

Attitude Instrument Flying

Attitude Instrument Flying

Review of Fundamentals, Techniques, and Practical Examples

What is Attitude Instrument Flying (AIF)?

- Primary method of aircraft control using the attitude indicator.
- Used when outside visual references are unavailable (IMC).
- Foundation skill for instrument rating.

Control and Performance Concept

- Pitch + Power = Performance
- Set attitude and power → cross-check instruments → adjust.
- Applies to all phases of IFR flight.

Primary Flight Instruments

- Attitude Indicator – Aircraft orientation
- Heading Indicator – Direction
- Airspeed Indicator – Speed
- Altimeter – Altitude
- VSI – Vertical trend
- Turn Coordinator – Rate of turn

Instrument Scan Techniques

- Radial Scan (hub-and-spoke)
- Rectangular Scan
- Primary/Supporting Method

- Goal: continuous, organized cross-check

Trim and Control

- Trim reduces workload
- Set attitude, then trim off control pressure
- Avoid overcontrolling
- Use small, smooth inputs

Example: Straight-and-Level Flight

- Set cruise power
- Adjust pitch to maintain altitude
- Cross-check: altimeter, VSI, airspeed
- Trim to relieve pressure

Example: Standard Rate Turn

- Bank to achieve standard rate ($\sim 3^\circ/\text{sec}$)
- Use turn coordinator and heading indicator
- Maintain altitude with slight back pressure
- Roll out $\frac{1}{2}$ bank angle before desired heading

Example: Constant Airspeed Climb

- Set climb power
- Pitch for target airspeed
- Cross-check airspeed + VSI
- Maintain heading with rudder/aileron

Example: Constant Rate Descent

- Reduce power
- Pitch for desired descent rate
- Cross-check VSI and airspeed
- Adjust power to maintain speed

Common Errors

- Fixation on one instrument
- Omission of key instruments
- Overcontrolling
- Failure to trim
- Poor scan discipline

Practical IFR Tips

- Stay ahead of the aircraft
- Anticipate changes (power, configuration)
- Verbalize pitch + power settings during training
- Trim the aircraft (continuously, as needed)
- Use checklists consistently

Summary

- Attitude Instrument Flying is the foundation of IFR flying
- Pitch + Power = Performance
- Effective scan + smooth control = precision

- Trim – Trim – Trim!
- Practice builds proficiency and confidence

Attitude Instrument Flight - Fundamental skills

- 3 steps
 - Instrument cross-check
 - Develop a systematic method of scanning the instruments
 - Frequent errors: fixation, omission, and emphasis
 - Instrument interpretation
 - What is the airplane actually doing, according to my instruments?
 - Aircraft control
 - Adjustments of pitch, bank, and power to achieve a desired flight path

“Control and Performance” concept

- Control and Performance concept
 - Instruments can be grouped into “control”, “performance”, and “navigation” categories.
 - Basic idea: Establish specific aircraft attitude and power using the control instruments and the airplane will perform as expected
- Steps:
 - Establish attitude and/or power setting that will result in desired performance.
 - Trim to relieve control pressures.
 - Cross-check instruments to determine if attitude/power combination is yielding desired performance.
 - Adjust power and/or attitude if correction is necessary.

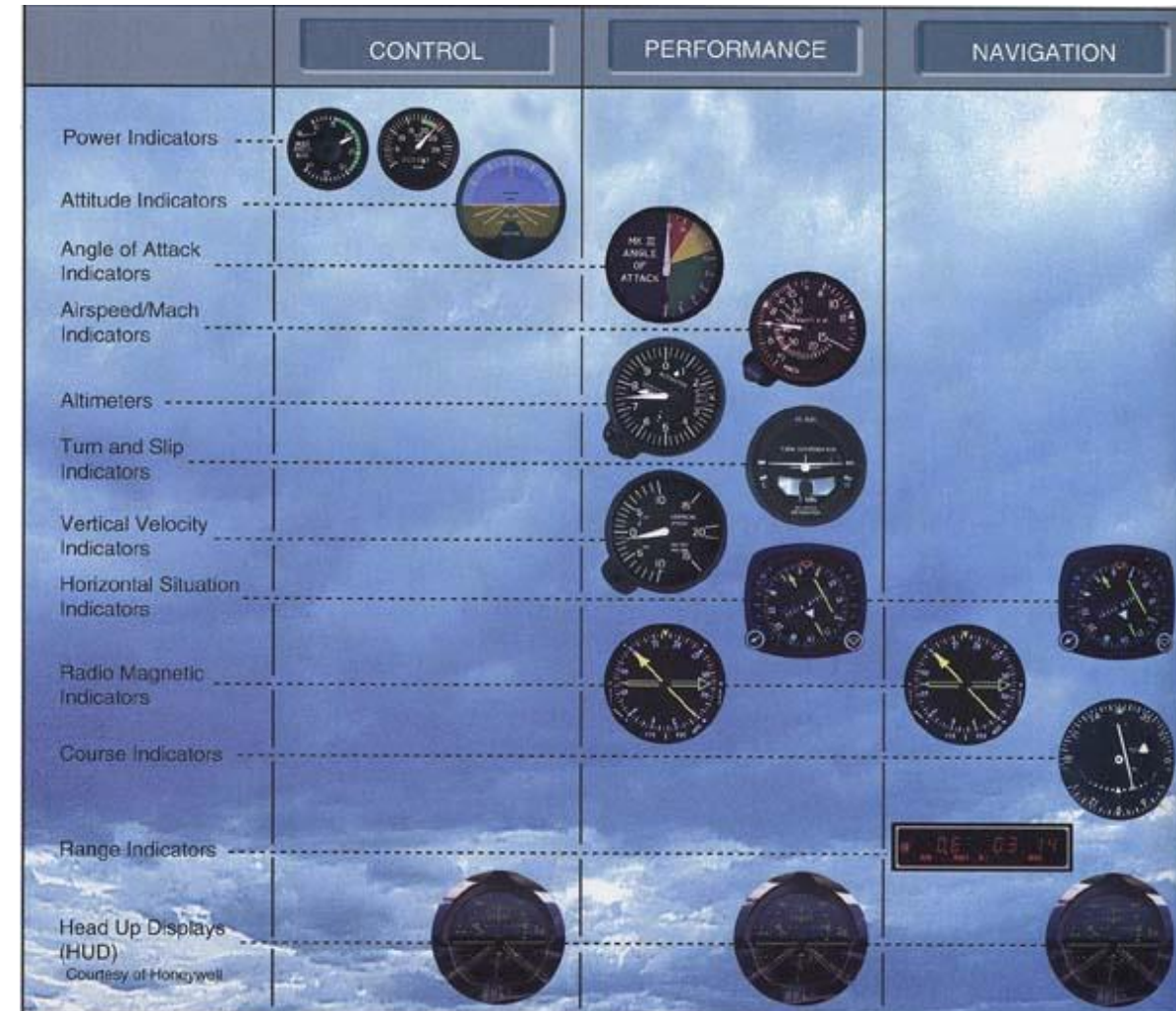


Figure 2-52. Control instruments directly indicate pitch and power. Performance instruments indicate how the aircraft responds to changes in pitch and power. Navigation instruments (discussed in Section C of this chapter) indicate the position of the aircraft relative to a facility or fix.

Instrument categorization and scanning technique (control and performance)

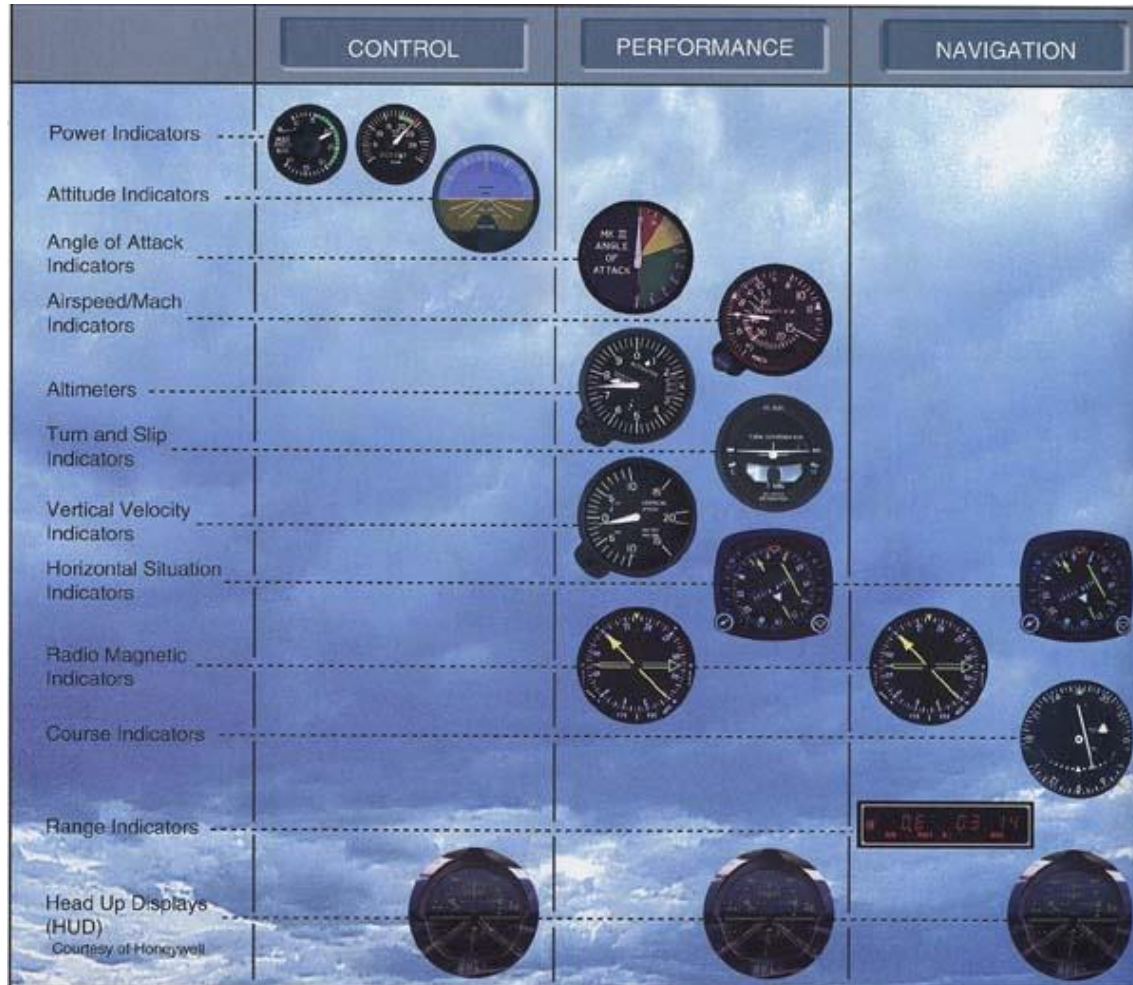


Figure 2-52. Control instruments directly indicate pitch and power. Performance instruments indicate how the aircraft responds to changes in pitch and power. Navigation instruments (dis-



Scan technique based on attitude indicator

“Primary/Support” concept

- Concept divides instruments into “primary” and “supporting” instruments, as opposed to “control,” “performance,” and “navigation” instruments.
 - “Primary” instruments provide essential information for a given flight maneuver.
 - “Secondary” instruments help you maintain the desired indications on the primary instruments.
 - An given instrument may be a primary or secondary instrument depending on the maneuver.
 - Less emphasis on attitude indicator – this method provides a way to control the airplane if the attitude indicator fails.

Primary/support instrument chart

Maneuver	Primary			Supporting		
	Pitch	Bank	Power	Pitch	Bank	Power
Straight and Level	Altimeter	Heading Indicator	Airspeed Indicator	Vertical Speed Indicator, Attitude Indicator	Turn Coordinator Attitude Indicator	Tach or MP
Standard-Rate Turn Establishing	Altimeter	Attitude Indicator then Turn Coordinator	Airspeed Indicator	Attitude Indicator Vertical Speed Indicator	Turn Coordinator, Attitude Indicator	Tach or MP
Standard-Rate Turn Turning	Altimeter	Turn Coordinator	Airspeed Indicator	Vertical Speed Indicator Attitude Indicator	Turn Coordinator, Attitude Indicator	Tach or MP
Constant Speed Climb or Descent Entry	Attitude Indicator	Heading Indicator	Tach or MP	Vertical Speed Indicator	Turn Coordinator Attitude Indicator	Airspeed Indicator
Constant Speed Climb or Descent Stabilized	Airspeed Indicator	Heading Indicator	Tach or MP	Vertical Speed Indicator	Turn Coordinator Attitude Indicator	Airspeed Indicator
Constant Rate Climb or Descent Entry	Attitude Indicator	Heading Indicator	Tach or MP	Vertical Speed Indicator	Turn Coordinator Attitude Indicator	Airspeed Indicator
Constant Rate Climb or Descent Stabilized	Vertical Speed Indicator	Heading Indicator	Airspeed Indicator	Attitude Indicator	Turn Coordinator Attitude Indicator	Tach or MP
Changing Airspeed In Turns	Altimeter	Turn Coordinator	Tach or MP, then Airspeed Indicator	Vertical Speed Indicator, Attitude Indicator	Attitude Indicator	

Some useful rules of thumb

- Pitch control
 - Use half bar width for less than 100' deviation from desired altitude
 - Correct back at twice the rate of the deviation.
 - Use full bar width for greater than 100' deviation from desired altitude
- Bank control
 - Correct a heading deviation with an angle of bank equal to heading deviation or standard rate turn, whichever is less.
- Standard-rate turns
 - $(KTAS/100 + 5)^\circ \approx$ bank angle required for standard rate turn.
 - Start rollout when about half the bank angle prior to reaching the desired heading.

Climbs and descents

- Climbs
 - Procedure: simultaneously apply climb power and smoothly apply back pressure
 - Constant airspeed climb
 - Objective: maintain a particular airspeed for a given climb power setting
 - Once established, airspeed indicator is the primary pitch instrument, and the heading indicator is the primary bank instrument.
 - Constant rate climb
 - Objective: maintain a particular rate of climb for a given climb power setting
 - Once established, the VSI is the primary pitch instrument, airspeed indicator is the primary power instrument, and the heading indicator is the primary bank instrument.
- Descents
 - Constant airspeed descent
 - Typically utilized during the “cruise” portion of a descent. Reduce power to the recommended setting, pitch down about one bar width on the attitude indicator to maintain airspeed and accept the resulting rate of descent.
 - Constant rate descent
 - Typically utilized during an instrument approach where controlling descent rate is critical.
 - Once established, the VSI is the primary pitch instrument, the airspeed indicator is the primary power instrument, and the heading indicator is the primary bank instrument.
- Level-off: typically, level off within 10% of climb or descent rate.

Instrument failures



1. Look for an instrument that gives conflicting information compared to other instruments.
2. Know your systems – the attitude indicator and heading indicator are usually vacuum driven while the turn coordinator is usually electrically powered.
3. Vacuum system failure: pitch can be inferred from airspeed and altimeter; turn coordinator supplies bank information. Use timed turns with magnetic compass to fly desired headings.
4. Inform ATC of any instrument failures even if aircraft control is not immediately threatened.

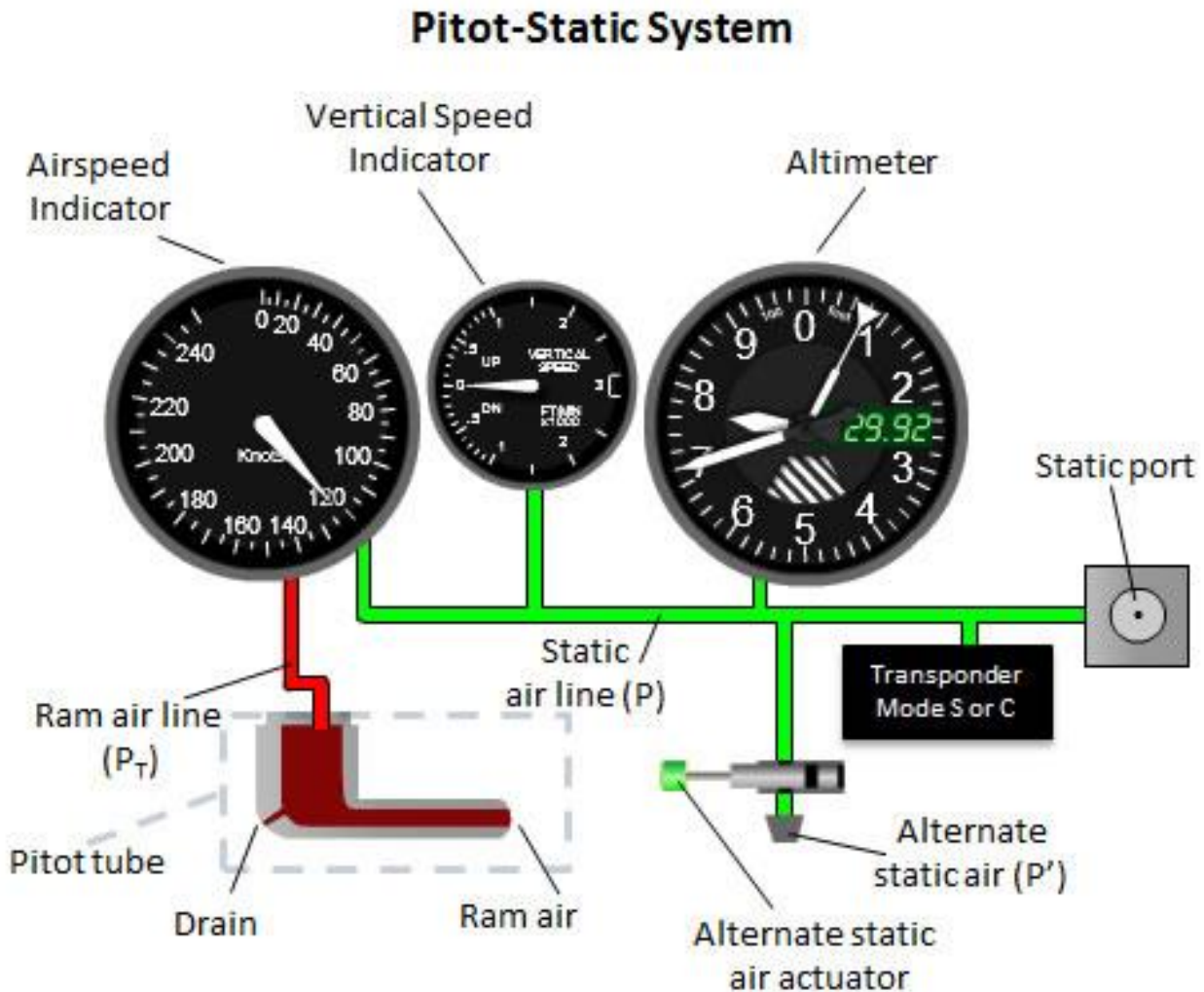
Partial panel flying




- Straight and level flight
 - Altimeter is primary pitch instrument with VSI supporting
 - Maintain constant heading with turn coordinator and magnetic compass
 - Beware of “compass dip” effects; do not “chase” the magnetic compass and rely on readings only after establishing straight and level, unaccelerated flight.
 - Amount of turning error on northerly (lag) and southerly headings (lead) is approximately the same as aircraft latitude.
- Turns and timed turns
 - Utilize turn coordinator to establish constant rate turns.
 - Use the clock, turn coordinator, and knowledge of initial heading to establish a desired heading
 - Example: Current heading is 150. You wish to turn right to a heading of 180. Promptly establish a standard rate ($3^{\circ}/\text{second}$) right hand turn. Promptly roll out after 10 seconds $((180 - 150)/3)$ have elapsed. Check result on magnetic compass after several seconds of straight and level, unaccelerated flight.

Partial panel flying, cont'd

- Climbs and descents
 - Rely on altimeter, VSI, and airspeed indicator to control pitch.
 - Do not fixate on power instruments.
- Pitot-static instrument failures
 - Affected instruments: airspeed indicator, altimeter, and VSI
 - Number of instruments affected and the manner in which they are affected depends on what portion of the static-pitot system is blocked.

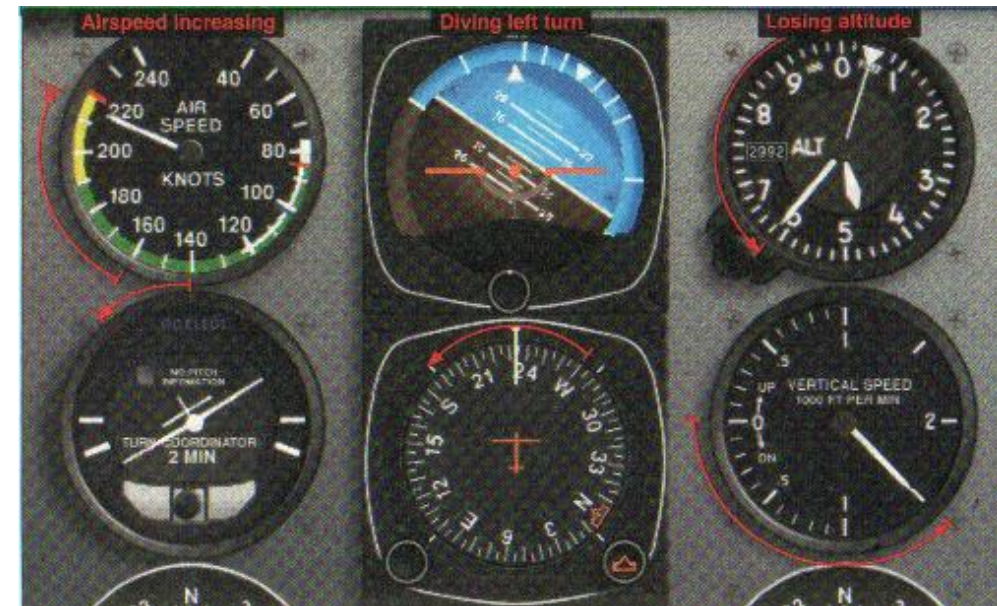
Static-pitot failures, cont'd



	 Indicated Airspeed	 Indicated Altitude	 Indicated Vertical Speed
Pitot Ram Air Source and Drain Hole Blocked	Increases with altitude gain; decreases with altitude loss	Unaffected	Unaffected
Pitot Ram Air Source Blocked and Drain Hole Open	Displays zero knots	Unaffected	Unaffected
Static Source Blocked	Decreases with altitude gain; increases with altitude loss	Does not change with altitude gain or loss	Does not change with vertical speed changes
Both Static and Pitot Sources Blocked	All indications remain constant, regardless of changes in airspeed, altitude, and vertical speed.		

Unusual attitude recovery

- Causes: failure of attitude indicator, disorientation, wake turbulence, lapse of attention, or abnormal trim.
- Two basic types that are demonstrated and practiced: nose-high climbing turn, and nose-low spiraling descent
 - **Nose-high indications:** airspeed dropping rapidly, rapid altitude increase, high rate of climb, and nose high attitude indication.
 - Nose high recovery: Add power, lower nose to level flight attitude, and roll out of bank with coordinated aileron and rudder.
 - **Nose-low indications:** airspeed increasing rapidly, rapid altitude loss, high rate of descent, and nose low attitude indication.
 - Nose low recovery: Reduce power, roll out of bank with coordinated aileron and rudder, and gradually raise nose to level flight attitude.

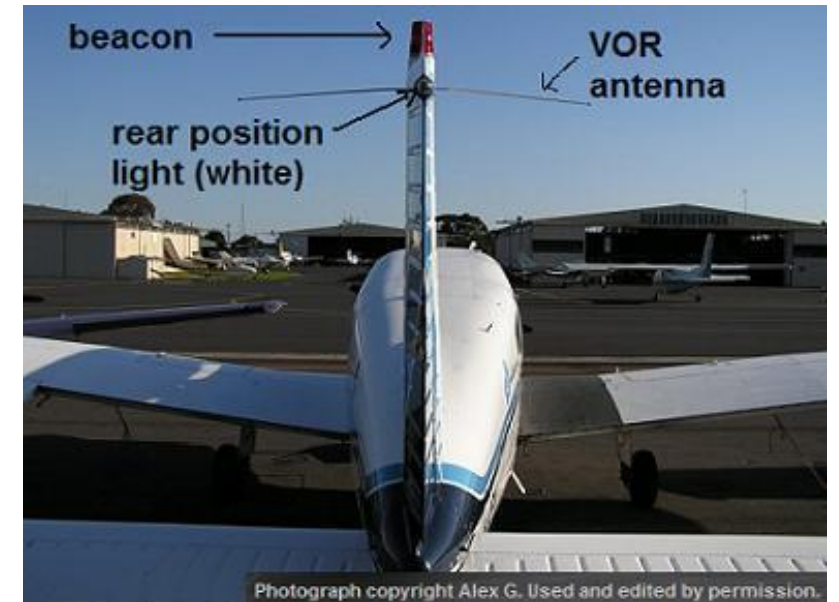


Partial panel unusual attitude recovery

- Use turn coordinator to stop turn
- Infer pitch from airspeed indicator, altimeter, and VSI
 - Aircraft is passing through level flight attitude when airspeed indicator and altimeter stop and reverse their previous trend and VSI starts moving back toward zero.

Instrument Navigation

VOR (VHF Omnidirectional Range) components



Horizontal Situation Indicator



1. HSI can not “reverse sense” except when tuned to a localizer
2. Selected course and how it’s oriented to the airplane is graphically obvious – it’s no longer necessary to “mentally rotate” the airplane to a heading that agrees with the selected course to get the “sensing” correct.
3. Functions of heading indicator and conventional VOR indicator are combined into one display
4. Each dot represents a 2 degree angular displacement from the radial – for localizers, each dot is one half of a degree of displacement.
5. Actual displacement from radial is approximately 200 feet per NM range from VOR per dot of CDI deflection

Garmin G1000 PFD



Questions

- How many dots is a “half-scale” deflection of the CDI? How many degrees angular displacement does this represent?
- An airplane’s CDI is showing 2 dots deviation from center and the airplane is located 15 NM from the VOR. What is the absolute deviation from the radial?
- An airplane’s CDI is showing 1 dot deviation and is located 2 NM from the localizer. What is the absolute deviation from the radial?
- An airplane’s CDI is showing 2 and a half dots displacement when connected to an IFR approved GPS and while flying on the final approach segment of an RNAV/GPS approach. What is the absolute deviation from the radial?

HSI interpretation – match the aircraft position with the HSI presentation

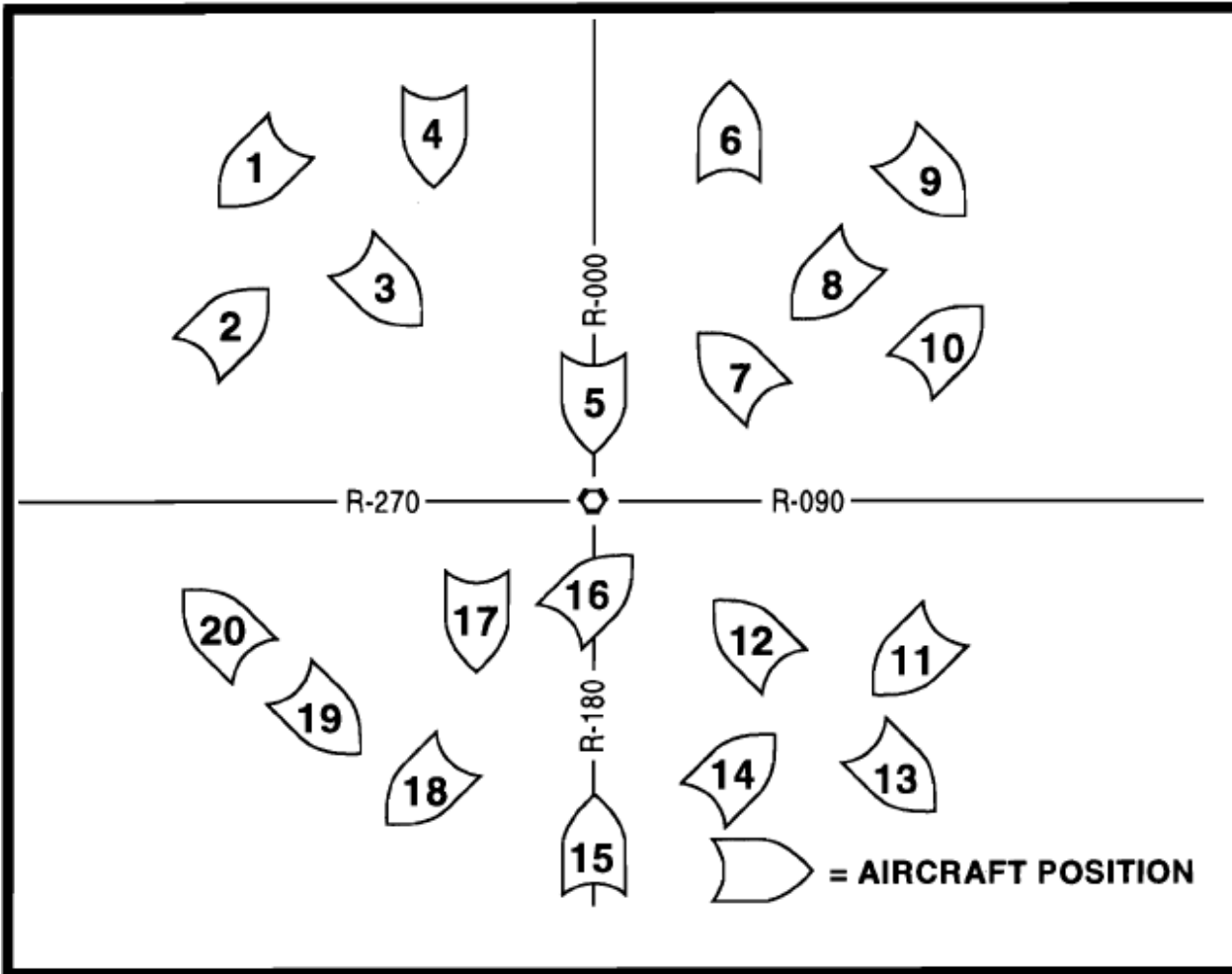


FIGURE 98.—Aircraft Position.

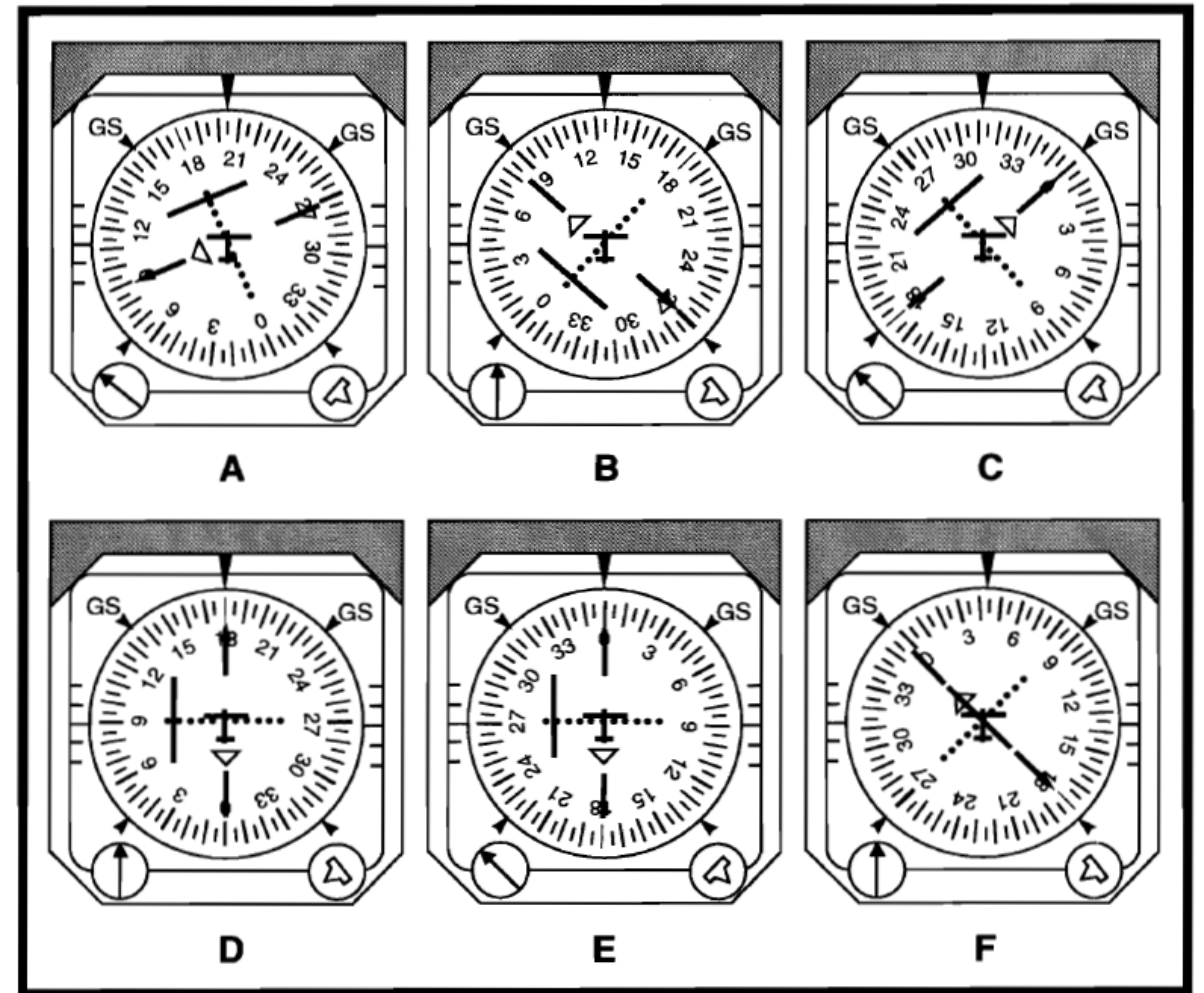
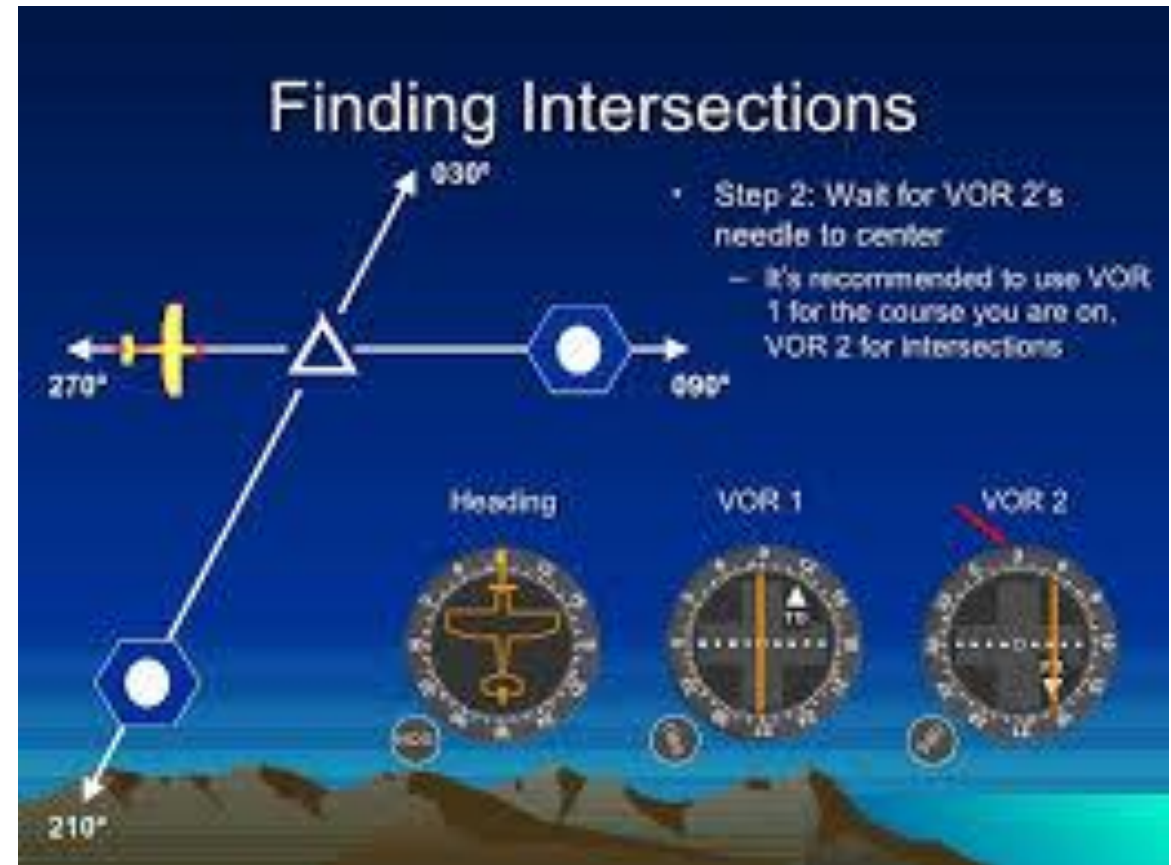
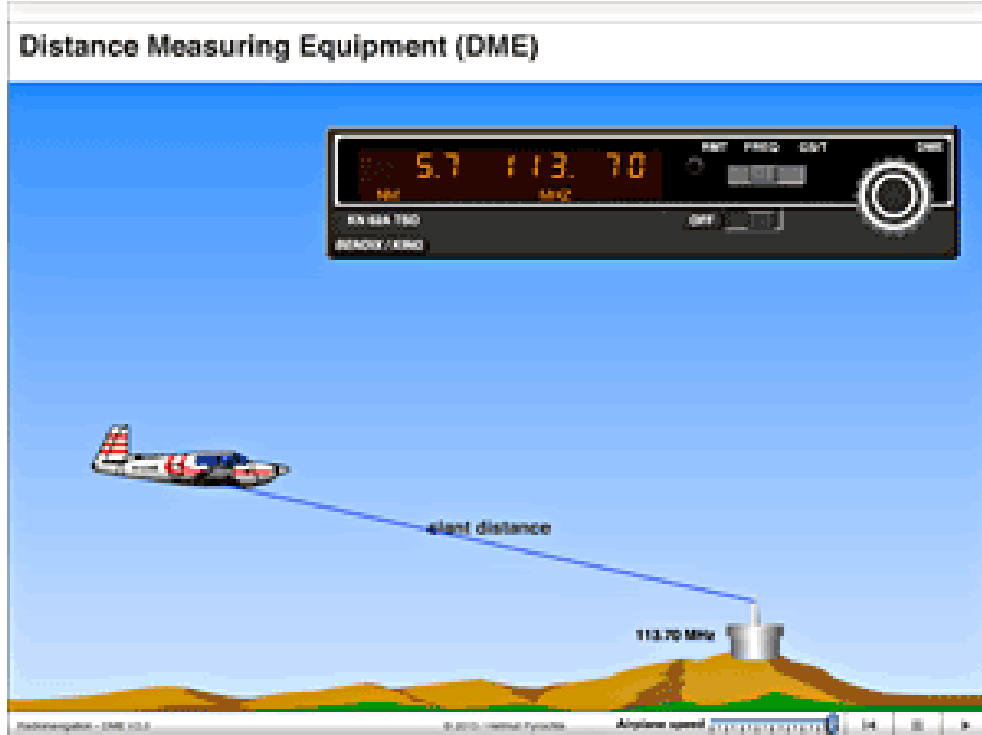
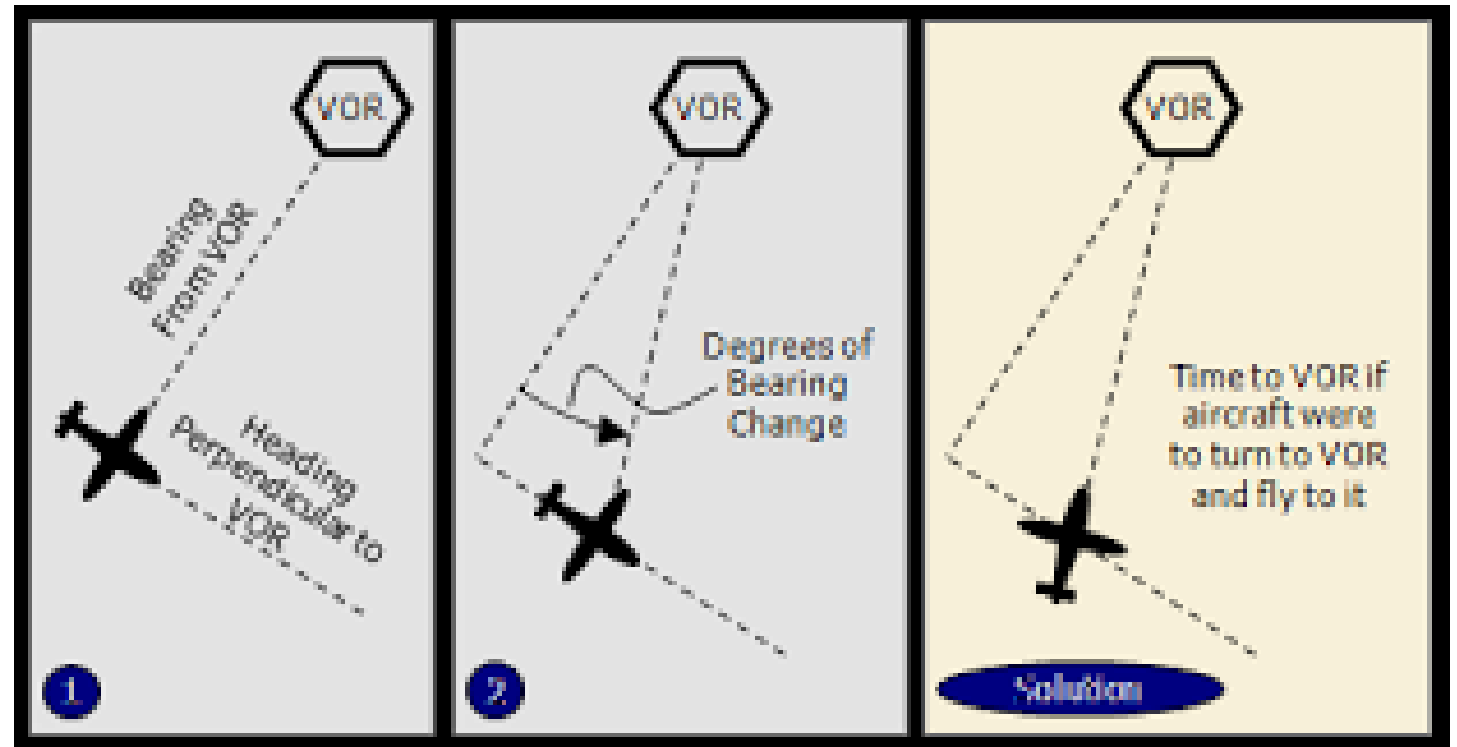


FIGURE 99.—HSI Presentation.

Determining progress using VORs



Time and distance to station



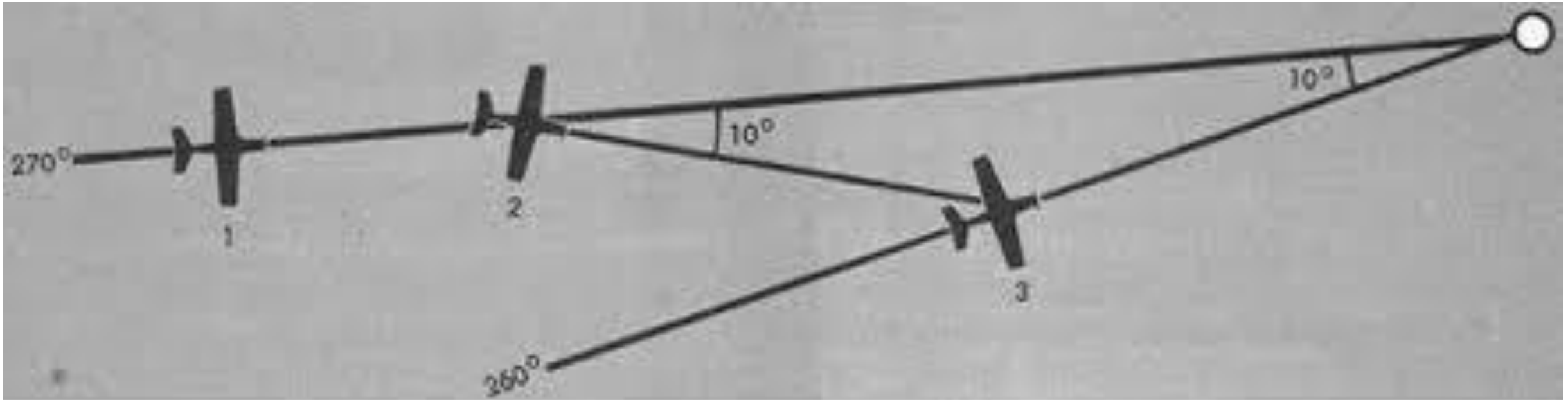
$$\text{Time to station} = \frac{60 \times \text{minutes flown between bearing change}}{\text{Degrees between bearings}}$$

$$\text{Distance to station} = \frac{\text{TAS} \times \text{minutes flown}}{\text{Degrees between bearings}}$$

Question

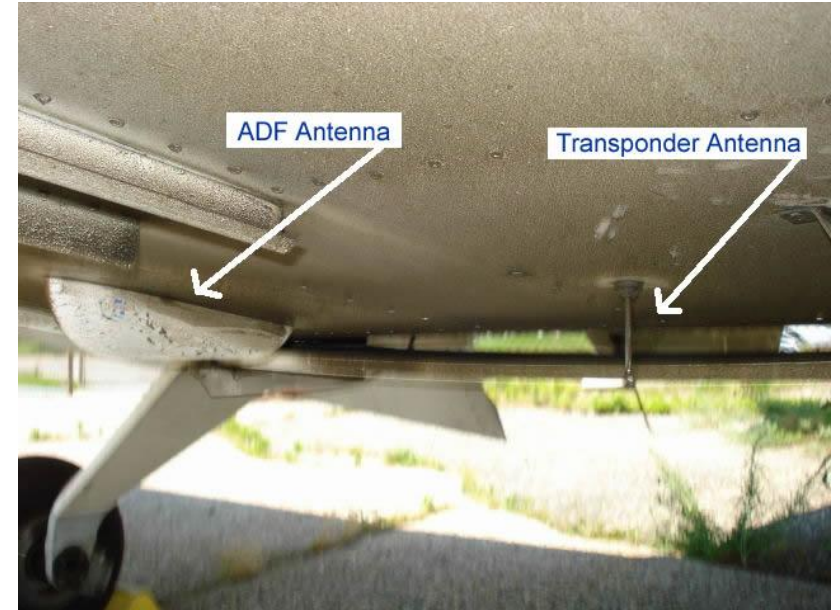
- It takes 1 minute to fly from the 090° radial to the 080° radial on a perpendicular course. How long will it take to arrive at the VORTAC when you intercept the 070° radial and fly direct to the station at the present speed assuming no wind? If your speed is 100 KTAS, what is the distance to the station?

Isosceles triangle method



1. Turn away from the course 10 degrees (or any known angle).
2. Twist course selector on HSI or VOR the same amount in the opposite direction.
3. Note the time it takes for the CDI to center on the new course.
4. Time to station is the same time as it took for the CDI to center.

ADF navigation - components



Automatic Direction Finder (ADF) concepts

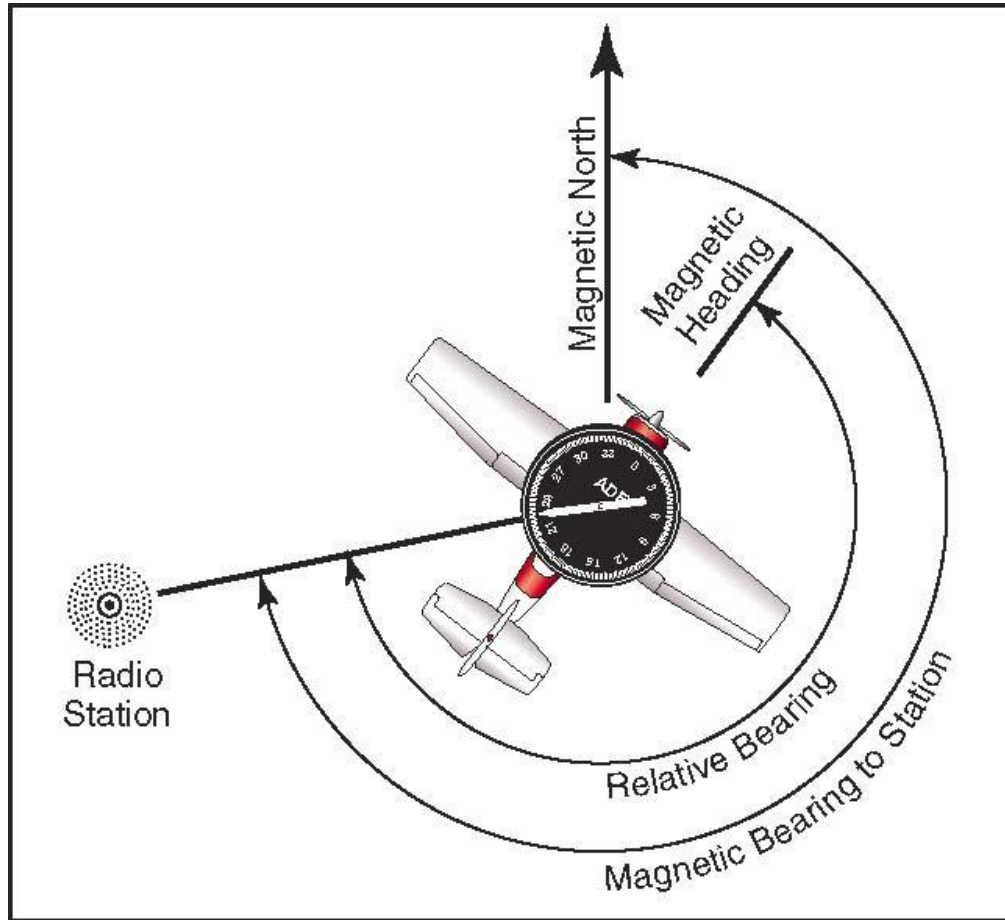


Figure 14-32. ADF terms.

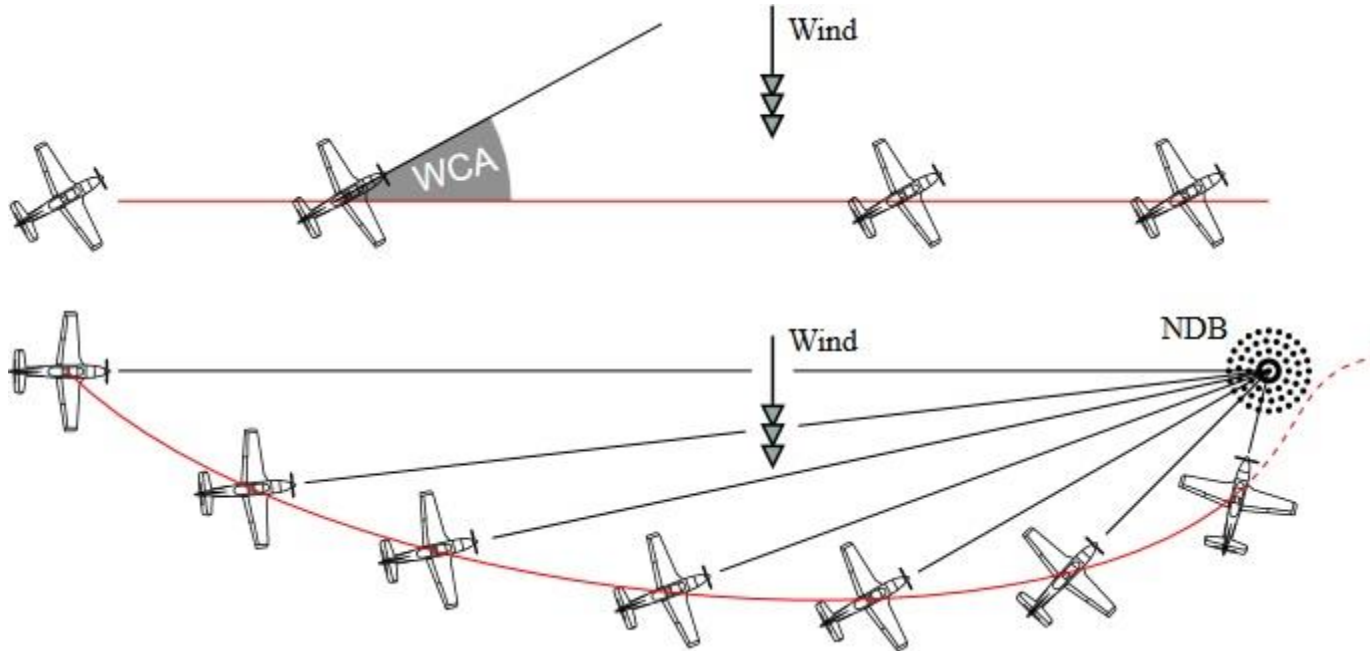
1. Needle indication is a function of aircraft heading (unlike VOR)
2. Thunderstorms and other electrical phenomena can interfere with NDB reception (unlike VOR)
3. $MB = MH + RB$
4. Some ADF indicators have fixed cards and others have movable cards. If the movable card is set to the current magnetic heading, then magnetic bearing to the station can be read directly from the display.
5. There is no "off" flag on the face of the ADF display (unlike VOR).

Radio Magnetic Indicator (RMI)



1. Combines functions of heading indicator and bearing information from two navigational sources.
2. Magnetic heading is obtained from a magnetic flux detector - it does not have to be set to the magnetic compass manually (unlike the HSI).
3. Toggle switches can select which navigation source to use.

Tracking an NDB



NDB Navigation Techniques

- Tracking:

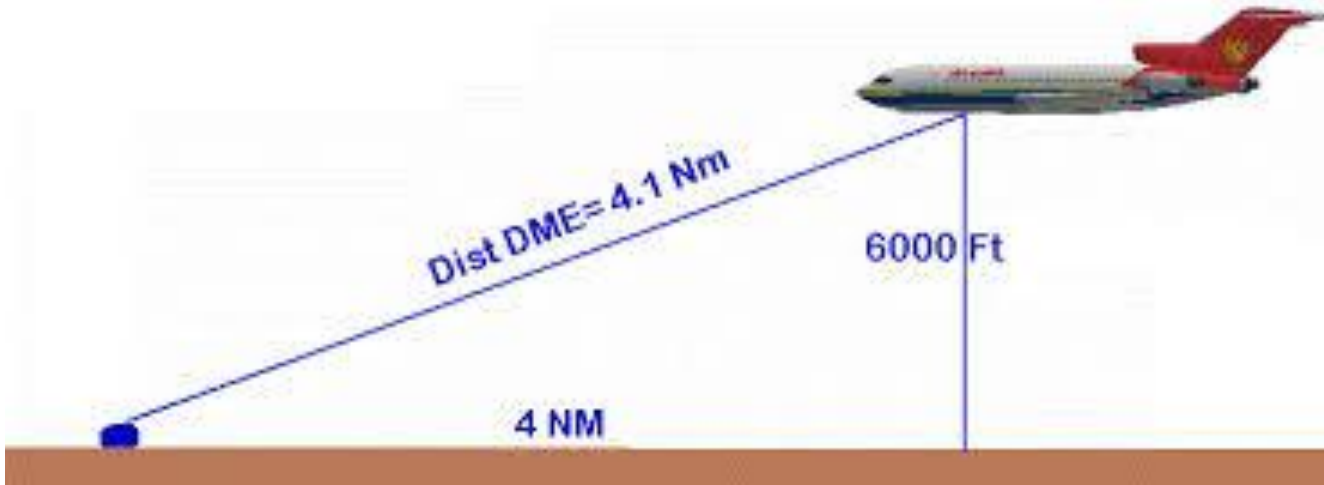
- Establishing a wind correction angle that negates the drift caused by the crosswind
- Principle: WHEN THE ANGLE OF DEFLECTION = THE ANGLE OF INTERCEPTION YOU'RE ON COURSE
- Or: when the angle formed by the aircraft heading and the desired course is the same as the angle between either the 0 or 180 mark on the indicator and the pointer, the aircraft is on course.

1. Select a heading that you think will give you the desired course.
2. If the ADF needle remains stationary, then you are tracking a course directly to or from the station.
3. If the needle moves left or right, then turn toward the needle double the amount of the relative bearing.
4. Hold the new heading until the relative bearing equals the course correction.
5. Turn back toward the station and establish a wind correction angle that gives a constant relative bearing to the station.
6. Station passage occurs when needle points to a wingtip or rotates near the 180 relative bearing position.

Questions

- Select the true statement regarding an RMI?
 - You must constantly adjust the RMI compass card to match your magnetic heading.
 - The number of under the head of the bearing pointer is the magnetic bearing from the station.
 - Relative bearing is the angle between the head of the bearing pointer and the aircraft heading index.
- When you are tracking outbound from an NDB with the proper drift correction established, which direction will the head of the ADF bearing pointer be deflected?
 - To the windward side of the aircraft's tail.
 - To the downwind side of the aircraft's tail.
 - To the downwind side of the aircraft's nose.
- What ADF or RMI indication would you expect when tracking on a bearing toward an NDB with a 10° left wind correction?
 - 0° relative bearing
 - 10° left of the aircraft's nose
 - 10° right of the aircraft's nose

Distance measuring equipment (DME)



1. Slant range will be very close to horizontal range if horizontal range is at least 1 NM for every 1000 ft of altitude above the station.

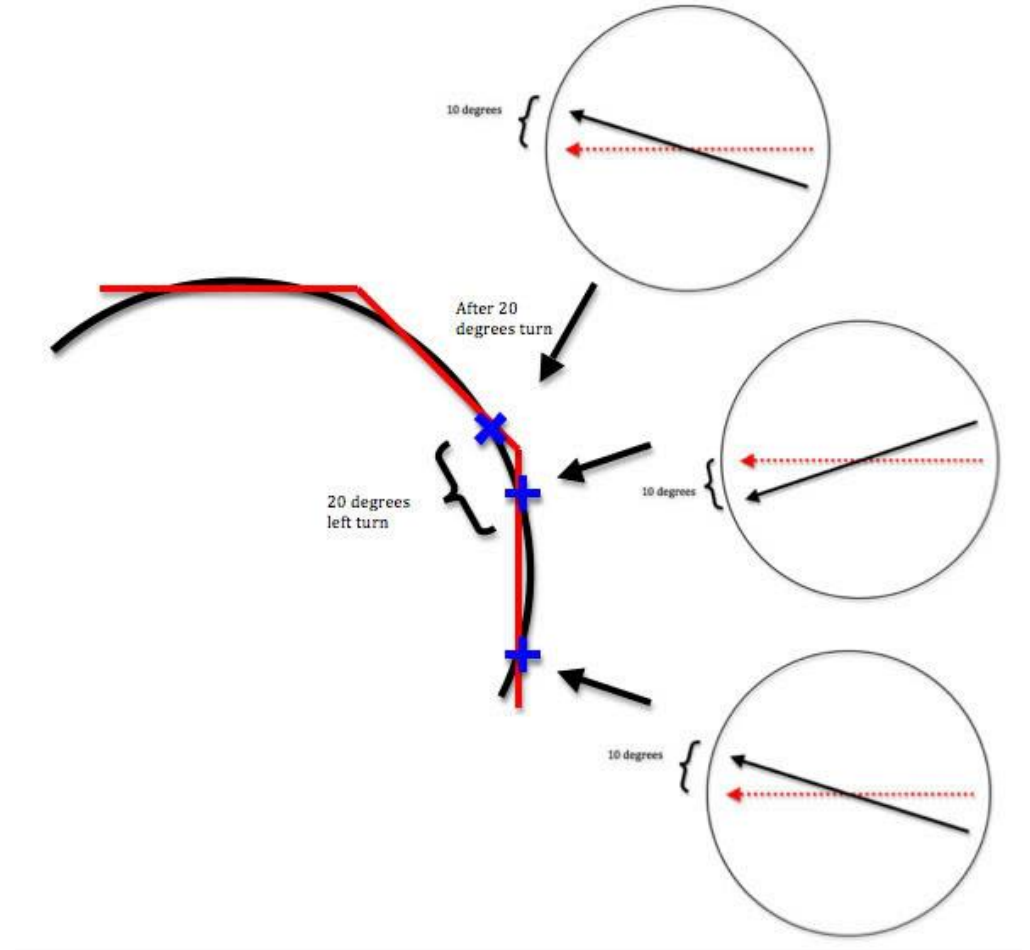
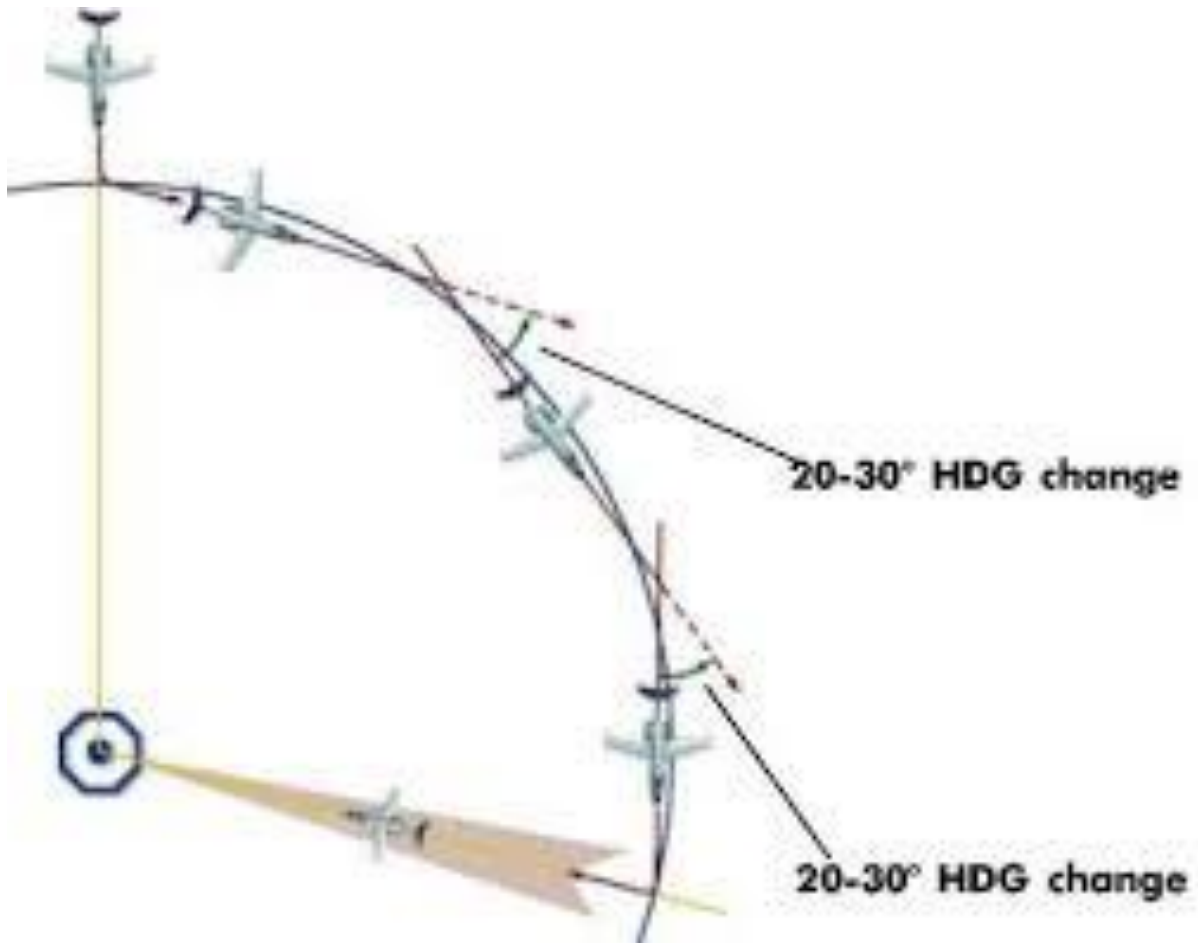


Distance and frequency readout



Distance, groundspeed, and estimated time enroute to station readout

DME arcs



Flying a DME arc with an RMI

DME arcs using VORs

Fly inbound on the 340 radial

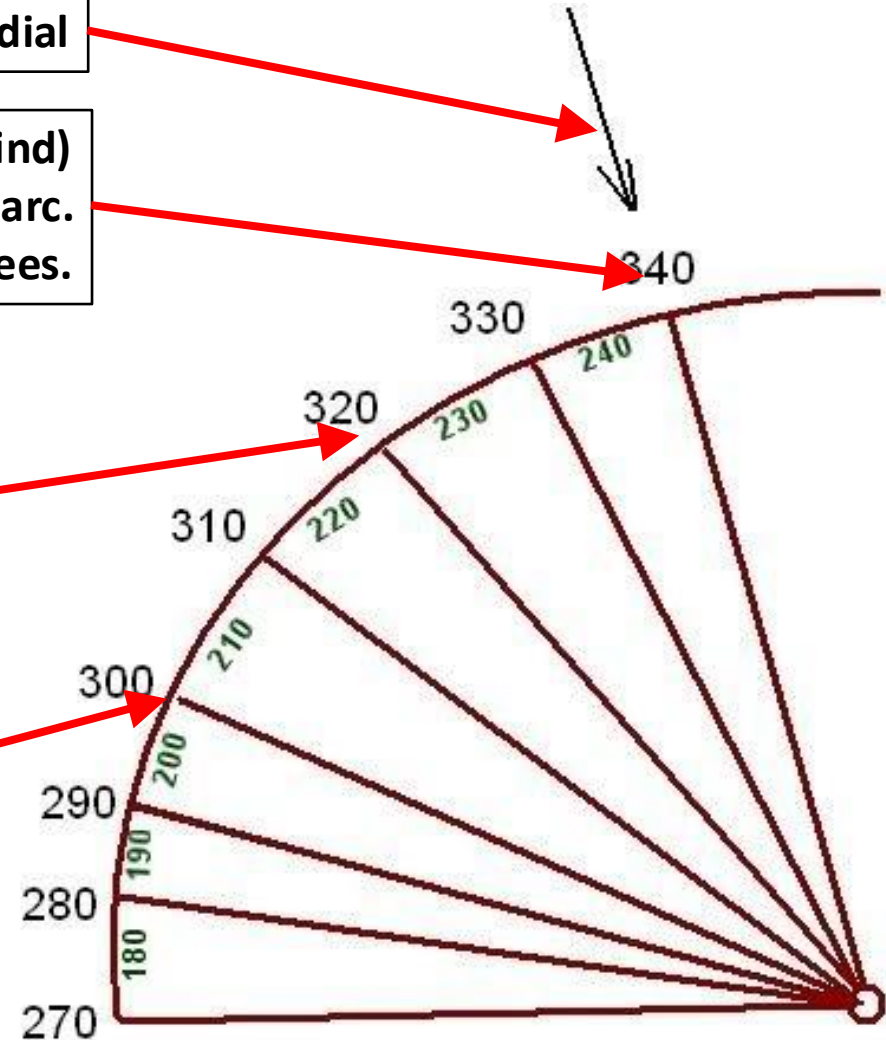
Turn right to a heading of 240 (zero wind)
approximately 0.5 NM before reaching the arc.
Set OBS to 320 degrees.

Fly constant heading until CDI centers.

Set OBS to 300 degrees.
Turn to a heading of 220 degrees.

Fly constant heading until CDI centers.

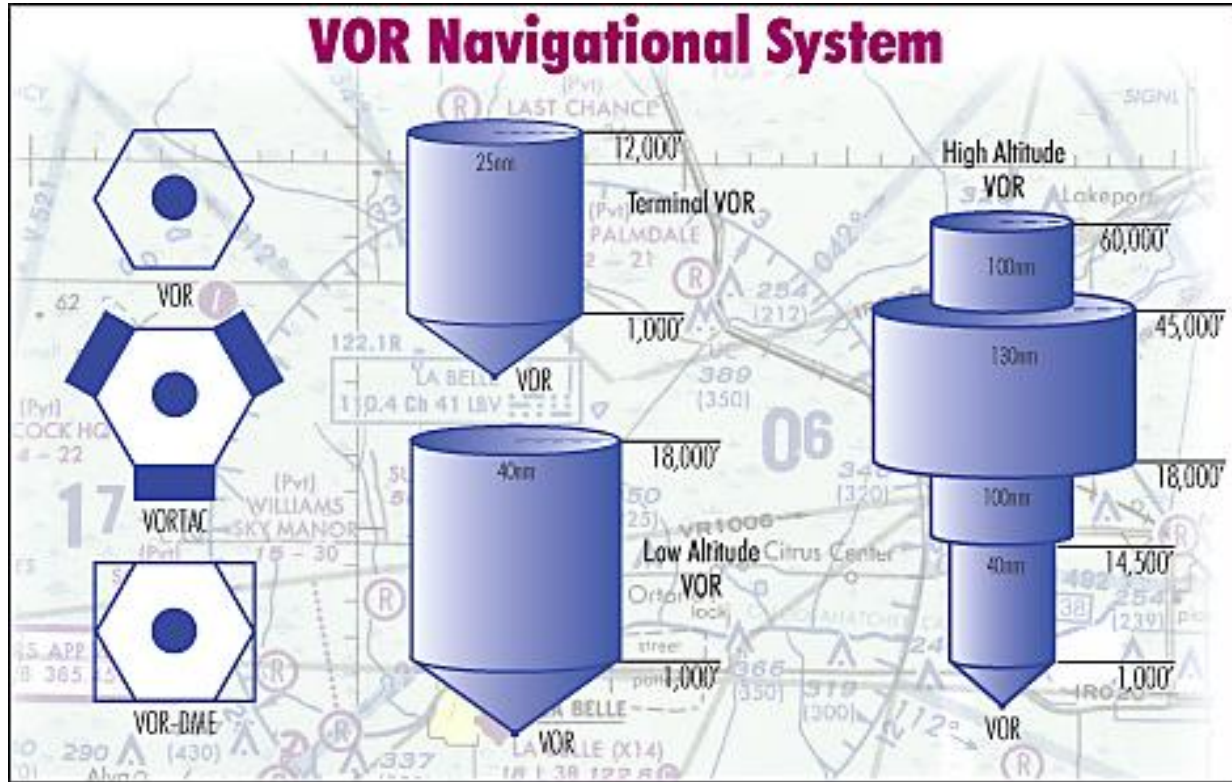
Set OBS to 280 degrees.
Turn to a heading of 200 degrees.



Question

- True or false: Normally, when flying a DME arc, the bearing pointer reaches the wingtip position when the airplane is slightly outside the arc.

Types of VORs and VOR checks



1. VORs must be checked within the past 30 days to use it under IFR. There are 3 ways to do this:
 - a) VOR Test Facility (VOT): Broadcasts only the 360° radial. May be used only on the ground or within designated airborne areas as the AFD notes. Tolerance is +/- 4° when OBS is set to 360 (FROM) or 180 (TO).
 - b) VOR checkpoints: Can be ground or airborne – check AFD to find the locations. Tolerance is +/- 4° for ground and +/- 6° for air.
 - c) Dual system check: Can be used anywhere where a VOR can be received as long as the two units are independent from each other except for the antennae. Tolerance is a maximum difference of 4°.

VOR identification

1. VORs:

- a) Tune nav receiver to appropriate frequency
- b) Select appropriate button on intercom panel so that you can hear transmissions on the VOR frequency
- c) Turn up volume and select "ident" feature on the nav radio to remove audio filter and permit hearing of the morse code identifier (1020 Hz).



DME identification

1. DMEs:

- a) Tune DME receiver to appropriate frequency
- b) Select appropriate button on intercom panel so that you can hear transmissions on the frequency
- c) Listen to the morse code identifier (1350 Hz). The identifier is at a slightly higher pitch than the VOR identifier and is transmitted at approximately 30 second intervals.



NDB identification

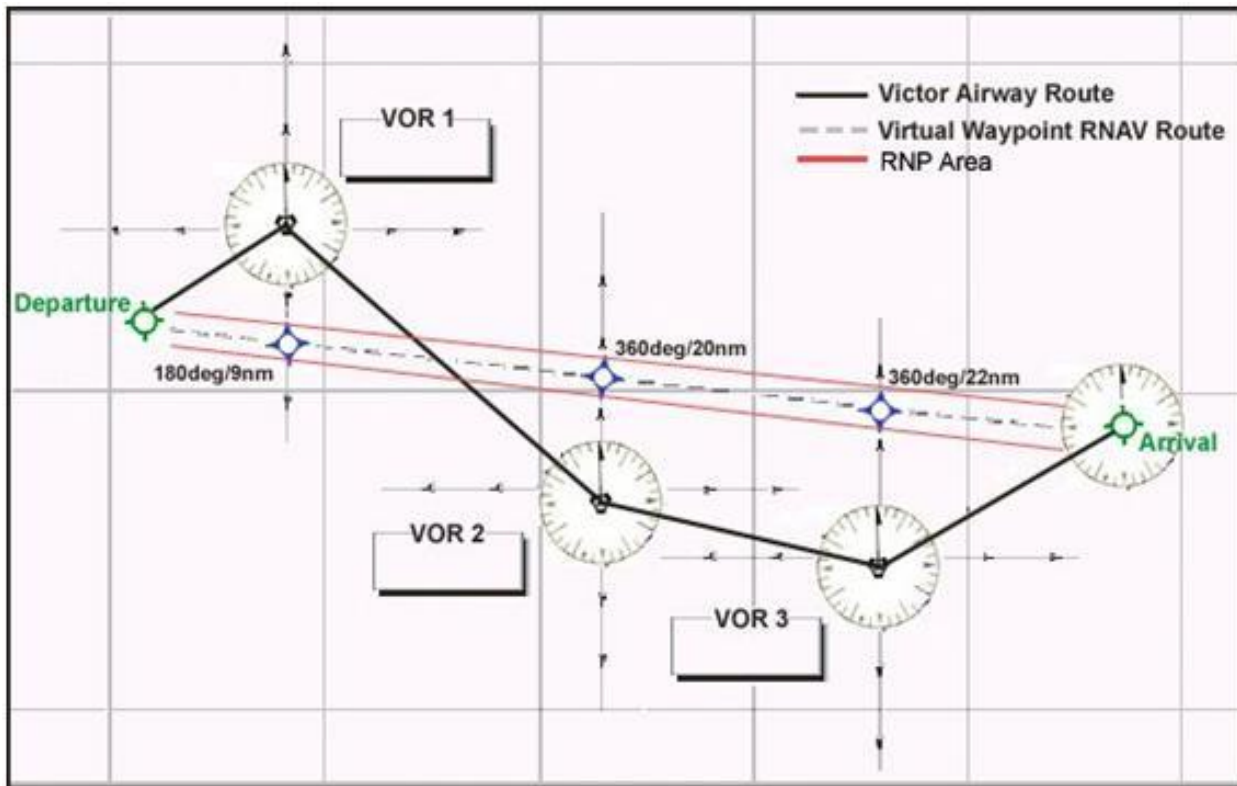
1. DMEs:

- Tune NDB receiver to appropriate frequency and turn up volume.
- Select appropriate button on intercom panel so that you can hear transmissions on the frequency
- Listen to the morse code identifier. Note that there is no "flag" on the indicator to visually alert the pilot of a failure.



Area navigation

1. Definition: Method of navigation that allows operations along any desired course within coverage of station-referenced signals or within the limits of self-contained system capability.
2. Major types:
 1. "VORTAC-based area navigation
 2. Inertial navigation system
 3. GPS



Global Positioning System (GPS)

1. Accuracy: 95% probability of horizontal accuracy within 33-66 feet, and 99.99% probability of accuracy within 98 feet.
2. Receiver Autonomous Integrity Monitoring (RAIM): Required for flying under IFR to assure that signal is reliable.
3. Regulatory requirements:
 - a) IFR certified receivers must be TSO-C129 compliant.
 - b) Wide Area Augmentation System (WAAS) certified receivers must be either TSO-C145A or TSO-C146A compliant.
 - c) Aircraft equipped with a non-WAAS receiver must have an alternate means of navigation suitable for the flight. "Active monitoring" of alternate means of navigation is required if RAIM is lost.
4. CDI deflection indicates absolute distance off course in NM, not angular displacement as a VOR CDI does.
 - a) Enroute, terminal and approach modes change the full scale deflection of the CDI.



An "INTEG" annunciation at the bottom left corner of the screen indicates that satellite coverage is insufficient to pass built-in receiver autonomous integrity monitoring (RAIM) tests. When this occurs, the GPS receiver will continue to provide navigation information, but should not be used for primary navigation guidance. Use the GNS 430W's VLOC receiver or another suitable navigation source.

Questions

- What is the maximum distance at which you can expect a reliable signal from a high altitude VOR? At what altitudes does this maximum range occur?
- True/false: The maximum allowable error on a VOR check using a VOT is 4°.
- What is the maximum allowable difference when checking two VORs against each other?
- True/false: When tuning a VOR and hearing the correct 1,020 Hz Morse code identifier signal, you are assured that both the VOR and DME are properly tuned and usable for navigation.
- True/false: If your airplane has an IFR-certified GPS (with RAIM capability), your airplane does not have to be equipped with an alternate means of navigation.
- Which RNAV system is completely self-contained, requiring no inputs from ground-based or space-based facilities?
- What horizontal position accuracy can you expect from GPS 99.99% of the time?
 - Within 100 meters
 - Within 200 meters
 - Within 300 meters
- For typical RNAV approach procedures in the U.S., the following RNP level is required:
 - RNP-0.3
 - RNP-1
 - RNP-2