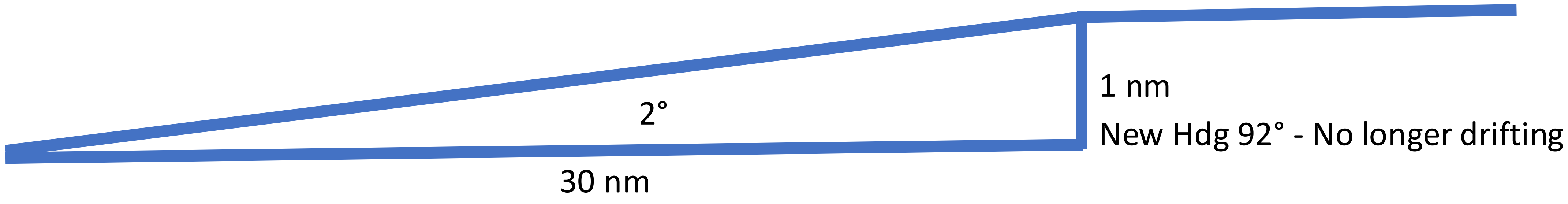
Getting back on course

1:60 Rule

Drift angle = (60/Distance Traveled)/Distance off course



Getting back on course

1:60 Rule

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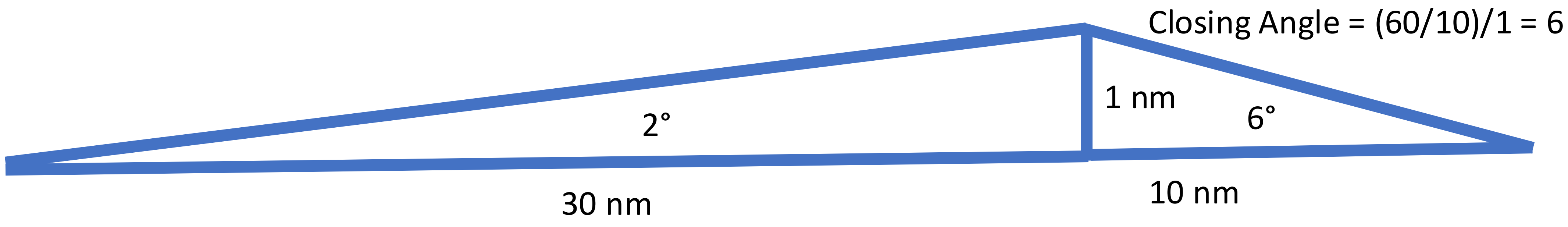

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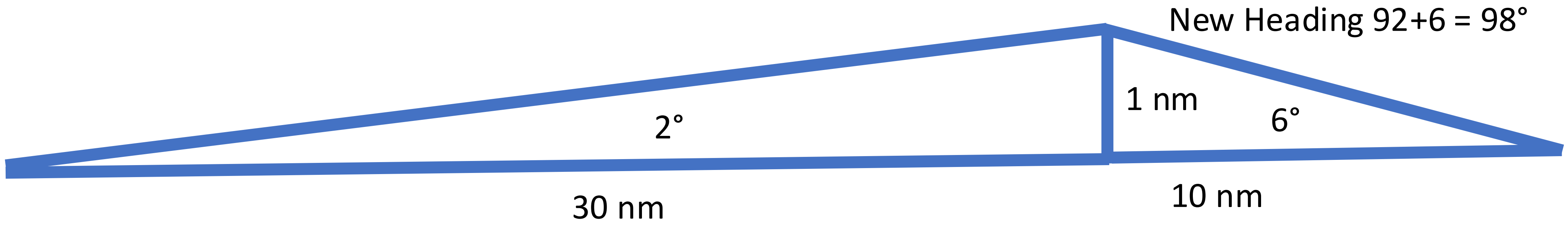
Getting back on course

1:60 Rule

Drift angle = (60/Distance Traveled)/Distance off course



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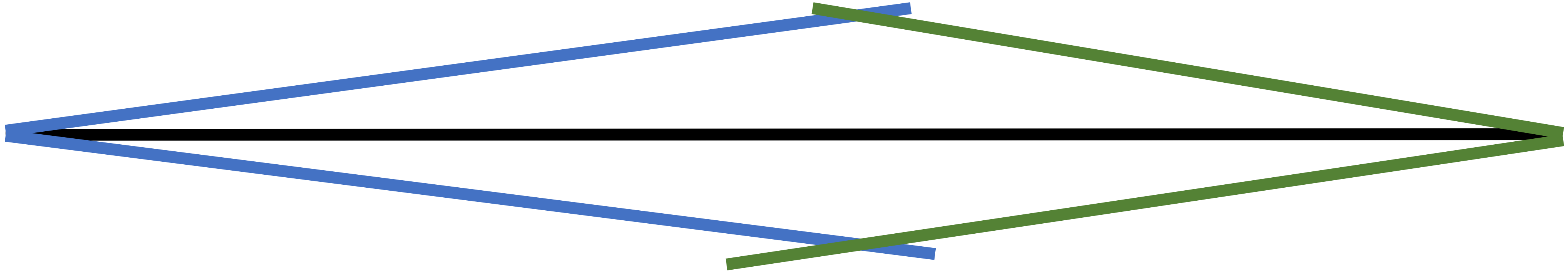
Getting back on course

Track Error + Closing Angle Method

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



Getting back on course

Track Error + Closing Angle Method

Blue Lines – 10° Error Lines from Departure

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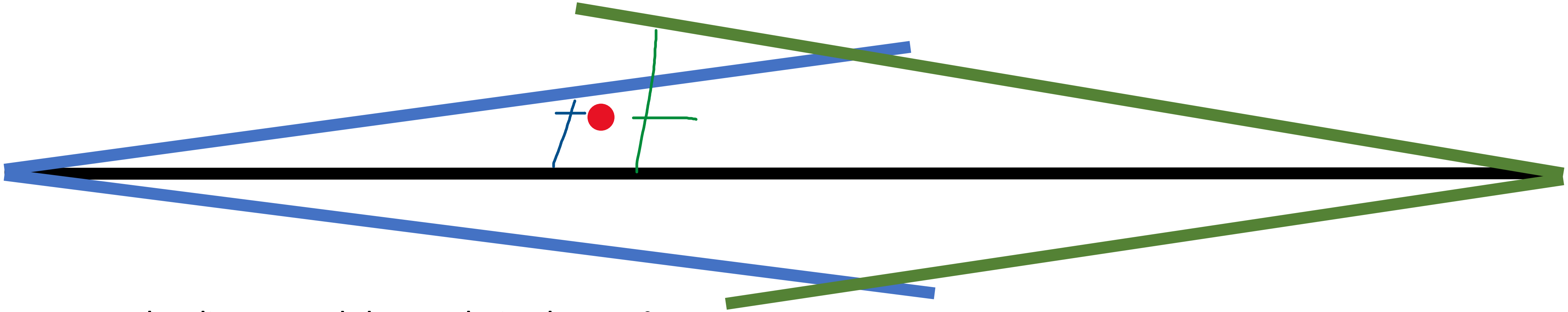

Blue line to red dot angle is about 8°

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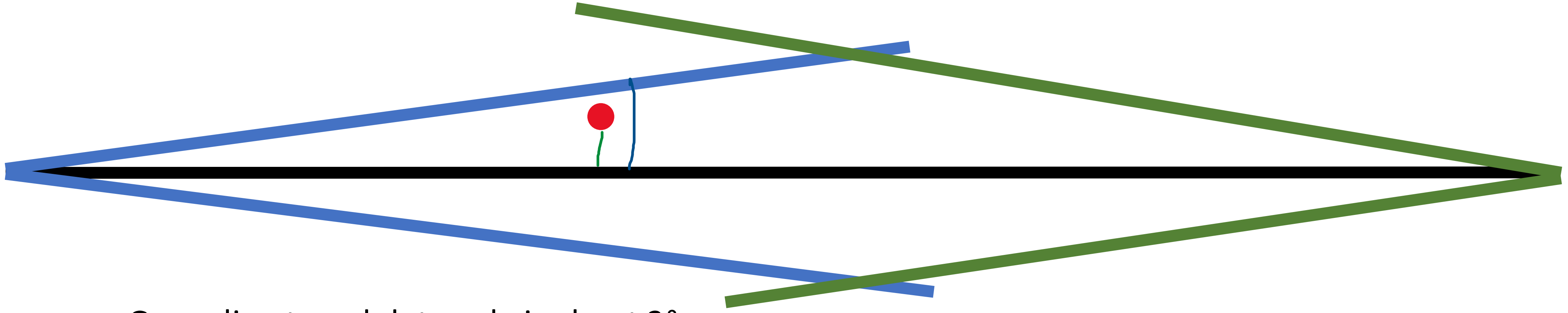
Getting back on course

Track Error + Closing Angle Method

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



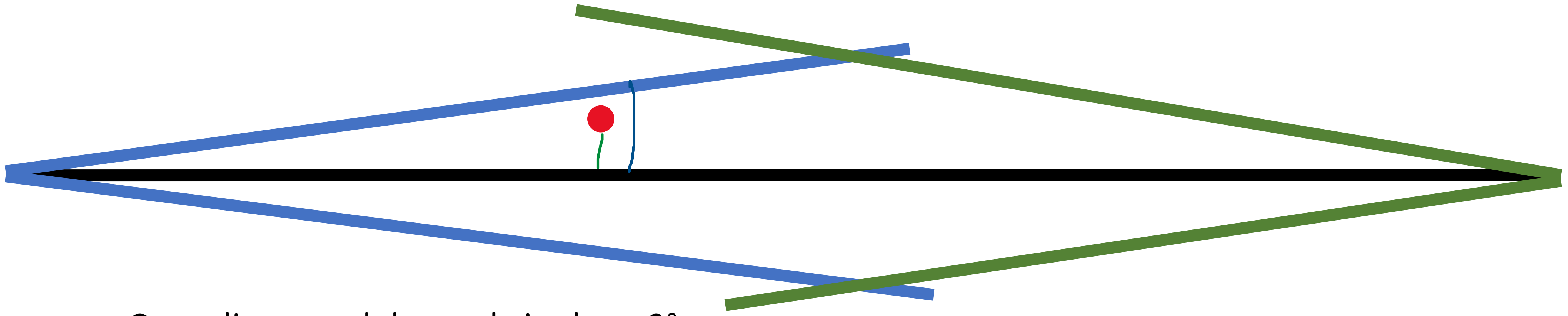
Green line to red dot angle is about 3°

Getting back on course

Blue line to red dot – Track Error

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



Green line to red dot angle is about 3°

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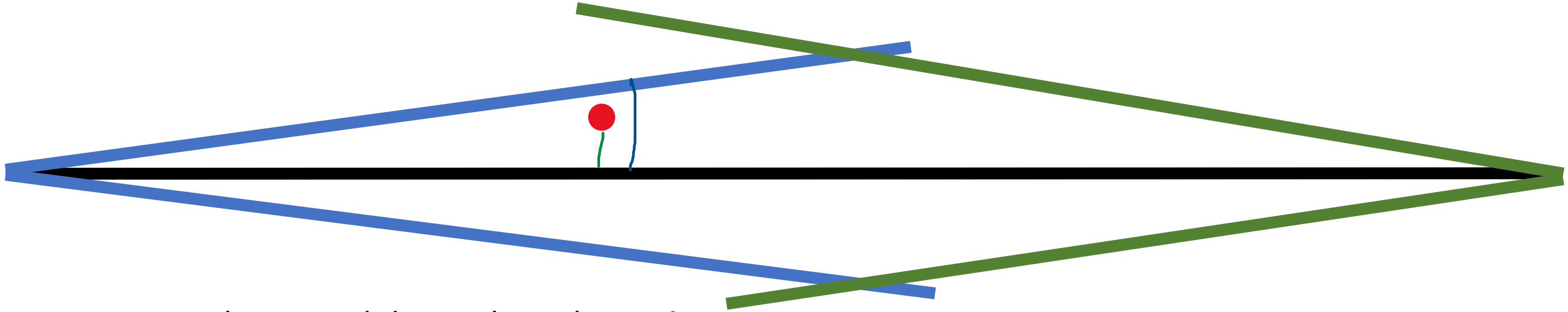
Getting back on course

Green line to red dot – Closing Angle

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



Green line to red dot angle is about 3°

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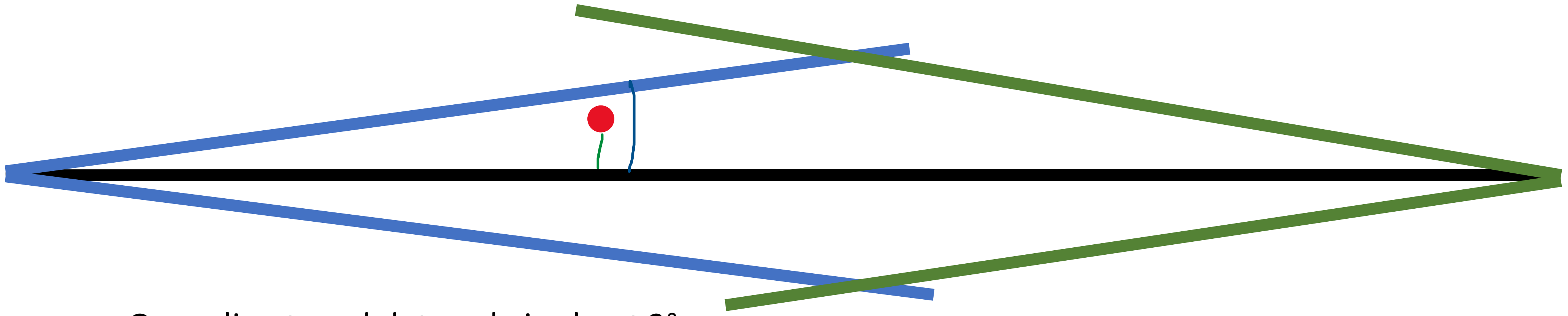
Getting back on course

Track error (8°) + Closing angle (3°) = 11°

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



Green line to red dot angle is about 3°

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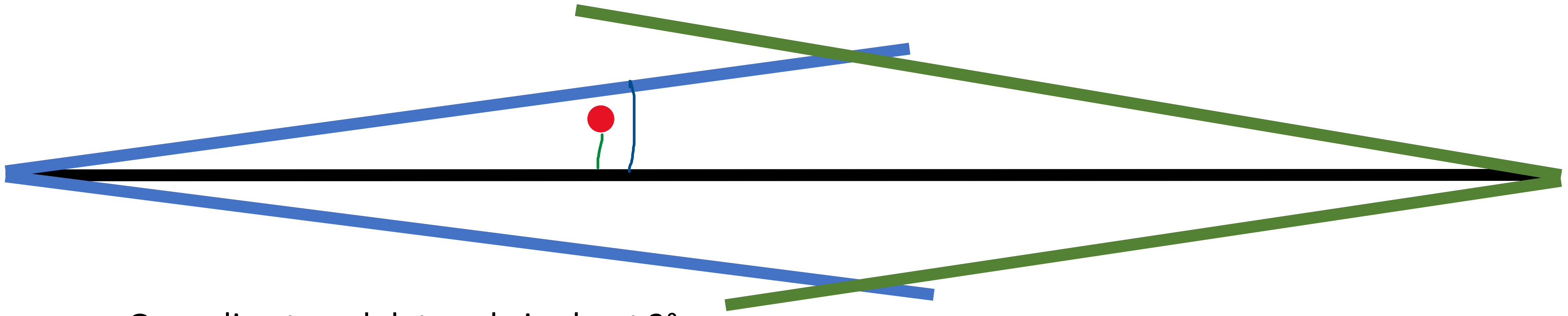
Getting back on course

Turn the airplane to the right 11° - Goes to destination

Blue Lines – 10° Error Lines from Departure

Green Lines – 10° Error Lines from Destination



Green line to red dot angle is about 3°