DOCUMENT
GSM-AUS-CPL.028

DOCUMENT TITLE

CPL NAVIGATION 2 (AUSTRALIA)

CHAPTER 8 – AIRWAYS NAVIGATION TECHNIQUES

Version 2.1
November 2017

CONTENTS ..... PAGE

AIRWAYS NAVIGATION TECHNIQUES

8.1 Introduction

The purpose of this chapter is to allow practice in a number of techniques for navigation by means of radio aids. The techniques are similar to those practiced in Navigation 1, which are based on pinpoints and visual position lines. Airways navigation techniques make similar use of radio bearings and do not require the bearings to be plotted on a chart.

The following types of navigation problems are solved by applying the following techniques:

- Calculating current drift.
- Finding a heading to parallel track.
- Finding a heading to steer, from an off-track position, to go directly to a beacon ahead.
- Conversion between various bearing types.

Three indicator types are commonly found in light aircraft:

- Fixed Card ADF (also known as a Relative Bearing Indicator – RBI)
- Omni-Bearing Selector (OBS)
- Radio Magnetic Indicator (RMI)

RBI

OBS

RMI

The techniques discussed solve the various problems through the use of the elements of the velocity triangle, whilst other techniques harness the 1-in-60 rule.

> Refer to Navigation 1 Chapter 5 for revision on the elements of the velocity triangle and Navigation 1 Chapter 10 for revision on the 1-in-60 rule.

8.2 Finding the Heading to Parallel Track

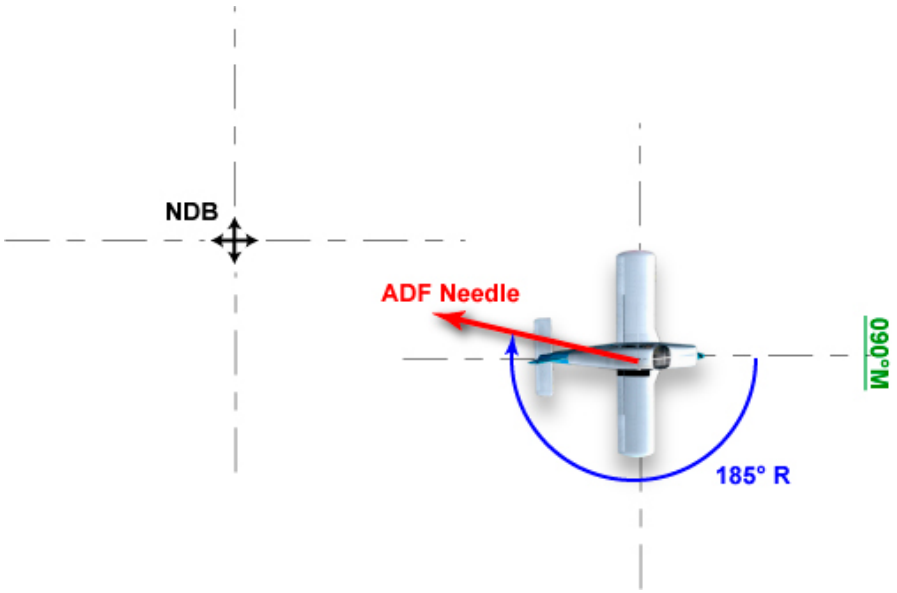
The aim of this technique is to identify the aircraft's current track to determine the correction required to heading, to continue the flight parallel to the flight plan track. This can be achieved in two ways:

- Making use of relative bearings on the Fixed Card ADF to calculate drift and applying the drift to the flight plan track to calculate the heading to parallel track.
- Making use of magnetic bearings on the RMI to calculate track error and applying the track error to the current heading to find the heading to parallel the flight plan track.

The techniques are only valid if the aircraft passed over the beacon, maintaining a constant heading and the calculated heading correction is the first correction made since passing overhead.

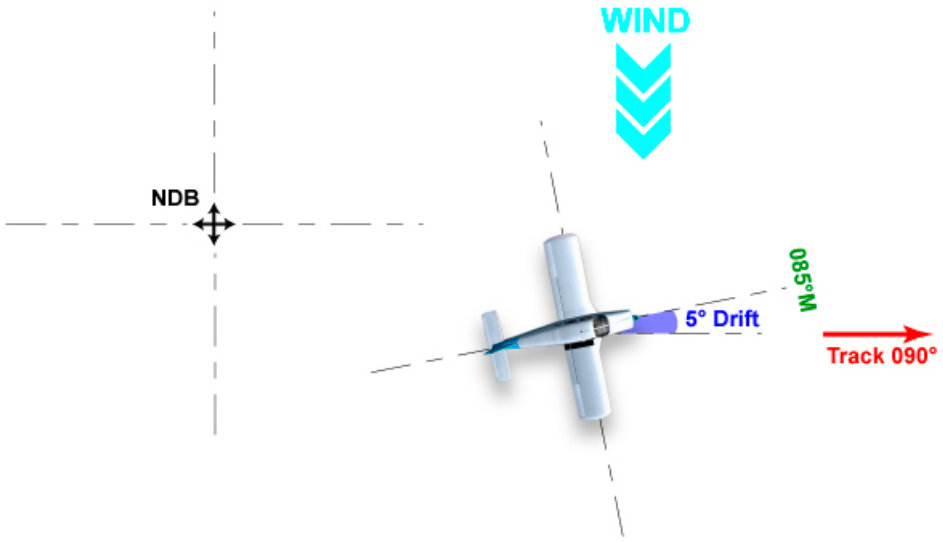
8.2.1 Relative Bearings and Drift Application

Example: An aircraft passed over an NDB intending to track 090°M. After a few minutes it is noted that the NDB bears 185° relative. What is the heading required to parallel track?



Use the relative bearing to find the drift. In this example if the relative bearing is 180°, the drift would be zero.

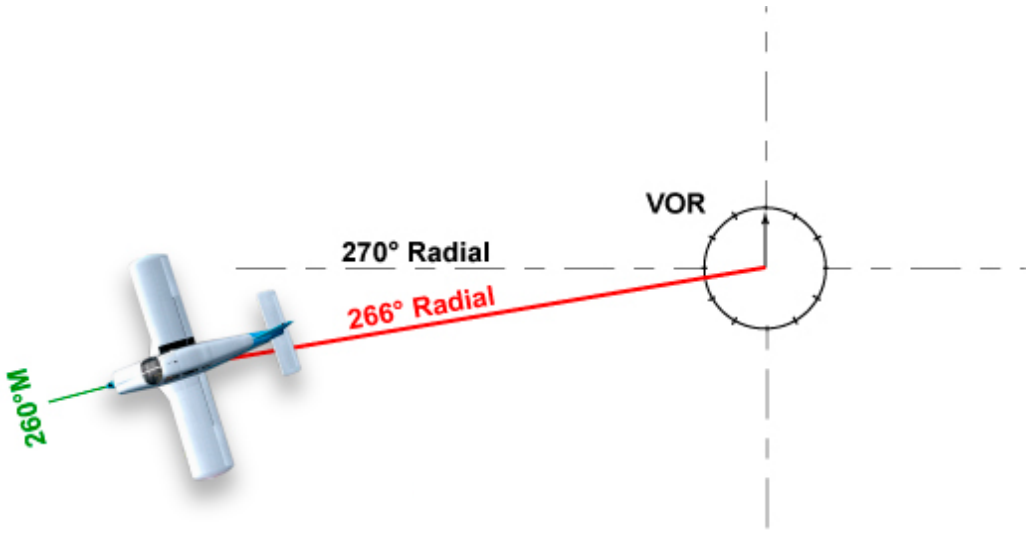
Working: The 185° relative bearing indicates that the aircraft is experiencing drift of 5° right. Applying this drift to the required track of 090°M gives 085°M as the heading to parallel track.



Drift, when applied to track, will give the heading to make good the track.

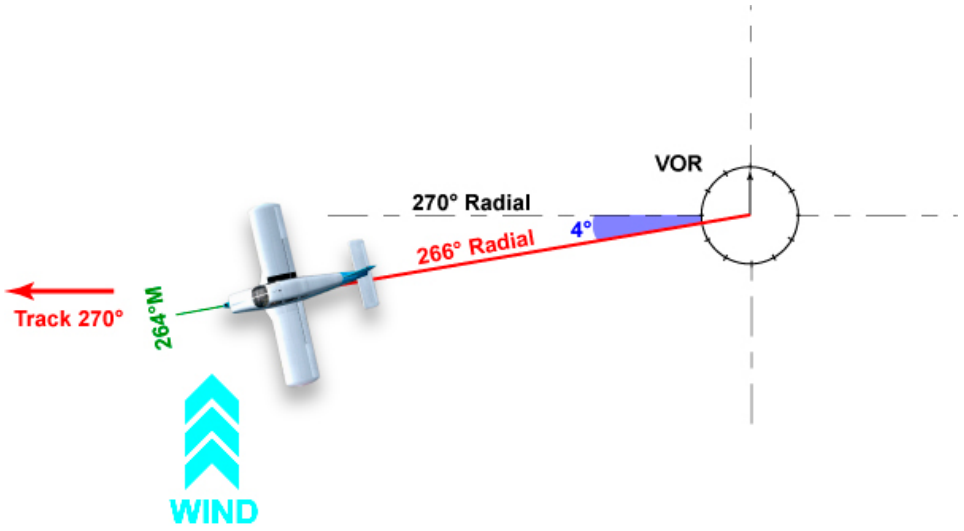
8.2.2 Magnetic Bearings and Track Error Application

Example: An aircraft passes over a VOR heading 260°M intending to track 270°M. After a few minutes it is noticed that the aircraft is on the 266° radial. What is the heading required to parallel track?



Track Error (TE) is the difference between the intended track and the actual track.

Working: The aircraft has a 4° left track error (266° radial instead of 270°). The alteration of heading required is 4° right, so the new heading is 260°M + 4° i.e. 264°M heading.



Track Error, when applied to current heading, will give the required heading to parallel track.

8.3 Finding the Direct Heading to the Turning Point Ahead

The aim of this technique is to identify what the aircraft's current position is in relation to the flight plan track between two navaids. The heading correction calculated is to proceed from the off-track position directly to the beacon located at the turning point ahead.

This is accomplished by any one of the following three methods:

- Making use of relative bearings on the Fixed Card ADF to calculate drift and applying the drift to the required track (as obtained from the RMI) to calculate the heading to intercept track at the beacon ahead of the aircraft.
- Making use of magnetic bearings on the RMI to calculate track error and closing angle to apply the total correction to the current heading to find the heading to intercept track at the beacon ahead of the aircraft.
- Alternatively the magnetic bearings on the RMI can be used to calculate the current drift, which can then be applied to the required track (as obtained from the RMI) to calculate the heading to intercept track at the beacon ahead of the aircraft.

The technique discussed below is only valid if the aircraft passed over the first beacon, maintaining a constant heading and the heading correction made, is the first correction made since passing overhead.

The intention here is also that the heading correction should be the only correction required to intercept track at the beacon that lies ahead of the aircraft.

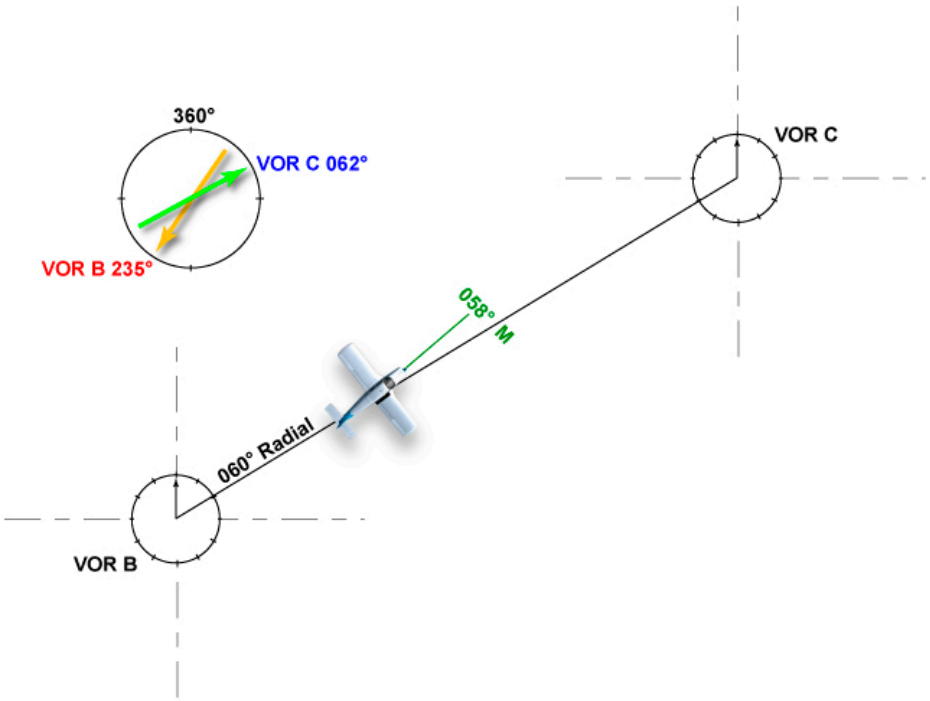
8.3.1 Track Error and Closing Angle Method

Example: An aircraft passes over VOR B en-route to VOR C along the 060° radial. Having maintained a heading of 058°M, the following bearings are obtained:

VOR B 235°M

VOR C 062°M

What is the heading required to track direct to VOR C?



Use the principles of the 1 in 60 rule to find track error and closing angle.

This picture above illustrates the aircraft's intention to be on track, maintaining R060 outbound from VOR B, while steering a heading of 058°M. This means the aircraft expected a drift value of 2° right, which was corrected for, when it left VOR B.

At the aircraft's current position, the VOR bearings to both stations should have differed by exactly 180°, if the aircraft was on track (on R060). The split in the needles show that the aircraft is actually left of track and that a correction to the heading currently being steered is required. Any correction will be to the right.

This correction can be determined in two ways:

- Calculate the current drift and apply it, finding the direct heading for VOR C.
- Calculate the track error and closing angle in order to find the total correction necessary to steer directly for VOR C.

Working:

The bearing to VOR B is 235°M so the aircraft is currently on the 055° radial. When compared with the 060° radial, track error is noted to be 5° left.

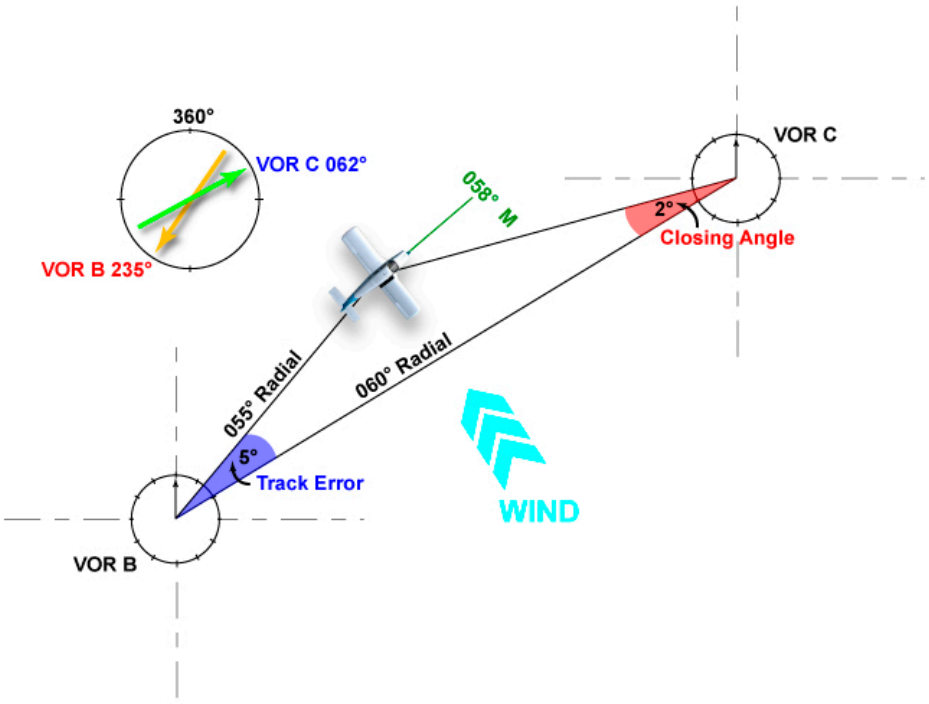
The bearing to VOR C is 062°M. When compared with the 060° radial, it gives a closing angle of 2°.

The total correction required is the track error plus the closing angle. Since the aircraft is left of track the correction needs to be to the right.

According to the principles of the 1 in 60 rule, the total correction is always applied to the current heading to find the direct heading for the point ahead.

Alter heading by 5° + 2° = 7° right. New heading is 058°M + 7° = 065°M.

Use the bearing TO the beacon ahead of the aircraft and the required track to find the closing angle.



Use the bearing FROM the beacon behind the aircraft and the required track to find the track error.

Total correction is track error plus closing angle and is applied to current heading to obtain the required heading to go directly to the point ahead.

8.3.1.1 Track Error and Closing Angle Method Shortcut on RMI

This shortcut method is still reliant on the aircraft passing over the first beacon, maintaining a constant heading and the correction calculated is the first and final correction made for the beacon ahead of the aircraft where the track will be intercepted.

Example: The RMI indications were obtained en-route between NDB V and VOR W. No alteration of heading has been made since passing over NDB V.

Working:

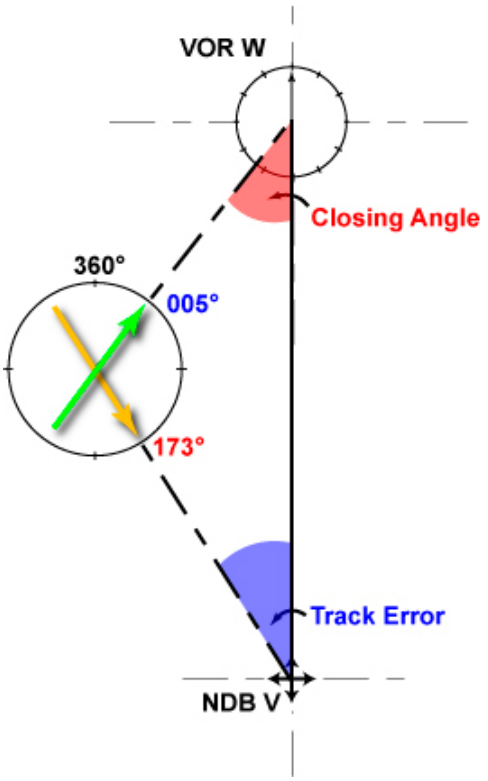
When using the track error and closing angle method to find the direct heading for the point ahead, there is a quick way to find the total correction required.

The smaller angle between the needles is equal to the track error plus the closing angle (in other words the total correction).

Just like before the total correction is applied to the current heading to find the required heading for the point ahead.

In this example, the smaller angle between the needles is 12° and so the heading should be altered 12° right on to 012°M.

It is assumed in this case that the original heading was 000°M. This shortcut method of finding track error and closing angle is only available on the RMI.



8.4 Converting Between Different Types of Bearings

When bearings are used, it is important to take note of the fact that there is more than one type of bearing that can be referred to. Some types of bearings are named making use of Q-codes, and are as follows:

- **QUJ** - True track/bearing to the station.
- **QTE** - True track/bearing from the station.

- **QDM** - Magnetic track/bearing to the station.
- **QDR** - Magnetic track/bearing from the station.

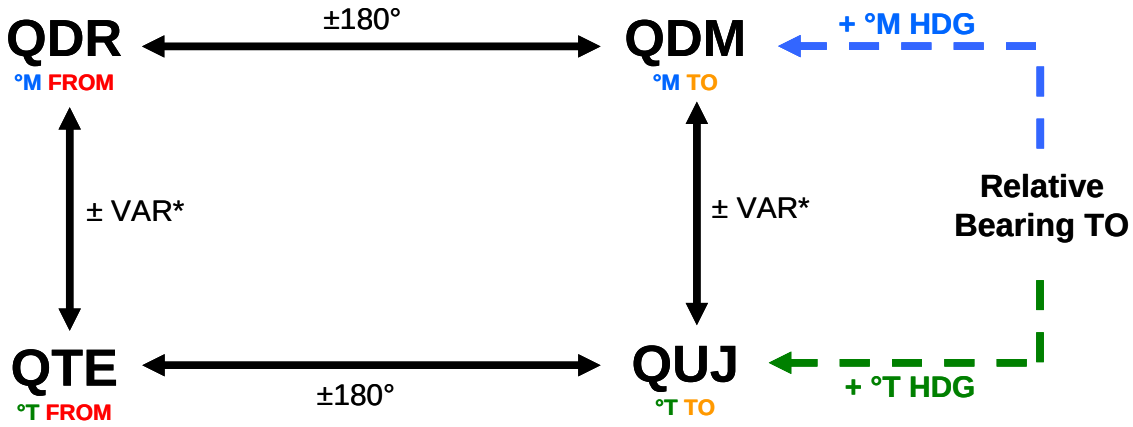
All these bearings are with reference to North, either True North or Magnetic North.

QTE's are used when plotting bearings on a chart. QDM's are used when homing in on a beacon or flying a holding pattern or NDB letdown. QDR's are used to track a specific magnetic track away from a station.

In the case of the NDB & ADF, we can also have relative bearings. Relative bearings are with reference to the aircraft's nose, i.e. the aircraft's heading and are therefore based on a different reference than any of the Q-code bearings.

It is important to differentiate between the various types of bearings and be able to convert between them in order to interpret and apply the bearing information depicted by the various types of indicators.

The diagram below can be used for effecting conversions between different types of bearings:



*** Apply variation at the aircraft's position to convert NDB bearings, and apply variation at the station's position to convert VOR radials.**

Refer to Navigation 1 Chapter 5 for revision on bearing types, their use and the conversion process required.

8.5 Worksheet – Airways Navigation Techniques

1. The RMI display shown below was obtained by an aircraft en route between VOR A and VOR B. The direct track between A and B measures 332°M. The aircraft has maintained its present heading of 330°M since passing over A.

340° to B

146° to A

What should be the new heading to track direct to VOR B?

a. 344

b. 316

c. 340

d. 336.

2. You are heading 112°M towards NDB X along the direct track which measures 120°M. You are required to report abeam VOR Y which is to the left of track. The RMI display below shows the aircraft approaching the abeam position.

At what RMI reading to VOR Y will you make your transmission?

a. 012

b. 022

c. 030

d. 040.

3. You have maintained heading 058°M since passing overhead VOR L. The bearings to VOR L and VOR M are displayed on the RMI below.

045° to M

250° to L

What should be the new heading to track direct to VOR M?

a. 083

b. 045

c. 035

d. 033.

4. The direct track between F and G measures 247° magnetic. A few minutes after overflying NDB F the ADF shows 187° relative. Find the heading to parallel track.

5. The aircraft departs VOR P heading 077° magnetic with the intention of maintaining an airway centred on the 081° radial. Subsequently the RMI selected to VOR P reads 255°. Find the heading to parallel track.

6. Doppler equipment shows drift 4° left. The intended track is 357°. Find the heading to parallel track.

7. En-route between D and E, the following RMI readings are obtained:

VOR D 064°

NDB E 240°

Find the alteration to fly direct to E.

8. While flying between Q and R, the following ADF bearings are displayed simultaneously:

NDB R 008° relative

NDB Q 172° relative

Find the alteration of heading to fly direct to R.

9. The aircraft is outbound from NDB V intending to maintain track 004°M to VOR W. Some time later, after flying a constant heading, the following bearings are obtained:

NDB V 180° relative

VOR W 179° radial

Find the heading to steer for W.

10. Referring to the diagrams below. What is the magnetic bearing to the NDB?

HDG 143°M

027°R

11. An aircraft is tracking to an NDB, and the pilot notices a steady relative bearing of 354°R on the ADF. What is the drift?

12. Referring to the diagrams below. What is the magnetic bearing from the radio beacon?

HDG 246°M

210°R

13. An aircraft passes over an NDB and whilst tracking from this NDB has a steady relative bearing of 187°. What is the drift?

14. An aircraft tracks to a station on a steady heading of 016°M and the ADF indicator shows a steady relative bearing of 007°. What magnetic track is being maintained?

15. An aircraft is maintaining a track to the NDB of 106°M while on a heading of 118°M. What is the relative bearing on the ADF?

16. Refer to the diagrams below. After passing over the NDB, with no change to heading or drift, what will be the relative bearing while tracking from this NDB?

HDG 075°M

349°R

17. Refer to the diagram.

Which radial is the aircraft on?

a. 266

b. 258

c. 086

d. 078.

18. Refer to the diagram.

Which radial is the aircraft on?

a. 344

b. 164

c. 174

d. 356.

19. Refer to the diagram.

Which radial is the aircraft on?

a. 078

b. 082

c. 258

d. 262.

20. Refer to the diagram.

What is the magnetic bearing to the station?

a. 019

b. 031

c. 199

d. 211.

21. Refer to the diagram.

What is the magnetic bearing to the station?

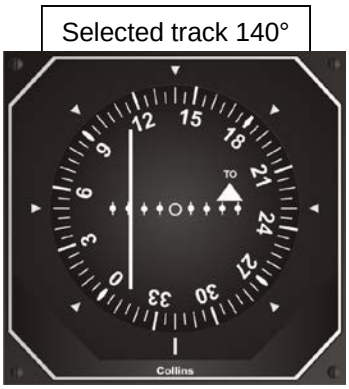
a. 224

b. 044

c. 236

d. 056.

22. Refer to the diagram.



Which radial is the aircraft on?

a. 148

b. 132

c. 328

d. 312.

23. Refer to the diagram.

What is the magnetic bearing to the station?

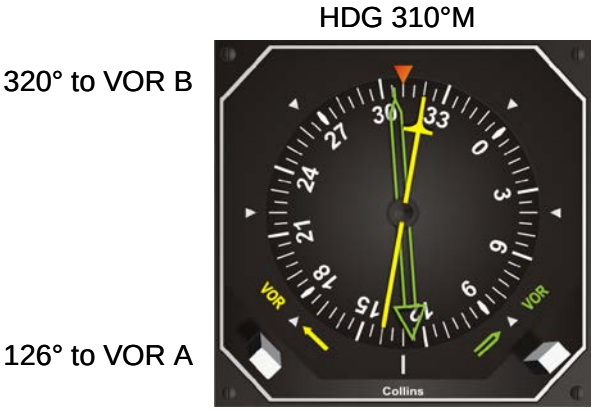
a. 292

b. 308

c. 112.

d. 128.

24. Refer to the diagram. An aircraft is tracking between VOR A and VOR B.



What is the new heading to track direct to B?

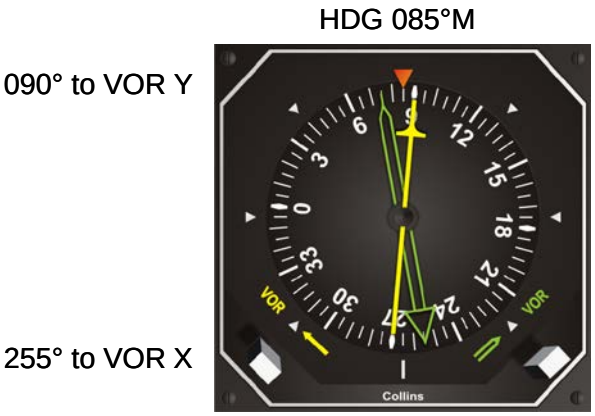
a. 324°M

b. 296°M

c. 320°M

d. 306°M.

25. Refer to the diagram. An aircraft is tracking between VOR X and VOR Y.



What is the new heading to track direct to Y?

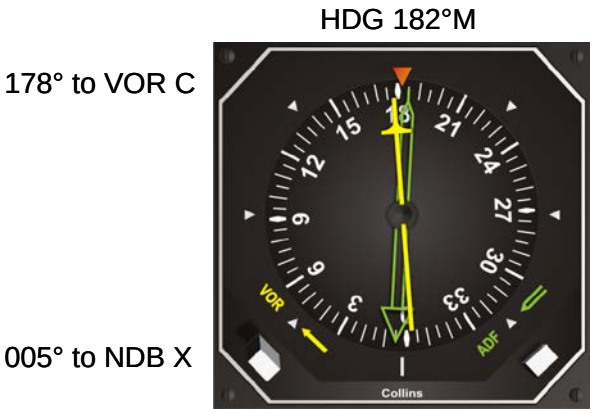
a. 070°M

b. 100°M

c. 095°M

d. 075°M.

26. Refer to the diagram. An aircraft is tracking between NDB X and VOR C.



What is the new heading to track direct to C?

a. 189°M

b. 178°M

c. 180°M

d. 175°M.

27. Refer to the diagram. An aircraft is tracking between NDB L and VOR B.

What is the new heading to track direct to B?

a. 165°M

b. 151°M

c. 147°M

d. 155°M.

28. An aircraft is flying between NDB R and VOR C along a track of 096°M. The heading of 084°M has not been changed since the aircraft flew over NDB R. The bearings obtained were: NDB R 188°R and VOR C R281.

What is the new heading to track direct to C?

a. 093°M

b. 075°M

c. 096°M

d. 264°M.

29. An aircraft is flying between NDB A and VOR Y. A constant heading of 140°M is maintained. The direct track AY is 135°M. The bearings obtained were:

NDB A 170°R

VOR Y RMI reads 138°

What heading should the aircraft fly to track direct from its present position to VOR Y?

a. 132°M

b. 170°M

c. 148°M

d. 140°M.

30. An aircraft is flying between VOR A and NDB U. A constant heading of 250°M is maintained. The direct track AU is 240°M. The bearings obtained were:

VOR A RMI reads 066°

NDB U 344°R

What heading should the aircraft fly to track direct from its present position to NDB U?

a. 244°M

b. 238°M

c. 262°M

d. 066°M.

31. An aircraft is flying between VOR M to NDB T. A constant heading of 350°M is maintained. The direct track MT is 360°M. The bearings obtained were:

VOR M R003

NDB T RMI reads 355°

What heading should the aircraft fly to track direct from its present position to T?

a. 358°M

b. 345°M

c. 347°M

d. 342°M.

32. An aircraft is flying between VOR X and NDB A. A constant heading of 080°M is maintained. The direct track XA is 090°M. The bearings obtained were:

VOR X RMI reads 274°

NDB A 006°R

What heading should the aircraft fly to track direct from its present position to A?

a. 072°M

b. 086°M

c. 090°M

d. 084°M.

8.5.1 Worksheet Answers

1A	17C
2C	18D
3D	19A
4. DR 7°R, HDG 240°M	20A
5. TMG 075°, TE 6°, HDG 083°M	21C
6. HDG 001°	22D
7. Alter heading 4°L	23B
8. TE 8°, a/h right 16°	24A
9. DR zero, HDG 359°M	25B
10. 170°M	26D
11. 6°L	27B
12. 276°M	28A
13. 7°R	29C
14. DR 7°R, TRK 023°M	30B
15. DR 12°L, 348°R	31D
16. 169°R	32A

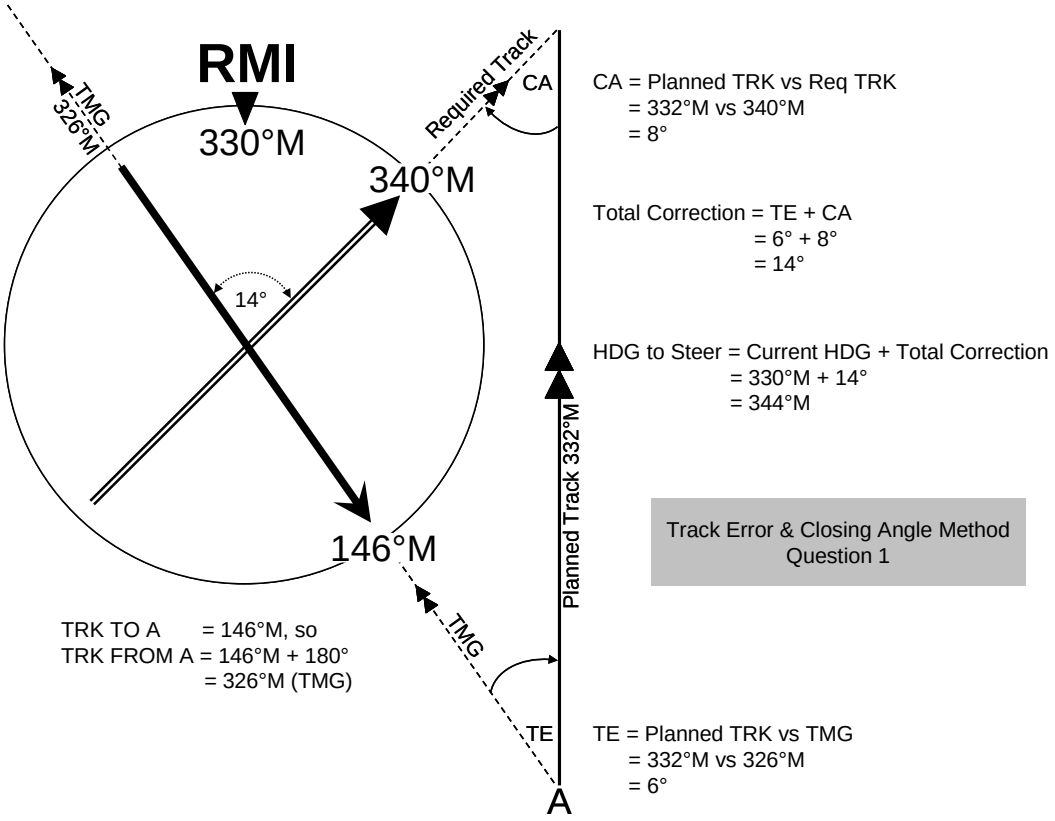
8.5.2 Worked Answers

8.5.2.1 Question 1 – TE & CA Method on RMI

This method can be used to solve bearing questions on the RMI for any beacon type.

Variables Required:

- Two bearings on the RMI to/from the two beacons in the scenario.
- Planned Track between the two beacons.
- Current Heading (usually kept constant since passing over the first beacon).



Steps to Solve:

- Find the current TMG by using the bearing information FROM the beacon behind the aircraft.
- Calculate the Track Error by comparing Planned Track against TMG.
- Identify the Required Track TO the beacon ahead by using the TO bearing information on the RMI that relates to the beacon ahead of the aircraft.
- Calculate the Closing Angle by comparing Planned Track against the Required Track.
- Calculate the Total Correction required by adding TE to CA.

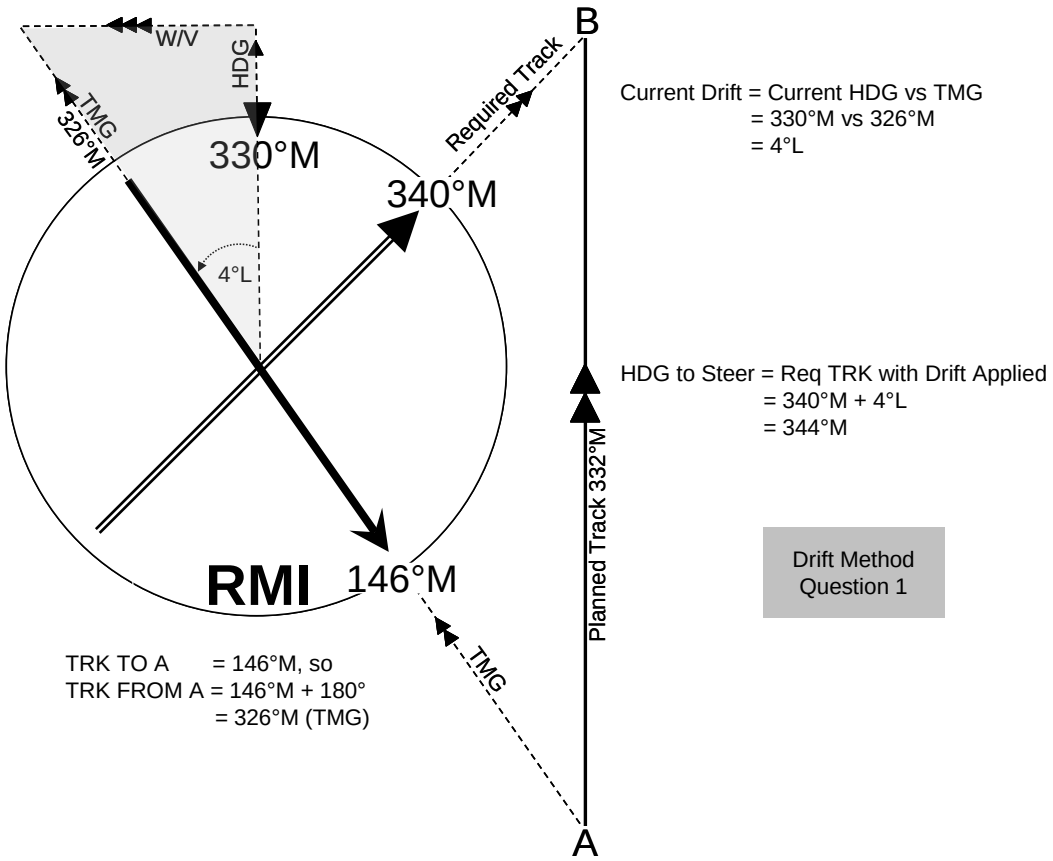
- Apply the Total Correction to the Current Heading. This will give the Required Heading to steer from the current position directly to the beacon ahead.
    - o When the aircraft is left of the Planned Track the Total Correction should be added to Current Heading to obtain the Required Heading.
    - o When the aircraft is right of the Planned Track the Total Correction should be subtracted from the Current Heading to obtain the Required Heading.

8.5.2.2 Question 1 – Drift Method on RMI

This method can be used to solve bearing questions on the RMI for any beacon type.

Variables Required:

- Two bearings on the RMI to/from the two beacons in the scenario.
- Planned Track between the two beacons **is not** required.
- Current Heading (usually kept constant since passing over the first beacon).



Steps to Solve:

- Find the current TMG by using the bearing information FROM the beacon behind the aircraft.

- Calculate the Current Drift by comparing Current Heading against TMG.
- Identify the Required Track TO the beacon ahead by using the TO bearing information on the RMI that relates to the upcoming beacon.
- Apply the Current Drift to the Required Track. This will give the Required Heading to steer from the current position directly to the beacon ahead.

Take Note:

- Current Drift is always between Current Heading & Current Track (TMG).
- Drift is always measured from the HDG vector to the TRK vector in terms of the Triangle of Velocities. This is how to tell is drift is left or right.
- When Drift is applied to TRK, the HDG so calculated must always counter the effects of the Drift so that the nose of the aircraft will point into the wind.

8.5.2.3 Question 4 – Finding Drift on RBI

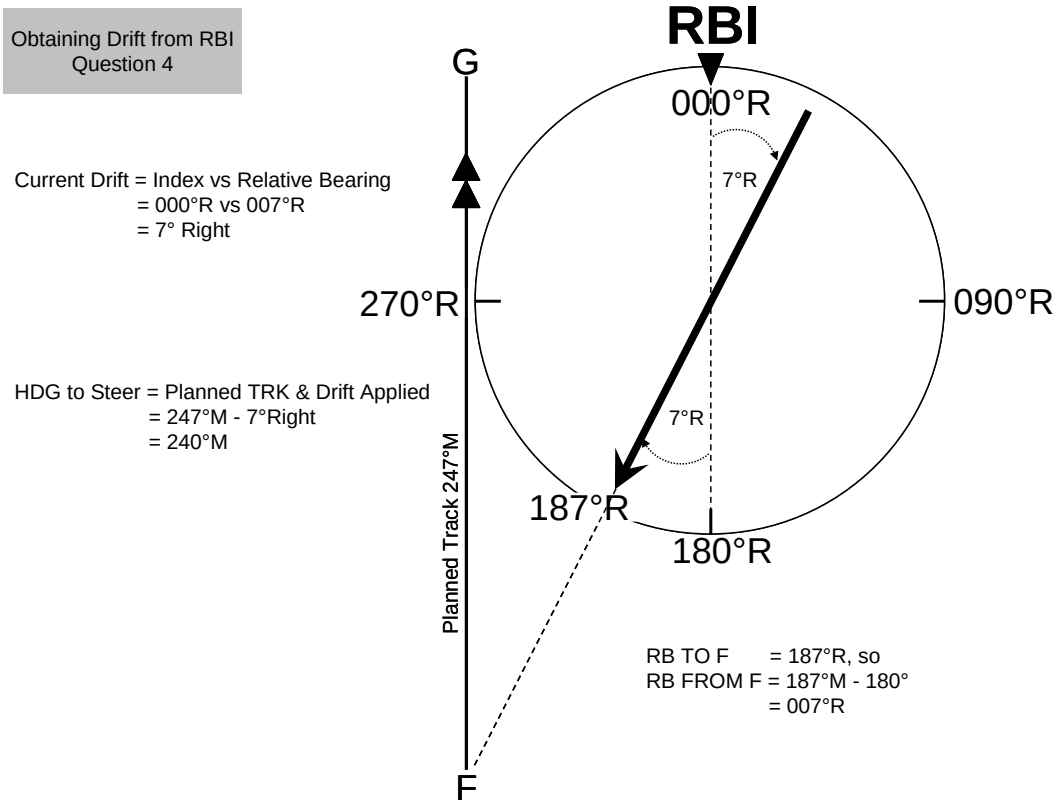
The procedure below is for finding the Current Drift from a RBI, when given a Relative Bearing to a beacon behind the aircraft. Once the Drift is obtained it can then be applied to resolve the scenario in terms of any Heading or Track requirements.

Variables Required:

- A Relative Bearing on the RBI/Fixed Card ADF to/from a beacon behind the aircraft together with **EITHER**:
- Planned Track between the two beacons, **OR**
- Current Heading (usually kept constant since passing over the first beacon).

Steps to solve:

- Calculate the Current Drift by using the top half of the instrument. The angle between the needle and the index is the amount of Drift and the side to which the needle is deflected represents the direction.
    - When the needle lies to the Right of the index, Drift is Right.
    - When the needle lies to the Left of the index, Drift is Left.
- Apply Drift:
    - Apply Drift to Required Track to get Required Heading to steer to destination.
    - Apply Drift to Planned Track to obtain the Required Heading to steer to parallel the Planned Track.
    - Apply Drift to Current Heading to obtain Current Track (TMG).



Take Note:

- Relative & Magnetic/True Bearings should not be resolved on the same indicator.
- For scenarios that give both Relative & Magnetic Bearing information, either use the Relative Bearing information to find Drift or convert the Relative Bearing into a True/Magnetic Bearing by using True/Magnetic Heading & resolve with the Drift method or TE & CA method (like on the RMI).

8.5.2.4 Question 17 – Finding Current Radial on OBI (TO Scenario)

The procedure below is for finding the Current Radial on the OBI when the Selected Track is TO the VOR.

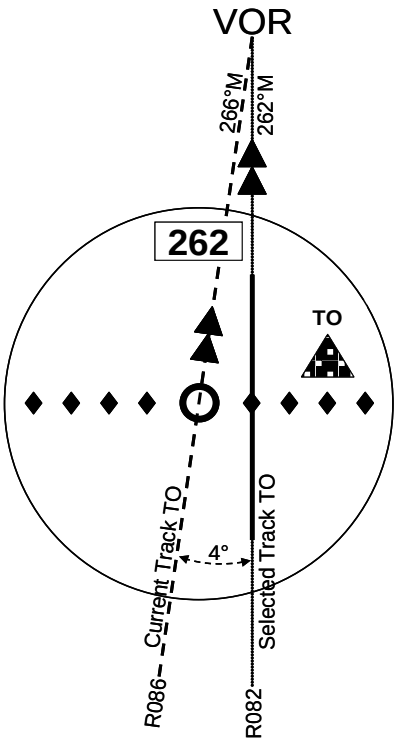
Variables Required: OBI displaying Selected Track, CDI bar showing position of Selected Track on a dot scale and a TO indicator.

Steps to Solve:

- Interpret the dot scale. A maximum of 10° deflection either side of the Selected Track can be shown on an OBI. Count the dots to assess how many degrees of deflection each dot represents. (5 dot scale means 2° per dot).
- Calculate the Angle Off the Selected Track.
    - o The position of the CDI bar relative to the centre dot gives the amount of degrees off the Selected Track.

- The CDI bar is a command instrument and tells the pilot which way to turn to intercept the Selected Track.

- Draw the Selected Track TO the VOR. A TO indication means the beacon is in front of the aircraft and the current Selected Track is a track that leads to the VOR.
- The reciprocal of the Selected Track is the Selected Track FROM the VOR, also called the Selected Radial.
- Apply Angle Off to the Selected Radial to find the aircraft's position (Current Radial). The centre dot is where the aircraft is and the CDI bar is the Selected Radial.



Finding Current Radial on OBI
(TO Scenario)
Question 17

5 dot scale, so 2° per dot

Selected TRK TO VOR = 262°M, so
Selected TRK FROM VOR = 262°M - 180°
= 082°M (R082)

CDI shows Fly 4° RIGHT to Selected Track, so
Aircraft is 4° LEFT of Selected Track
Current Radial = R082 + 4° = R086

If the TRK TO the VOR is Required:
Current TRK FROM VOR = 086°M (R086), so
Current TRK TO VOR = 086°M + 180°
= 266°M

Take Note:

- The reciprocal of the Current Radial is the Current Track TO the station.
- The Current Track TO the station is the TMG.

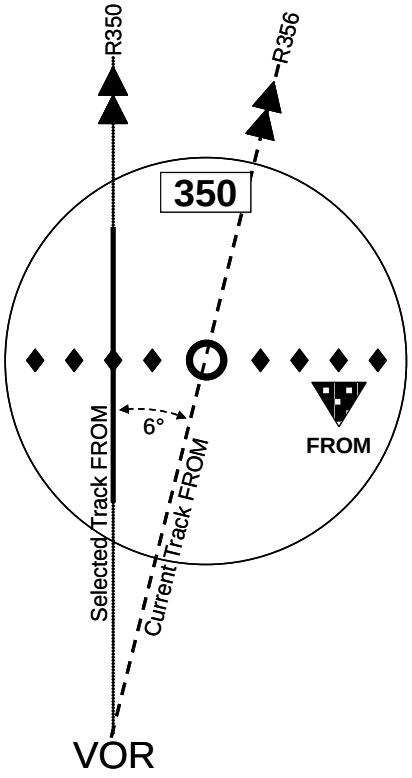
8.5.2.5 Question 18 – Finding Current Radial on OBI (FROM Scenario)

The procedure below is for finding the Current Radial on the OBI when the Selected Track is FROM the VOR.

Variables Required: OBI displaying Selected Track, CDI bar showing position of Selected Track on a dot scale and a FROM indicator.

Steps to Solve:

- Interpret the dot scale. A maximum of 10° deflection either side of the Selected Track can be shown on an OBI. Count the dots to assess how many degrees of deflection each dot represents. (5 dot scale means 2° per dot).
- Calculate the Angle Off the Selected Track.
  - The position of the CDI bar relative to the centre dot gives the amount of degrees off the Selected Track.
  - The CDI bar is a command instrument and tells the pilot which way to turn to reach the Selected Track.
- Draw the Selected Track FROM the VOR. A FROM indication means the beacon is behind the aircraft and the current Selected Track is a track that goes away from the VOR (Radial).
- Apply the Angle Off to the Selected Track to find the aircraft's position. The centre dot is where the aircraft is and the CDI bar is the Selected Track.



Finding Current Radial on OBI
(FROM Scenario)
Question 18

5 dot scale, so 2° per dot

CDI shows Fly 6° LEFT to Selected Track, so
Aircraft is 6° RIGHT of Selected Track
Current Radial = R350 + 6° = R356

If the TRK TO the VOR is Required:
Current TRK FROM VOR = 356°M (R356), so
Current TRK TO VOR = 356°M - 180°
= 176°M

Take Note:

- The current radial the aircraft is on represents the TMG of the aircraft.
- The reciprocal of the current radial is the current track/bearing TO the station.