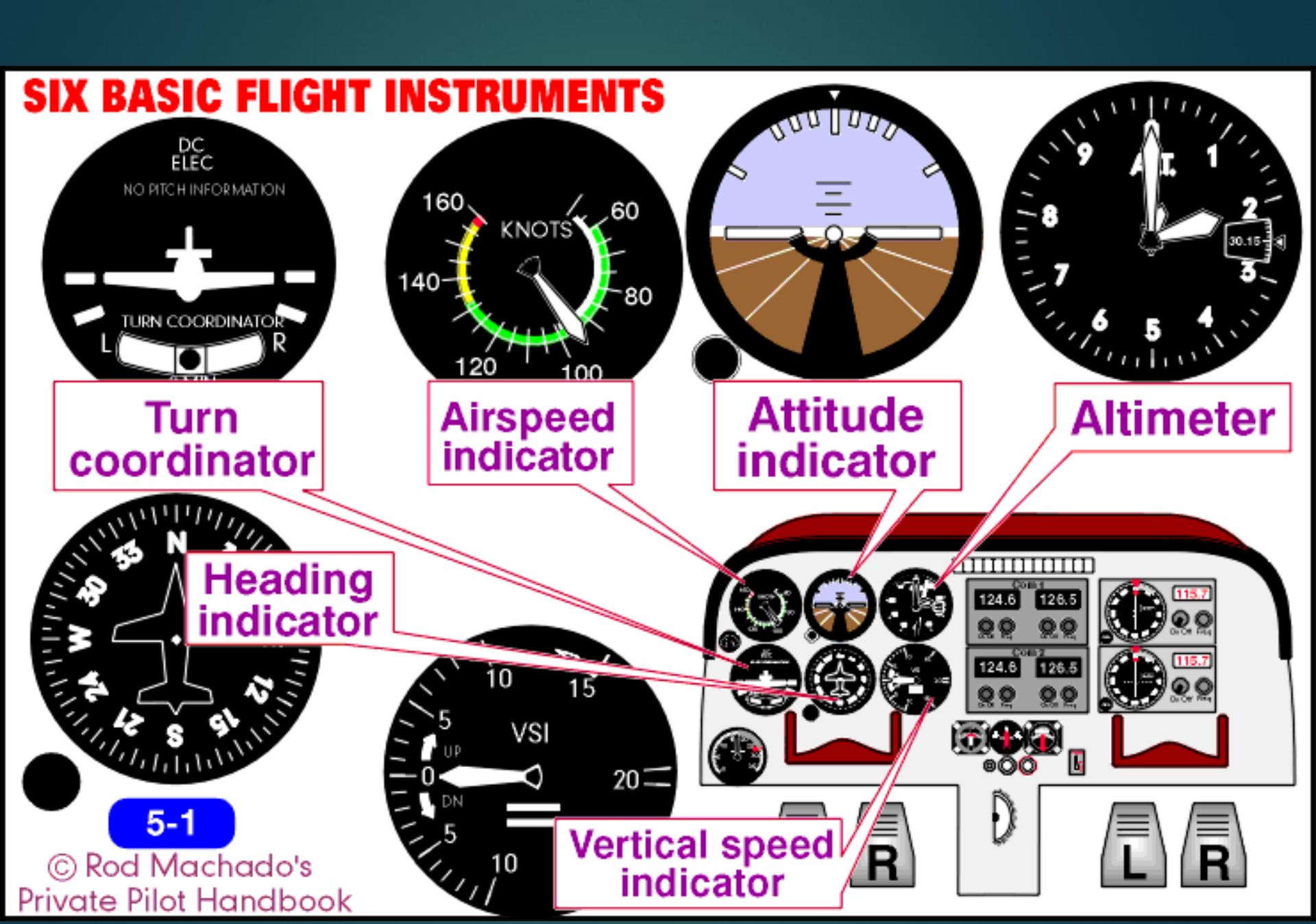
Flight Instruments

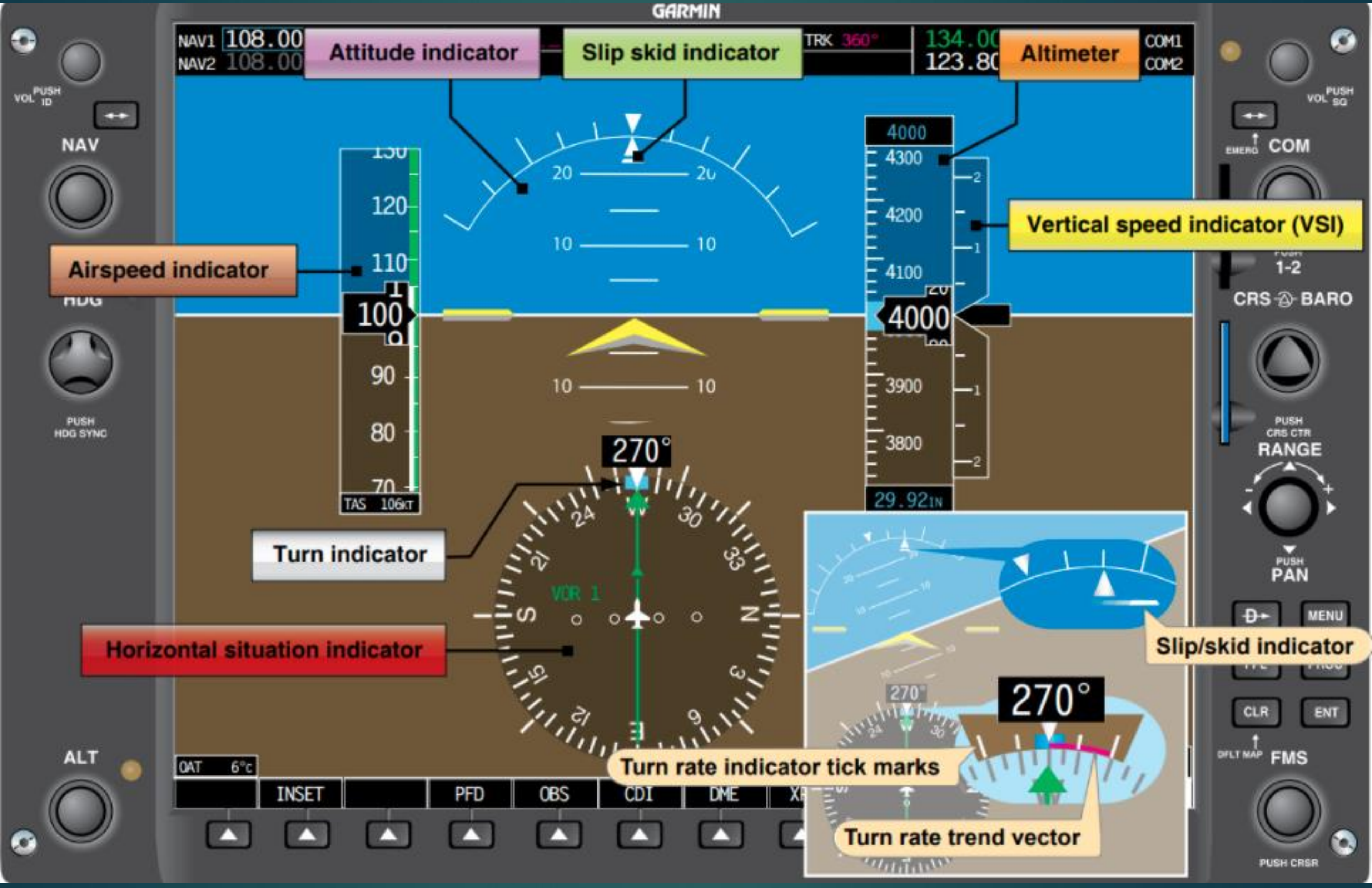
Flight Instruments: The Six-Pack + 1

- Pilot-Static: Airspeed and Altitude
  - Airspeed Indicator
  - Vertical Speed Indicator
  - Altimeter
- Gyroscopic: Heading, Bank, and Attitude
  - Turn Coordinator
  - Heading Indicator
  - Attitude Indicator
- Magnetic Compass: Heading

SIX BASIC FLIGHT INSTRUMENTS



5-1



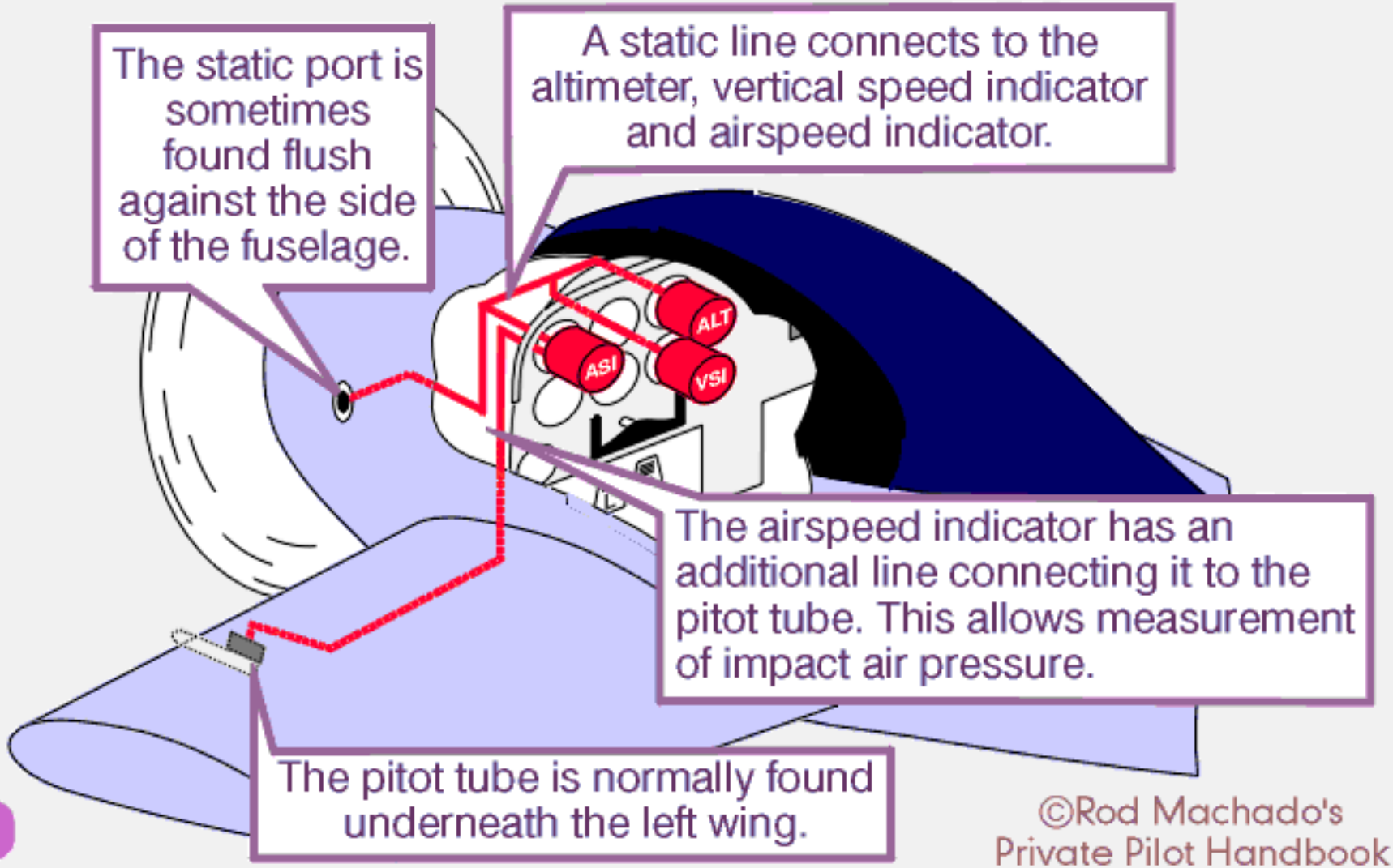
Attitude indicator
Slip skid indicator
Altimeter
Vertical speed indicator (VSI)
Airspeed indicator
Turn indicator
Horizontal situation indicator
Slip/skid indicator
Turn rate indicator tick marks
Turn rate trend vector

Flight Instruments: Engine Monitoring

- Tachometer - RPMs
- Oil
  - Oil temperature
  - Oil pressure
- Fuel
  - Fuel quantity
  - Fuel pressure
- Engine temperature
  - Cylinder head temperature
  - Exhaust gas temperature

Pitot-Static Instruments

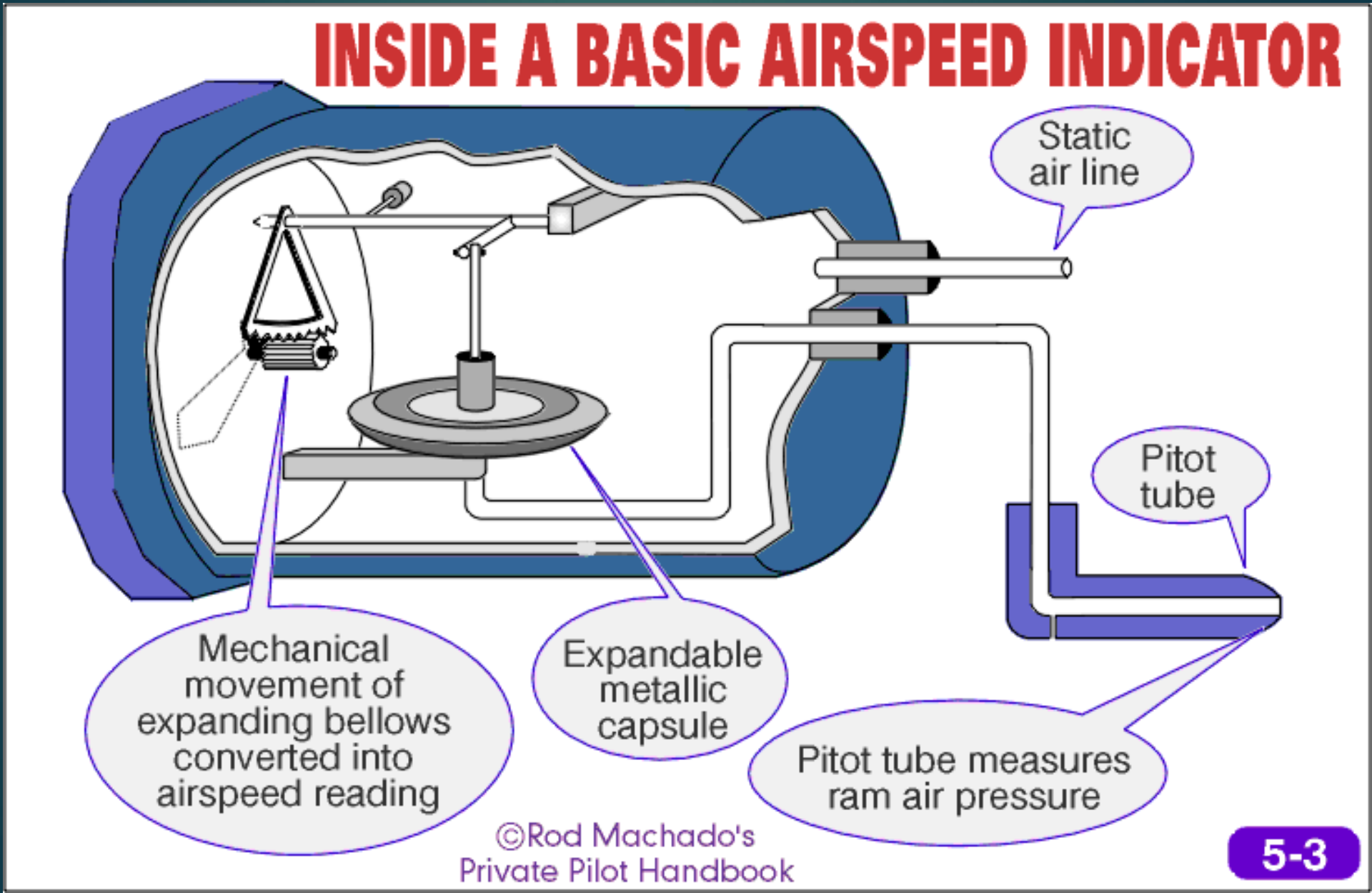
THE PITOT TUBE & STATIC PORT



Pitot-Static Instruments

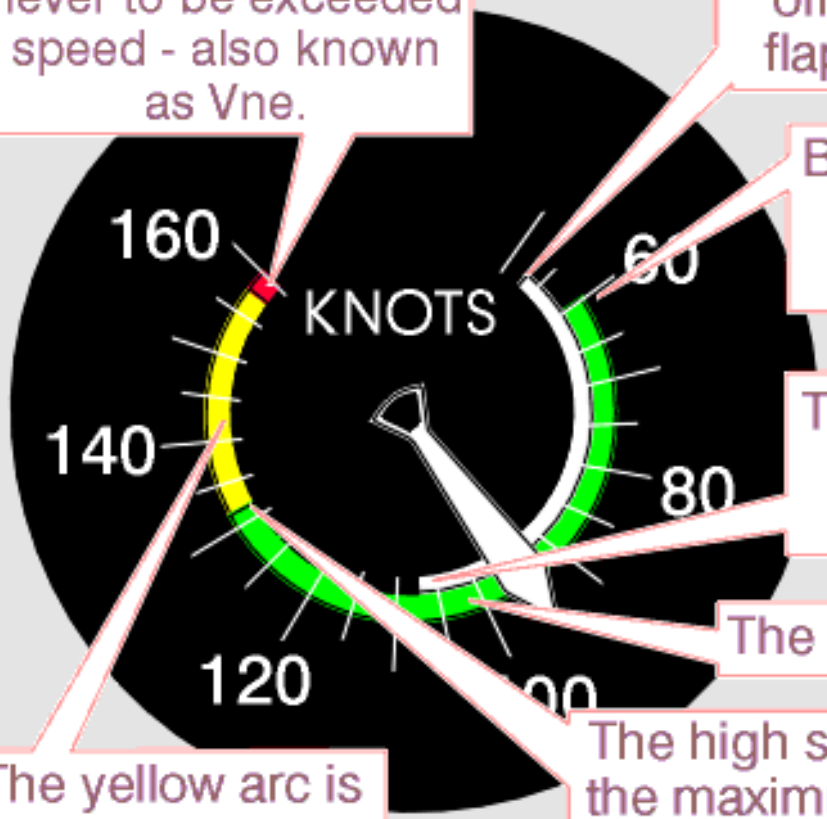
- **Airspeed Indicator (ASI)**
- Altimeter
- Vertical Speed Indicator (VSI)

Airspeed Indicator



Airspeed Indicator

AIRSPEED INDICATOR MARKINGS



The red line is the never to be exceeded speed - also known as Vne.

Beginning of the white arc is the power off stalling speed with gear and full flaps extended - also known as Vso.

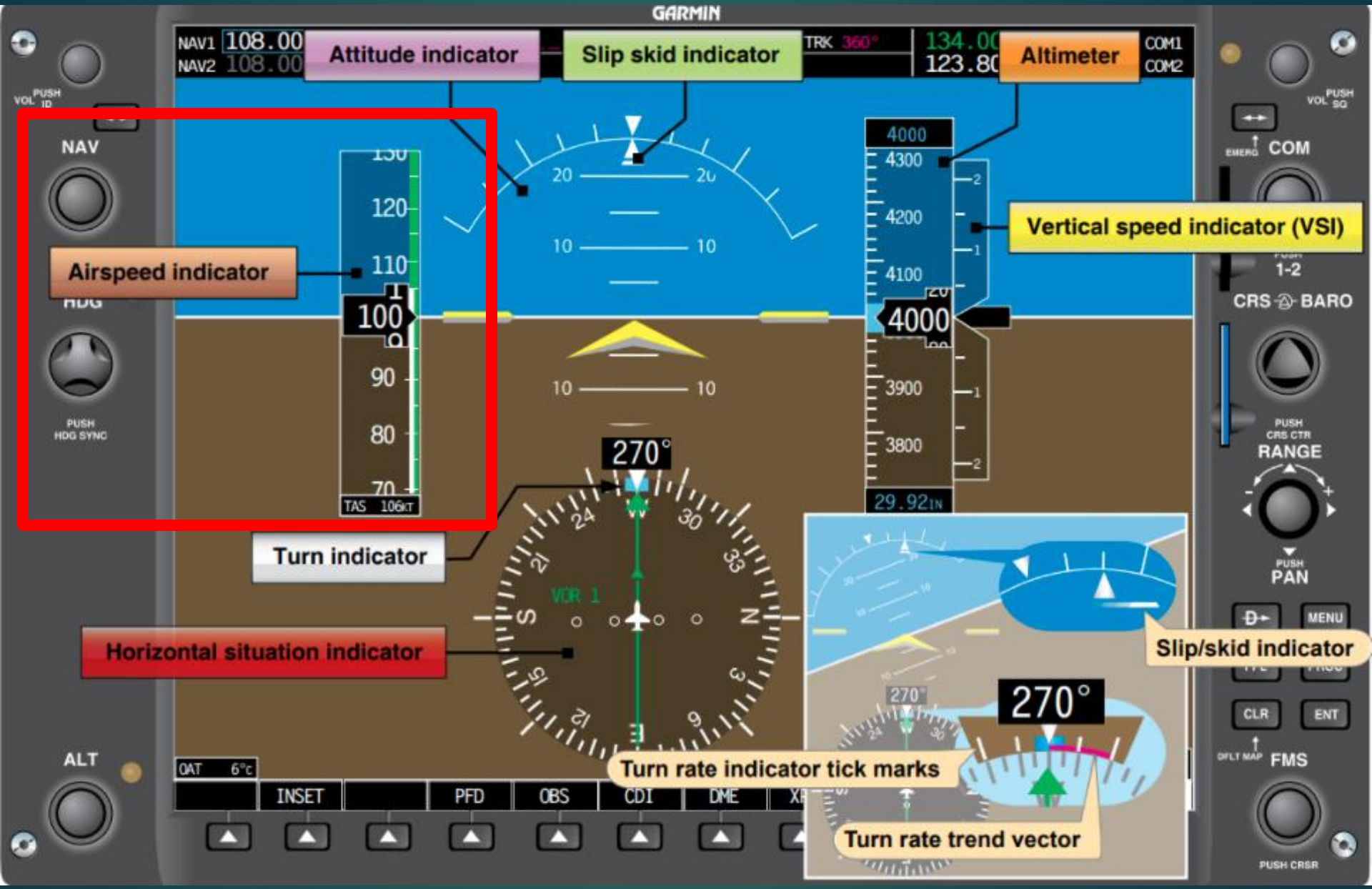
Beginning of the green arc is the power off stalling speed with the gear and flaps retracted - also known as Vs1.

The high speed end of the white arc is the maximum flap operating range - also known as Vfe.

The green arc is the normal operating range

The high speed end of the green arc is the maximum structural cruising speed - also known as Vno.

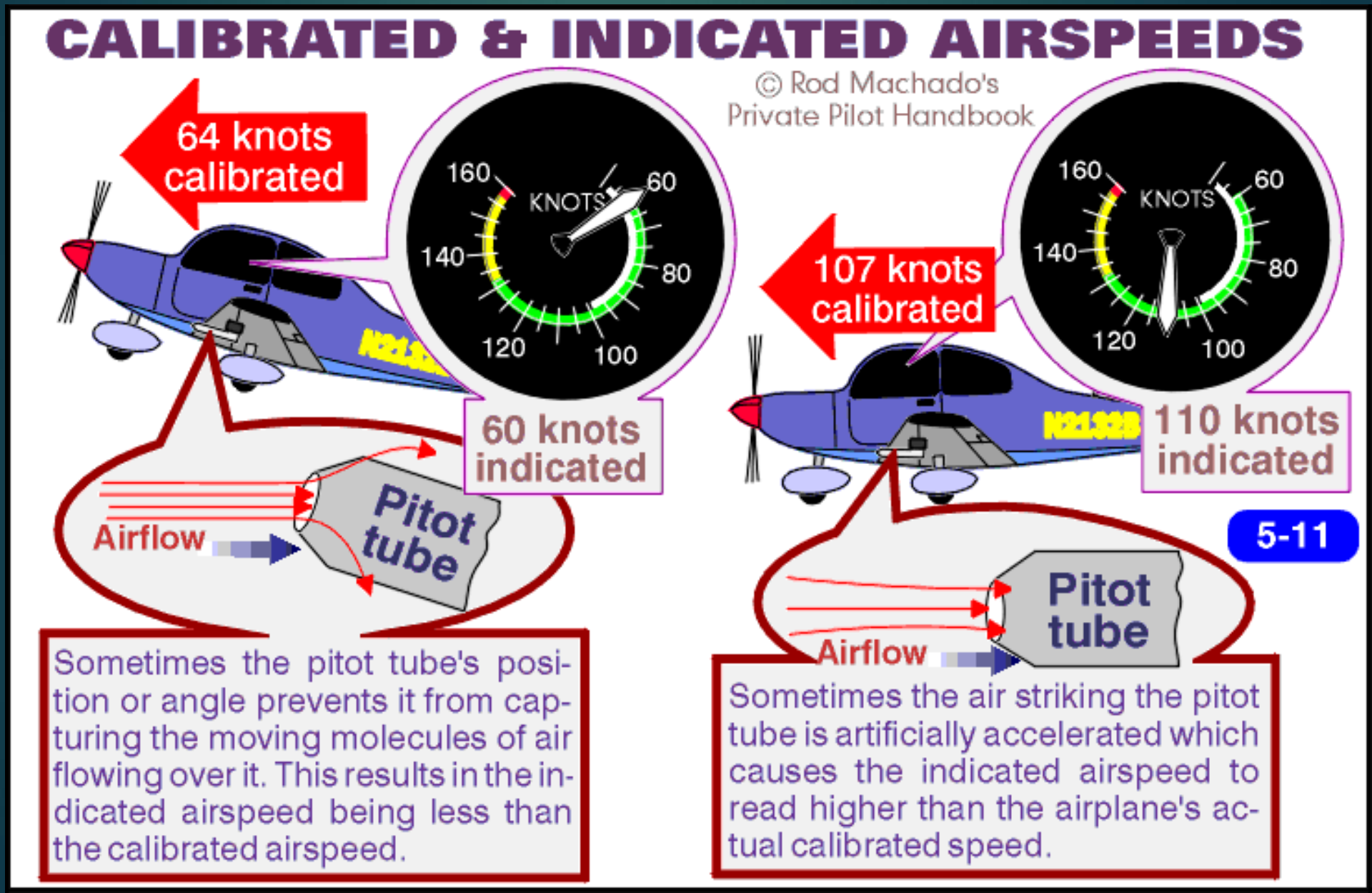
The yellow arc is the caution range.


GARMIN
NAV1 108.00
NAV2 108.00
Attitude indicator
Slip skid indicator
TRK 360°
134.00
123.80
Altimeter
COM1
COM2
Airspeed indicator
Vertical speed indicator (VSI)
Turn indicator
Horizontal situation indicator
Slip/skid indicator
Turn rate indicator tick marks
Turn rate trend vector
270°
100
4000
29.92IN
TAS 106KT
OAT 6°C
INSET
PFD
OBS
CDI
DME
NAV
ALT
COM
CRS BARO
RANGE
PAN
MENU
CLR
ENT
FMS

Definitions of Airspeeds

- Indicated
  - The airspeed displayed on your airspeed indicator
- Calibrated
  - Your indicated airspeed corrected for known instrument and positional errors
- True
  - Speed of the aircraft relative to the air it is flying through
- Ground Speed
  - Speed of the aircraft corrected for wind

Airspeed Indicator



Airspeed Indicator

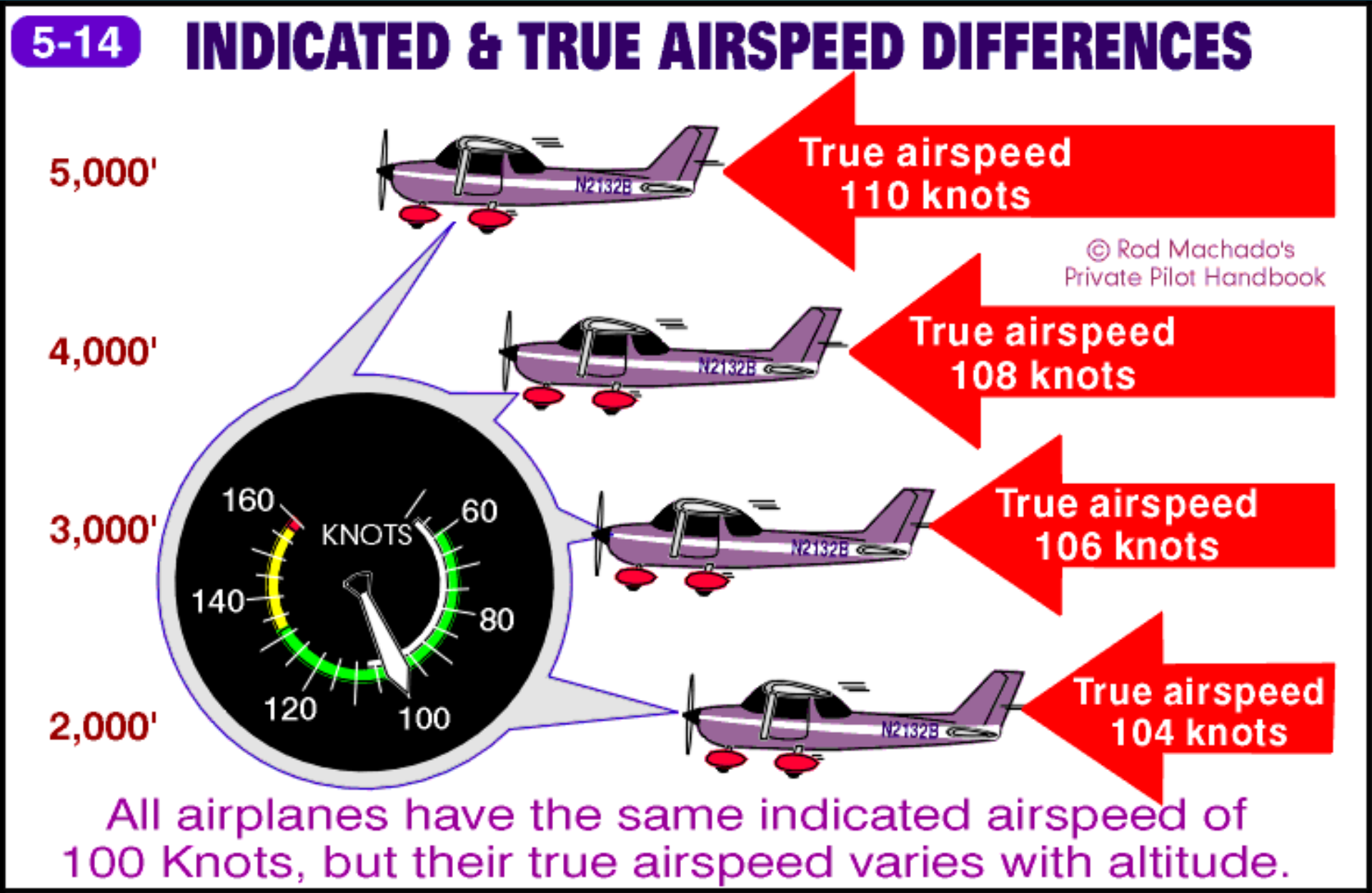
KIAS = Knots Indicated AirSpeed/KCAS = Knots Calibrated AirSpeed

AIRSPEED CALIBRATION CHART

FLAPS UP											
KIAS	50	60	70	80	90	100	110	120	130	140	150
KCAS	50	64	72	81	89	98	107	116	126	135	153
FLAPS 10°											
KIAS	40	50	60	70	80	90	100				
KCAS	55	58	64	72	81	90	107				
FLAPS 30°											
KIAS	40	50	60	70	80	85					
KCAS	54	57	62	71	80	85					

Condition: Power required for level flight or maximum rated RPM dive

Airspeed Indicator

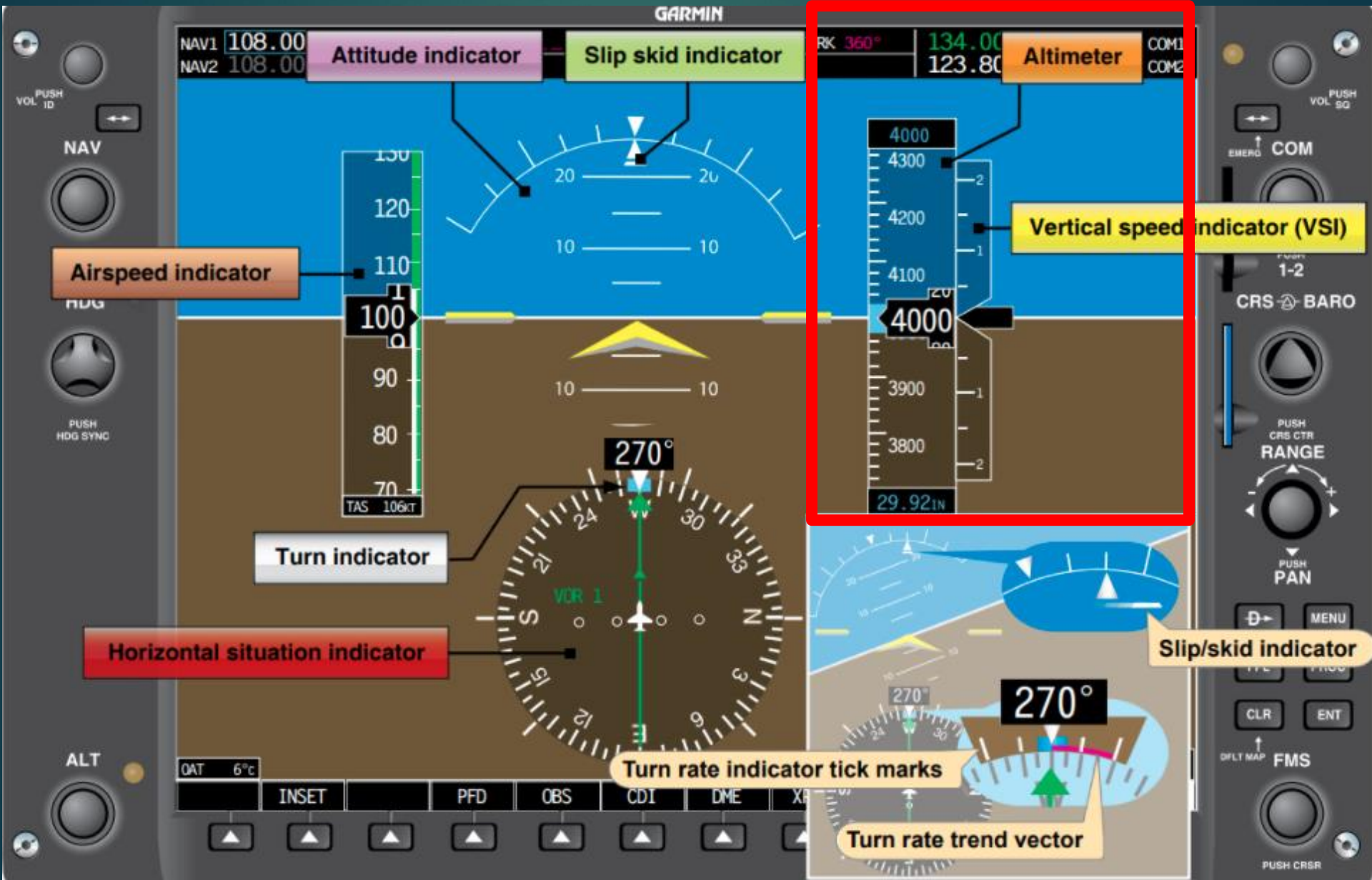


Pitot-Static Instruments

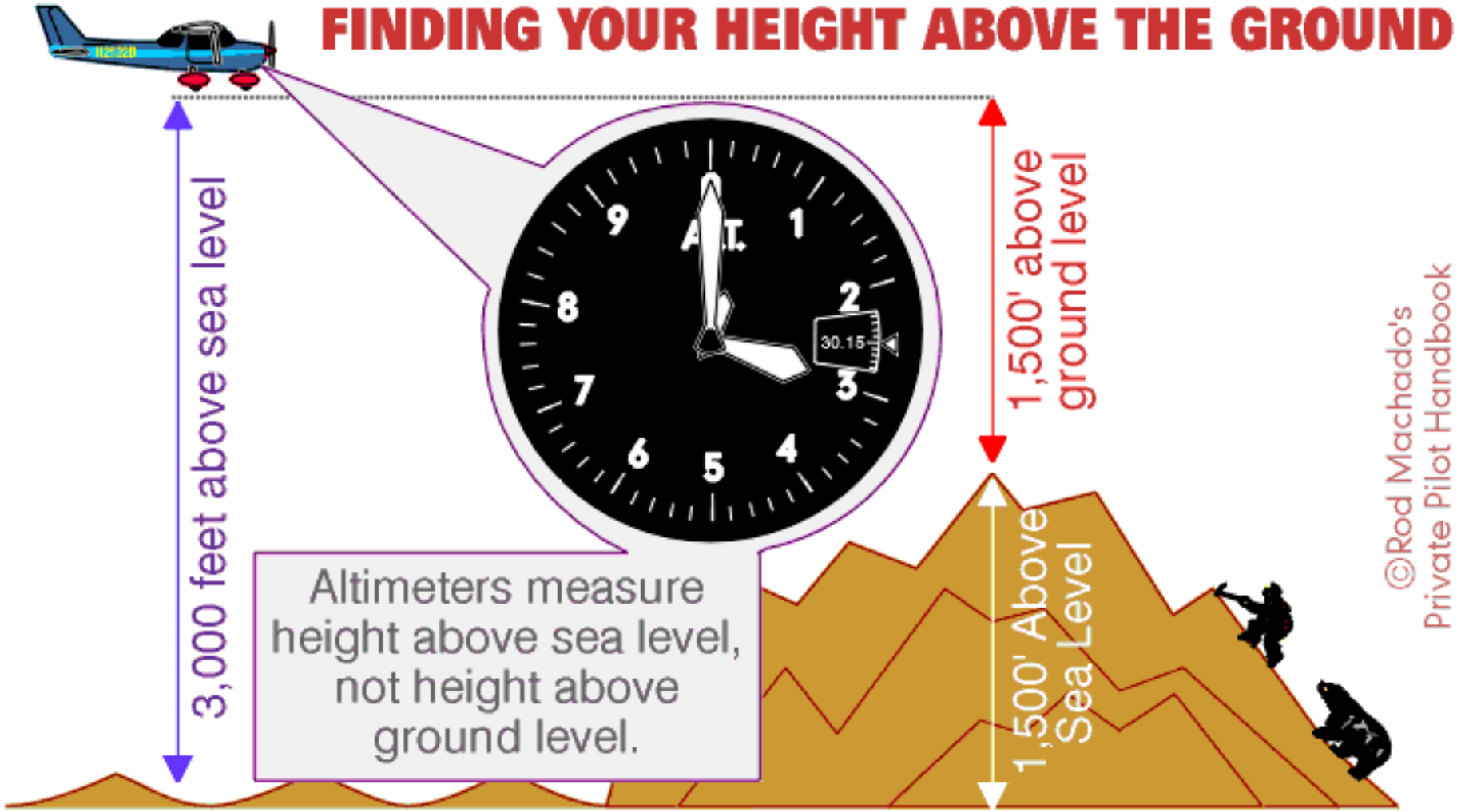
- Airspeed Indicator (ASI)
- **Altimeter**
- Vertical Speed Indicator (VSI)

Altimeter – Steam Gauge

Altimeter - Glass

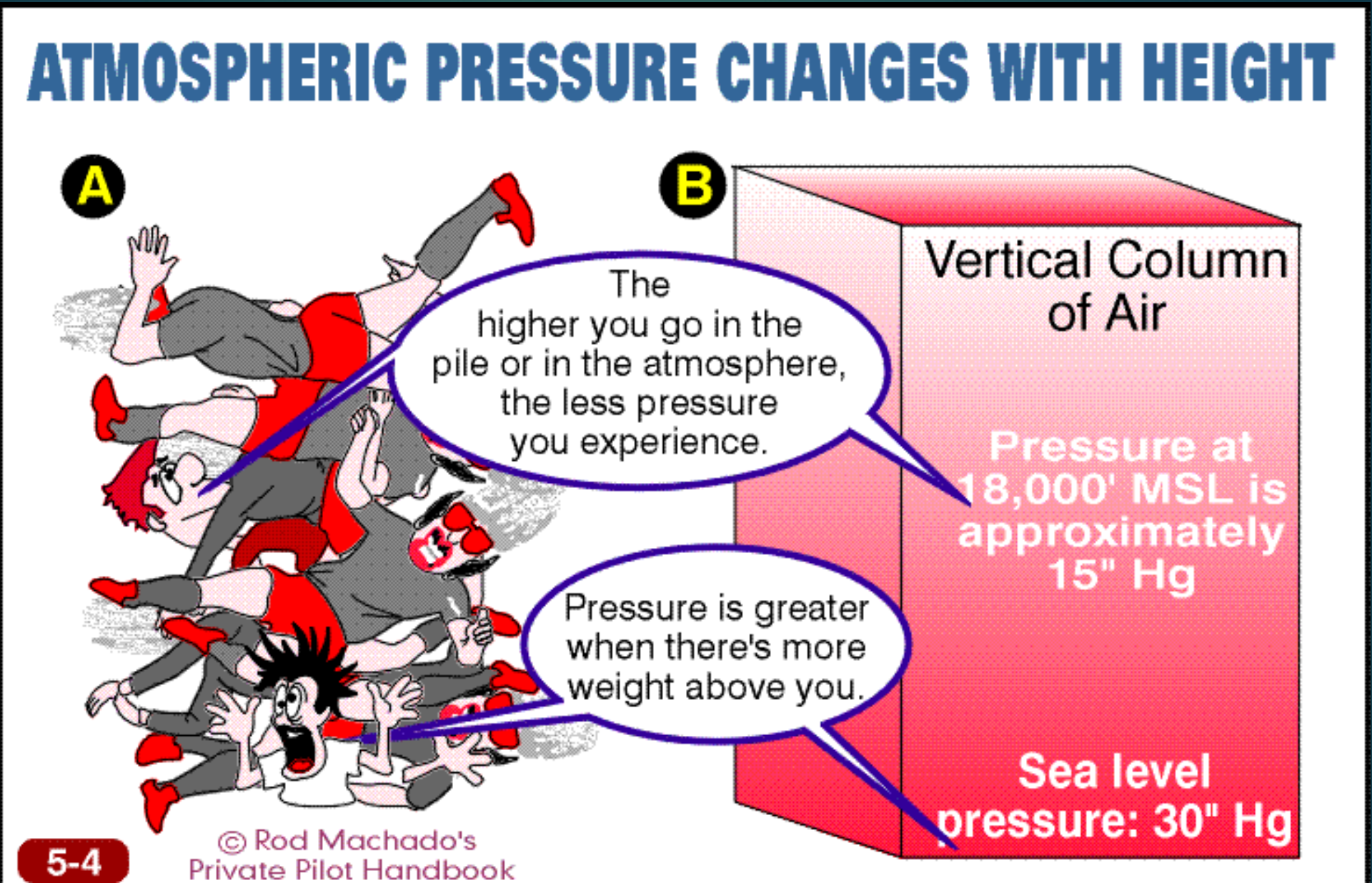


Altimeter

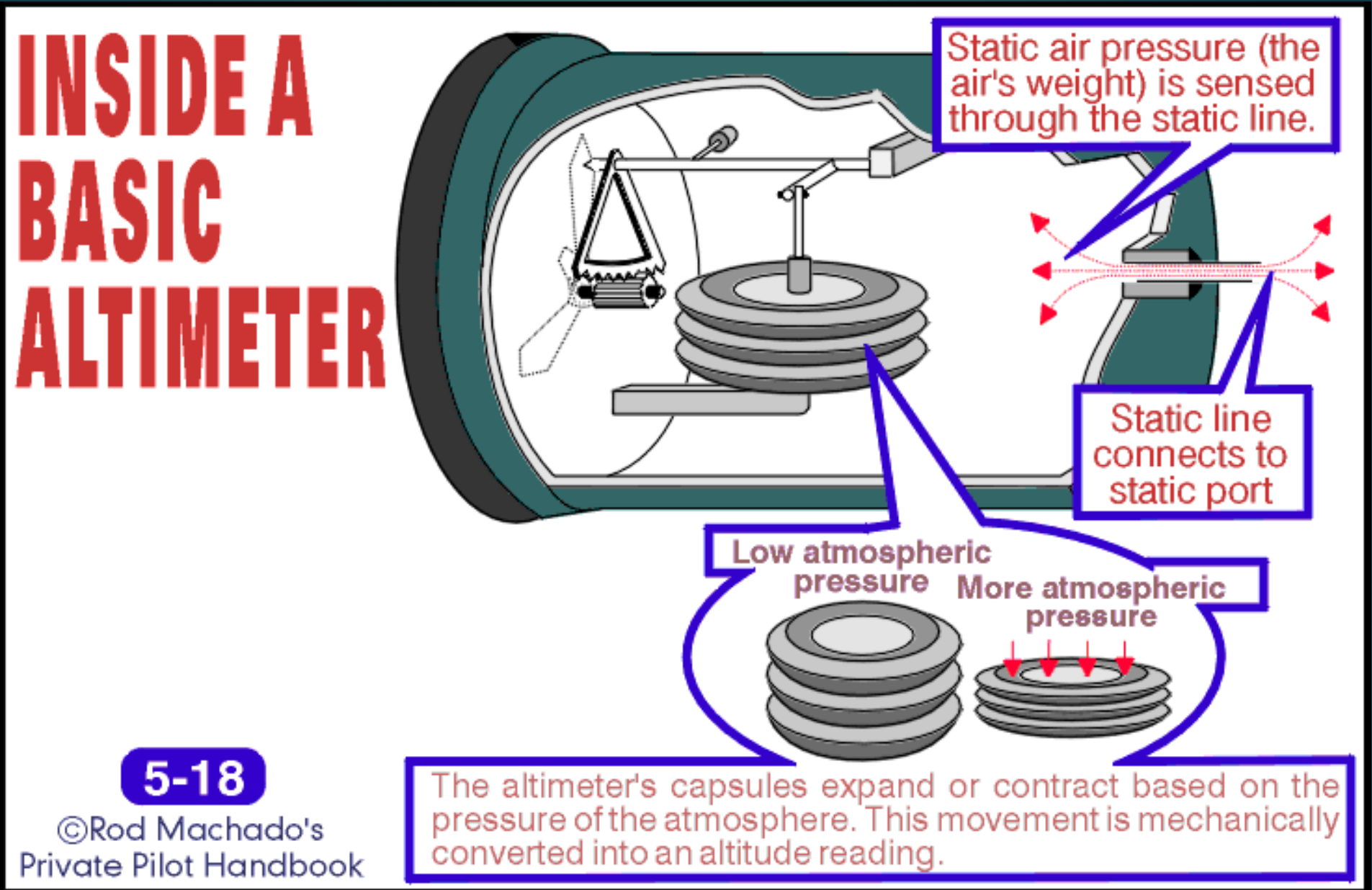


Finding your height above the ground requires that you subtract the ground's height (its MSL value is found on sectional charts—see Chapter 10) from your height above sea level (which is shown on your altimeter).

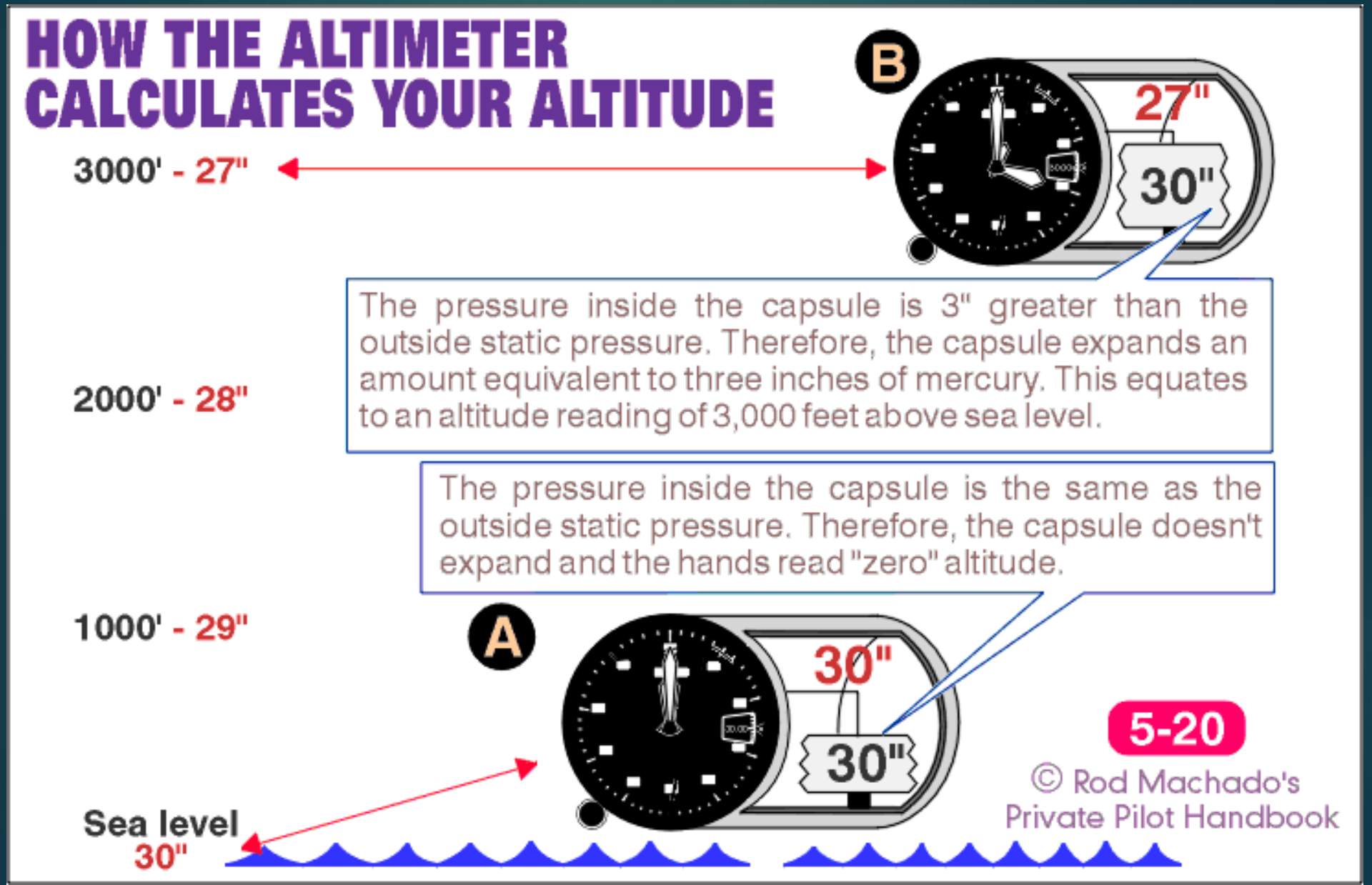
Altimeter


ATMOSPHERIC PRESSURE CHANGES WITH HEIGHT
A
B
The higher you go in the pile or in the atmosphere, the less pressure you experience.
Pressure is greater when there's more weight above you.
Vertical Column of Air
Pressure at 18,000' MSL is approximately 15" Hg
Sea level pressure: 30" Hg
5-4
© Rod Machado's Private Pilot Handbook

Altimeter


INSIDE A BASIC ALTIMETER
Static air pressure (the air's weight) is sensed through the static line.
Static line connects to static port
Low atmospheric pressure
More atmospheric pressure
The altimeter's capsules expand or contract based on the pressure of the atmosphere. This movement is mechanically converted into an altitude reading.
5-18
©Rod Machado's Private Pilot Handbook

Altimeter


HOW THE ALTIMETER CALCULATES YOUR ALTITUDE
3000' - 27"
2000' - 28"
1000' - 29"
Sea level
30"
B
27"
30"
The pressure inside the capsule is 3" greater than the outside static pressure. Therefore, the capsule expands an amount equivalent to three inches of mercury. This equates to an altitude reading of 3,000 feet above sea level.
A
30"
30"
The pressure inside the capsule is the same as the outside static pressure. Therefore, the capsule doesn't expand and the hands read "zero" altitude.
5-20
© Rod Machado's
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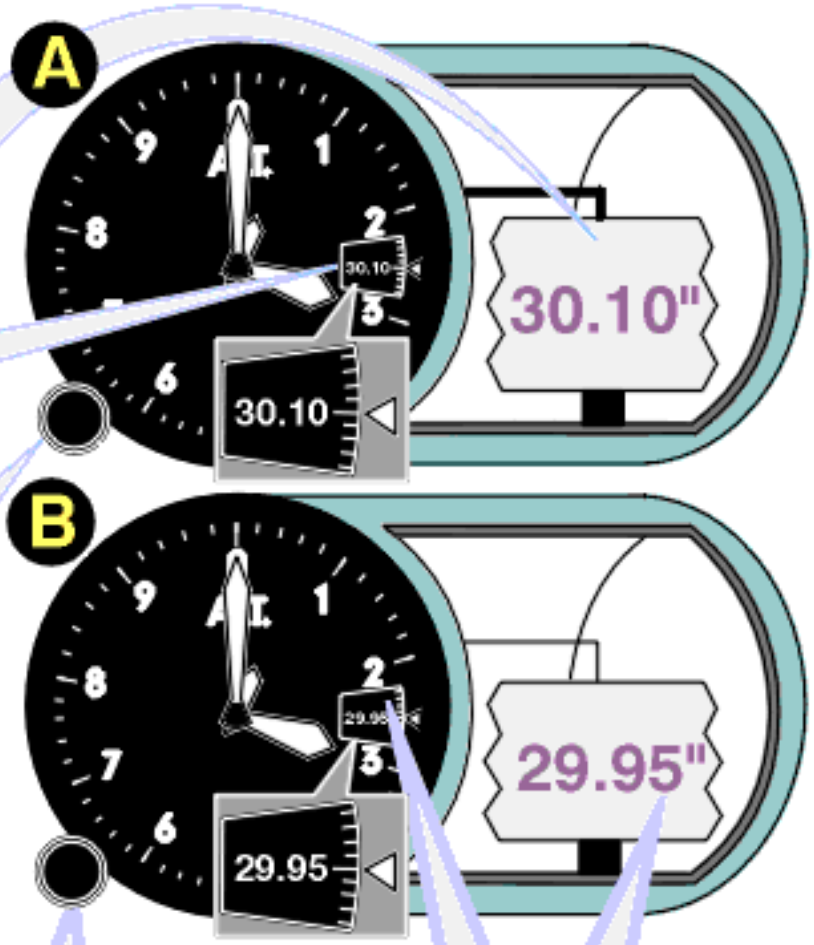
Altimeter

WHAT HAPPENS WHEN YOU CHANGE THE ALTIMETER SETTING

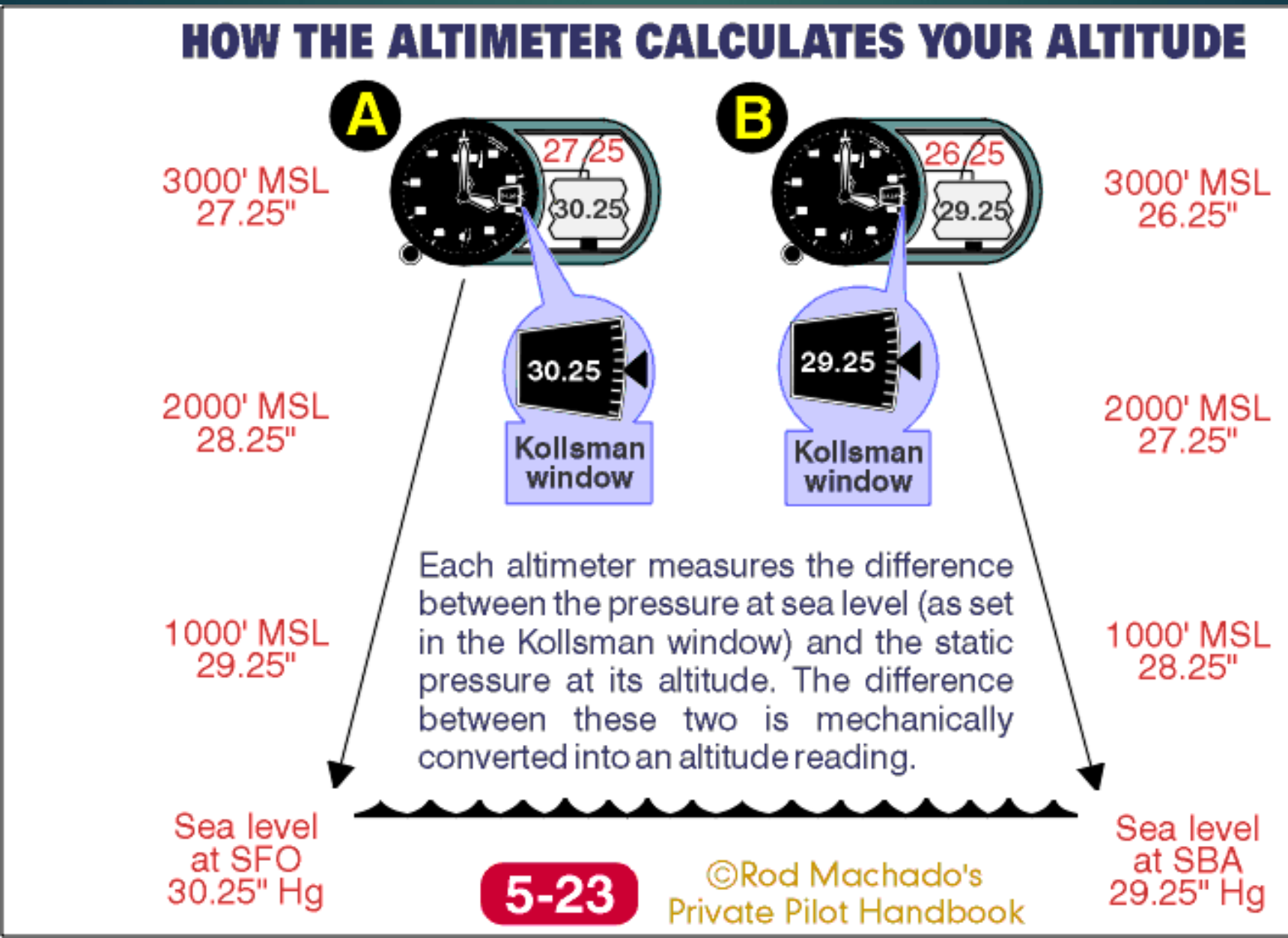


Rotating the altimeter's knob, changes the numbers in the Kollsman window. This mechanically repositions an internal linkage that changes the starting point from which the altimeter begins its measurement. It is, however, much easier to think of the pressure inside the sealed capsule changing to equal the barometric pressure value set in the Kollsman window (trust me! Think about it this way and you'll never have difficulty understanding how the altimeter works).

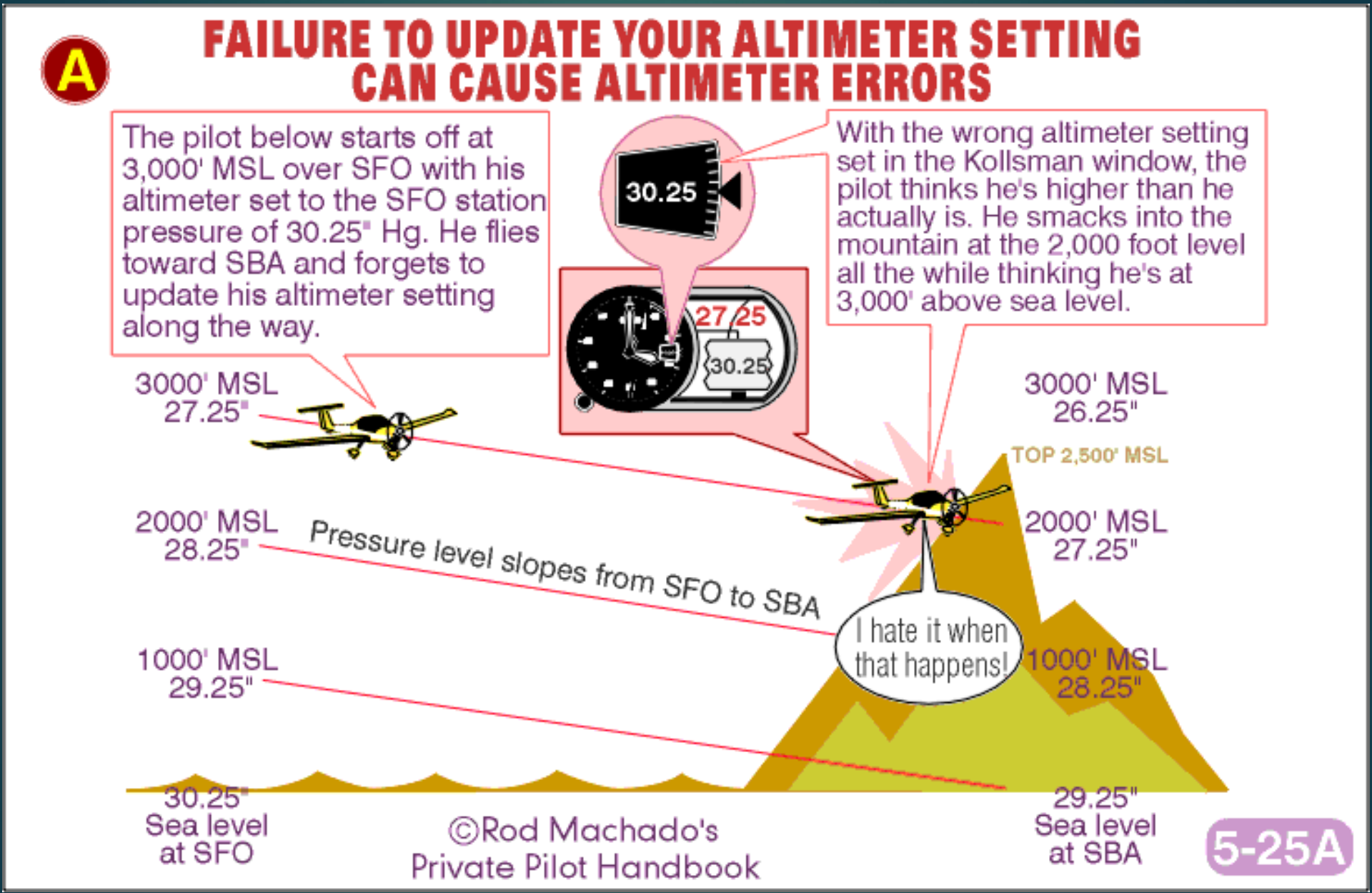
5-22

When the altimeter knob is rotated & 29.95" is set in the Kollsman window, the altimeter acts as if a pressure of 29.95" Hg has been set inside its sealed capsule.

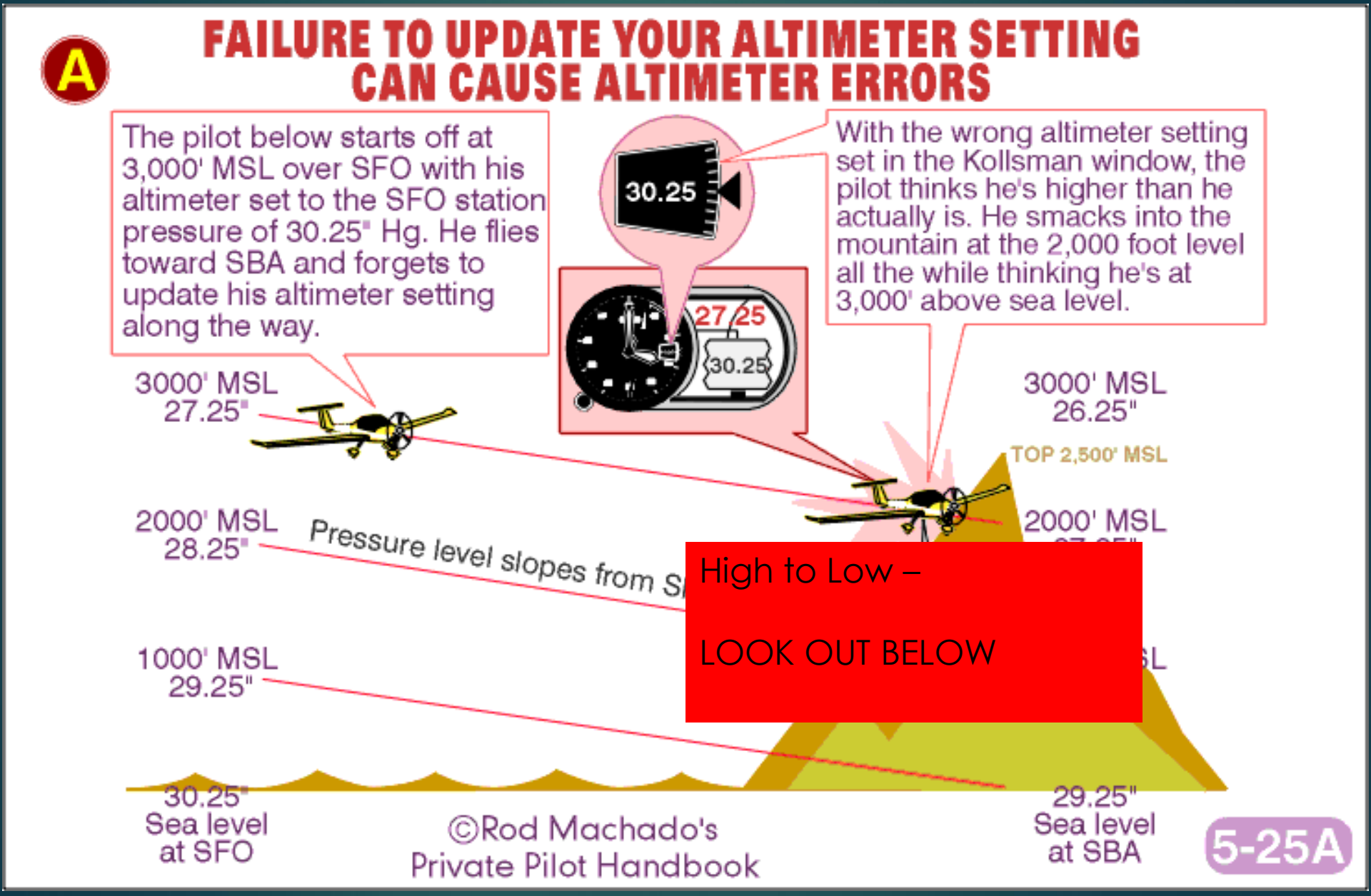
Altimeter


HOW THE ALTIMETER CALCULATES YOUR ALTITUDE
A
B
27.25
30.25
26.25
29.25
30.25
29.25
Kollsman window
Kollsman window
3000' MSL 27.25"
2000' MSL 28.25"
1000' MSL 29.25"
3000' MSL 26.25"
2000' MSL 27.25"
1000' MSL 28.25"
Each altimeter measures the difference between the pressure at sea level (as set in the Kollsman window) and the static pressure at its altitude. The difference between these two is mechanically converted into an altitude reading.
Sea level at SFO 30.25" Hg
Sea level at SBA 29.25" Hg
5-23
©Rod Machado's Private Pilot Handbook

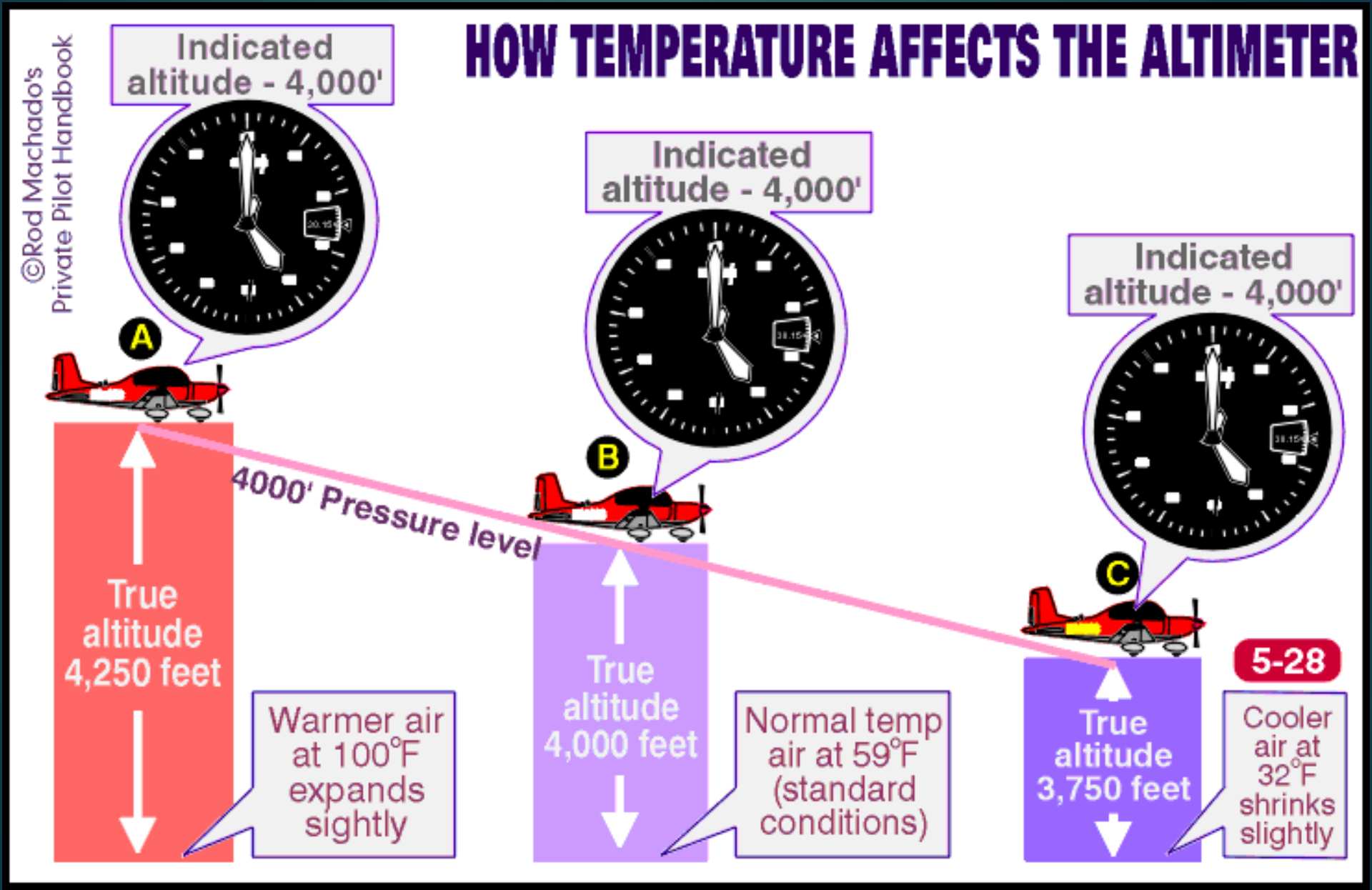
Altimeter


A
FAILURE TO UPDATE YOUR ALTIMETER SETTING CAN CAUSE ALTIMETER ERRORS
The pilot below starts off at 3,000' MSL over SFO with his altimeter set to the SFO station pressure of 30.25" Hg. He flies toward SBA and forgets to update his altimeter setting along the way.
With the wrong altimeter setting set in the Kollsman window, the pilot thinks he's higher than he actually is. He smacks into the mountain at the 2,000 foot level all the while thinking he's at 3,000' above sea level.
30.25
27.25
30.25
3000' MSL
27.25"
3000' MSL
26.25"
TOP 2,500' MSL
2000' MSL
28.25"
Pressure level slopes from SFO to SBA
2000' MSL
27.25"
I hate it when that happens!
1000' MSL
29.25"
1000' MSL
28.25"
30.25"
Sea level
at SFO
29.25"
Sea level
at SBA
©Rod Machado's
Private Pilot Handbook
5-25A

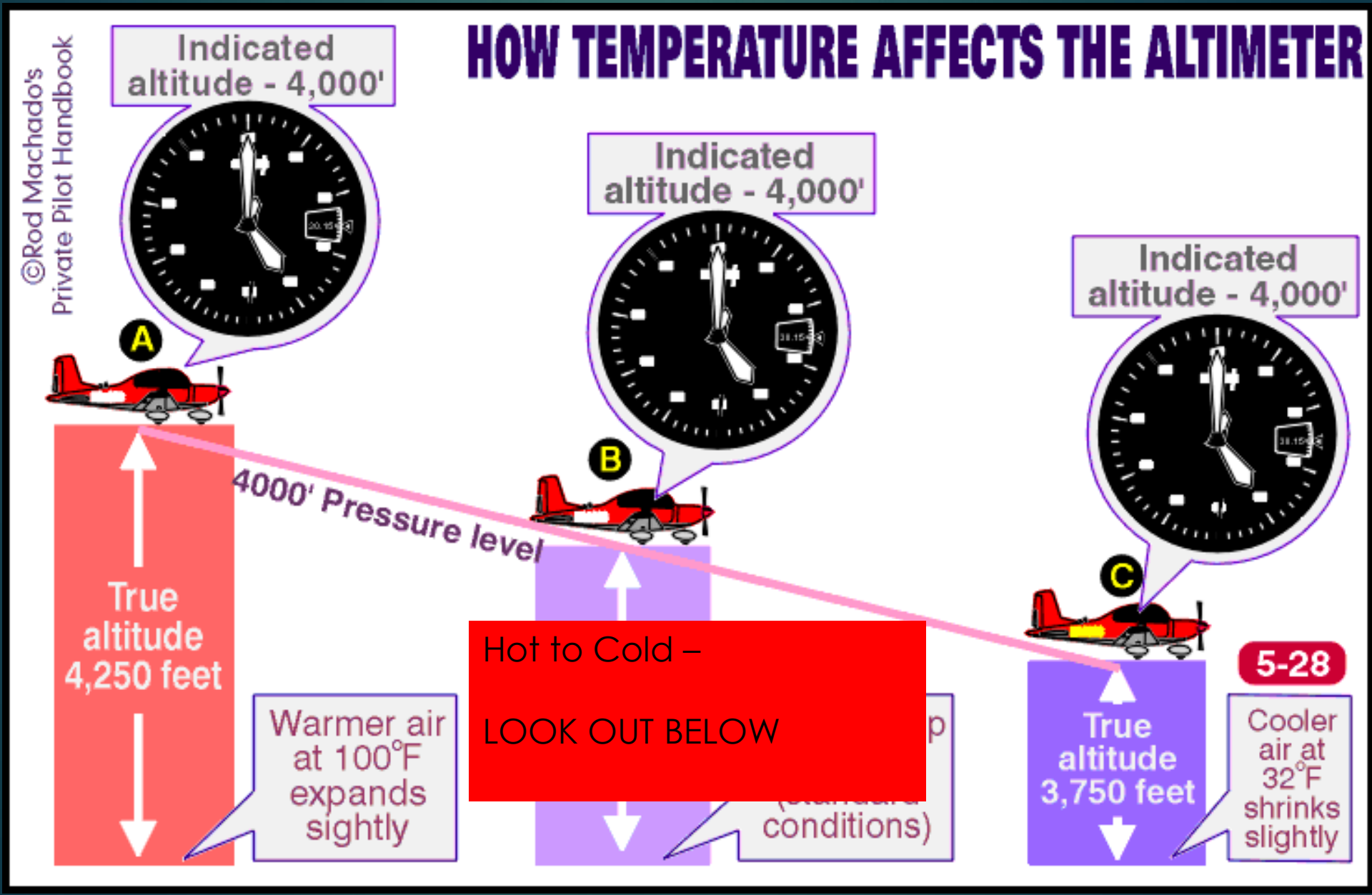
Altimeter


A
FAILURE TO UPDATE YOUR ALTIMETER SETTING CAN CAUSE ALTIMETER ERRORS
The pilot below starts off at 3,000' MSL over SFO with his altimeter set to the SFO station pressure of 30.25" Hg. He flies toward SBA and forgets to update his altimeter setting along the way.
With the wrong altimeter setting set in the Kollsman window, the pilot thinks he's higher than he actually is. He smacks into the mountain at the 2,000 foot level all the while thinking he's at 3,000' above sea level.
30.25
27.25
30.25
3000' MSL
27.25"
3000' MSL
26.25"
TOP 2,500' MSL
2000' MSL
28.25"
Pressure level slopes from S
2000' MSL
1000' MSL
29.25"
High to Low –
LOOK OUT BELOW
30.25"
Sea level
at SFO
©Rod Machado's
Private Pilot Handbook
29.25"
Sea level
at SBA
5-25A

Altimeter


HOW TEMPERATURE AFFECTS THE ALTIMETER
©Rod Machado's Private Pilot Handbook
Indicated altitude - 4,000'
Indicated altitude - 4,000'
Indicated altitude - 4,000'
A
B
C
4000' Pressure level
True altitude 4,250 feet
Warmer air at 100°F expands sightly
True altitude 4,000 feet
Normal temp air at 59°F (standard conditions)
True altitude 3,750 feet
Cooler air at 32°F shrinks slightly
5-28

Altimeter



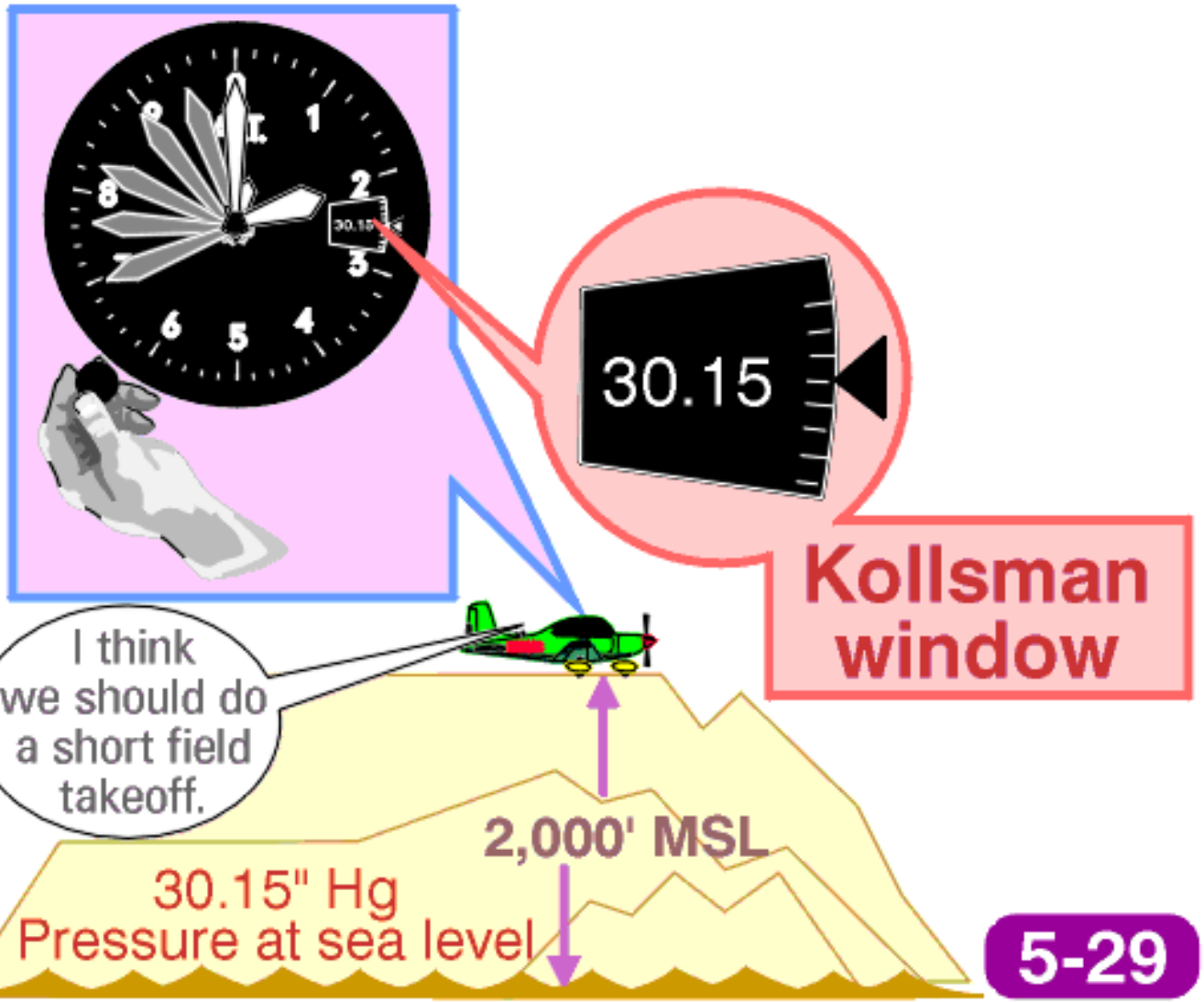
Hot to Cold –

LOOK OUT BELOW

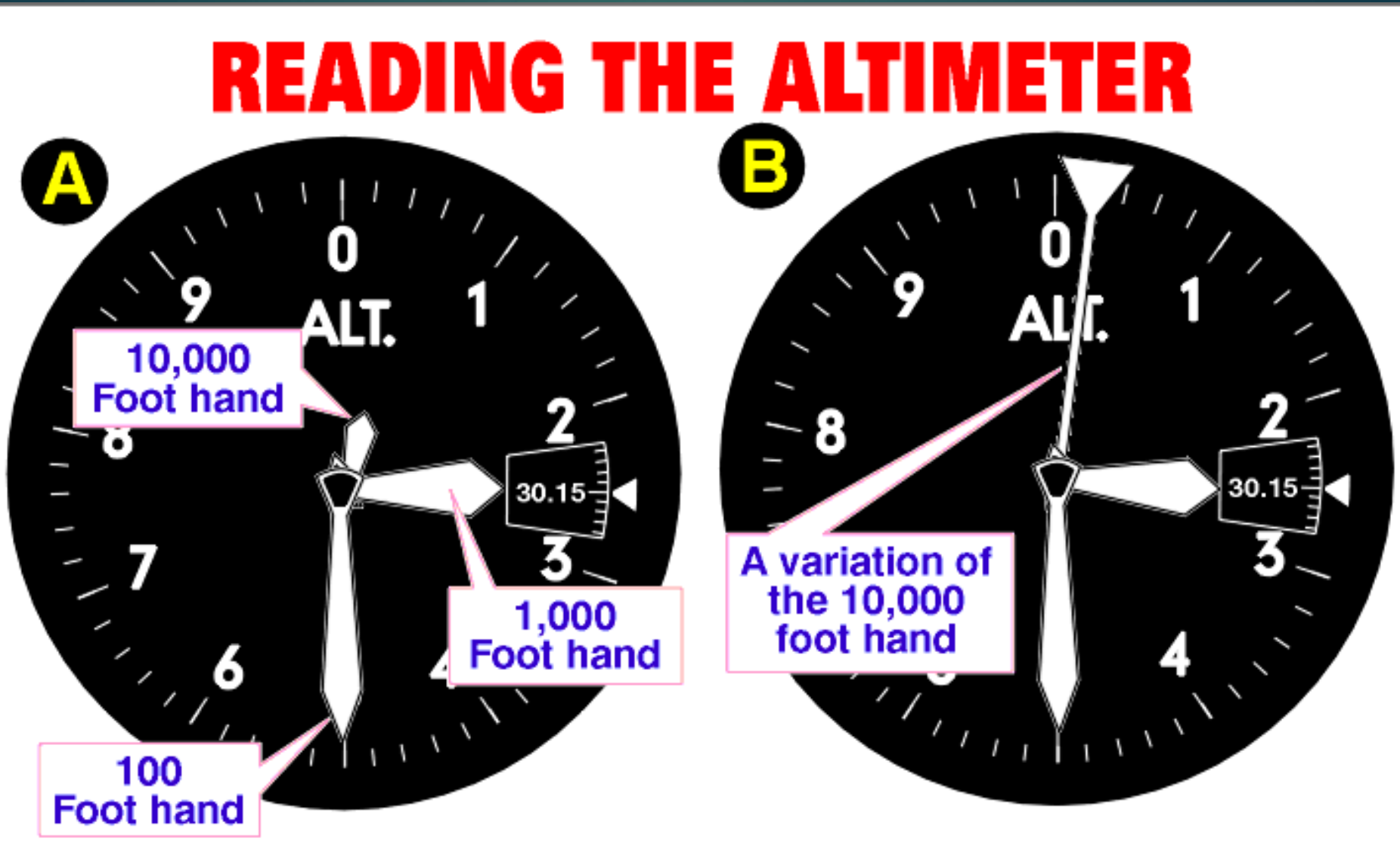
Altimeter

WHEN THE ALTIMETER SETTING ISN'T AVAILABLE

If the altimeter setting is not available while on the ground at an airport, simply rotate the knob until the altimeter hands indicate field elevation. The numbers in the Kollsman window would be your altimeter setting if it were available from attached.



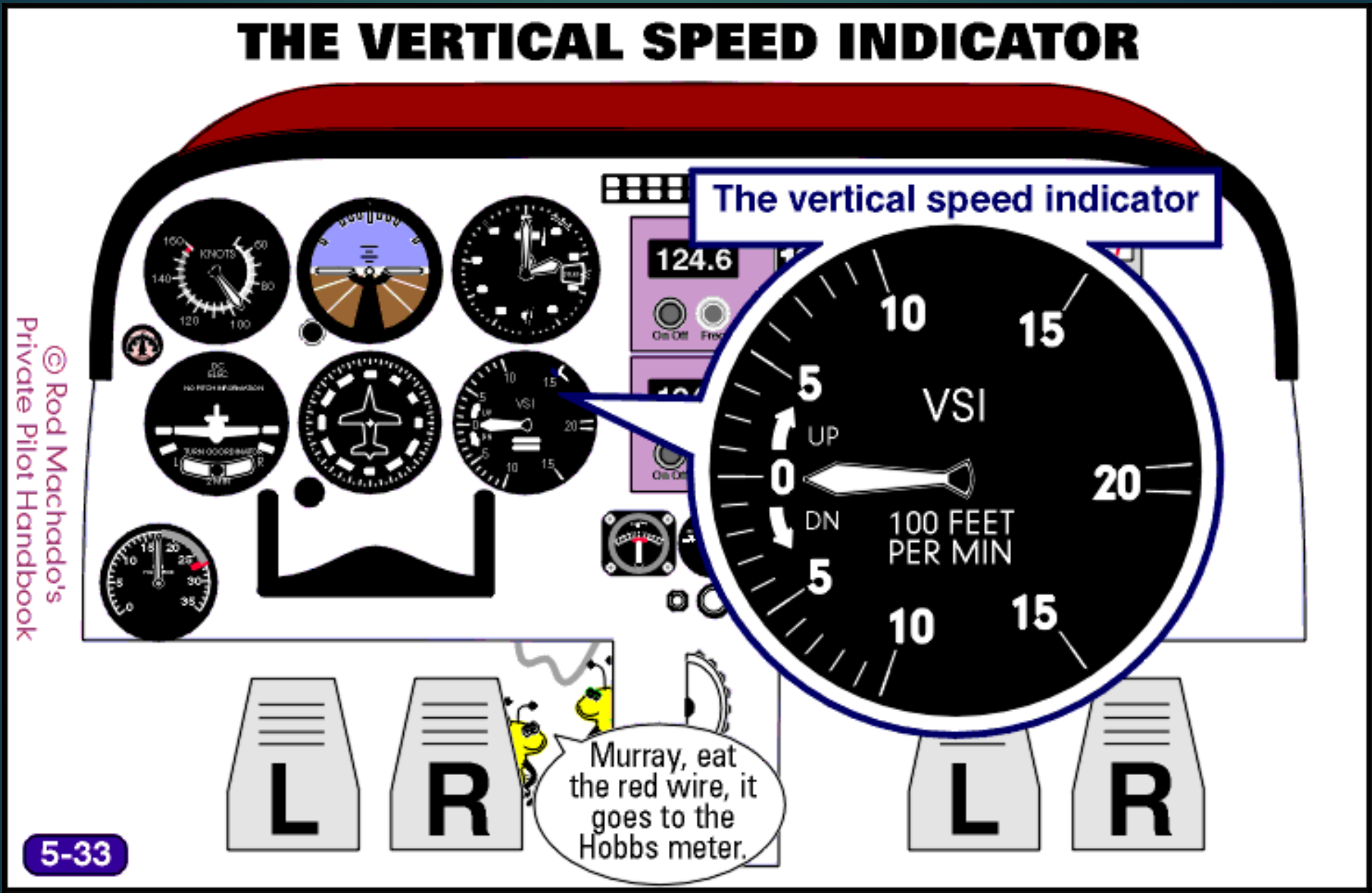
Altimeter



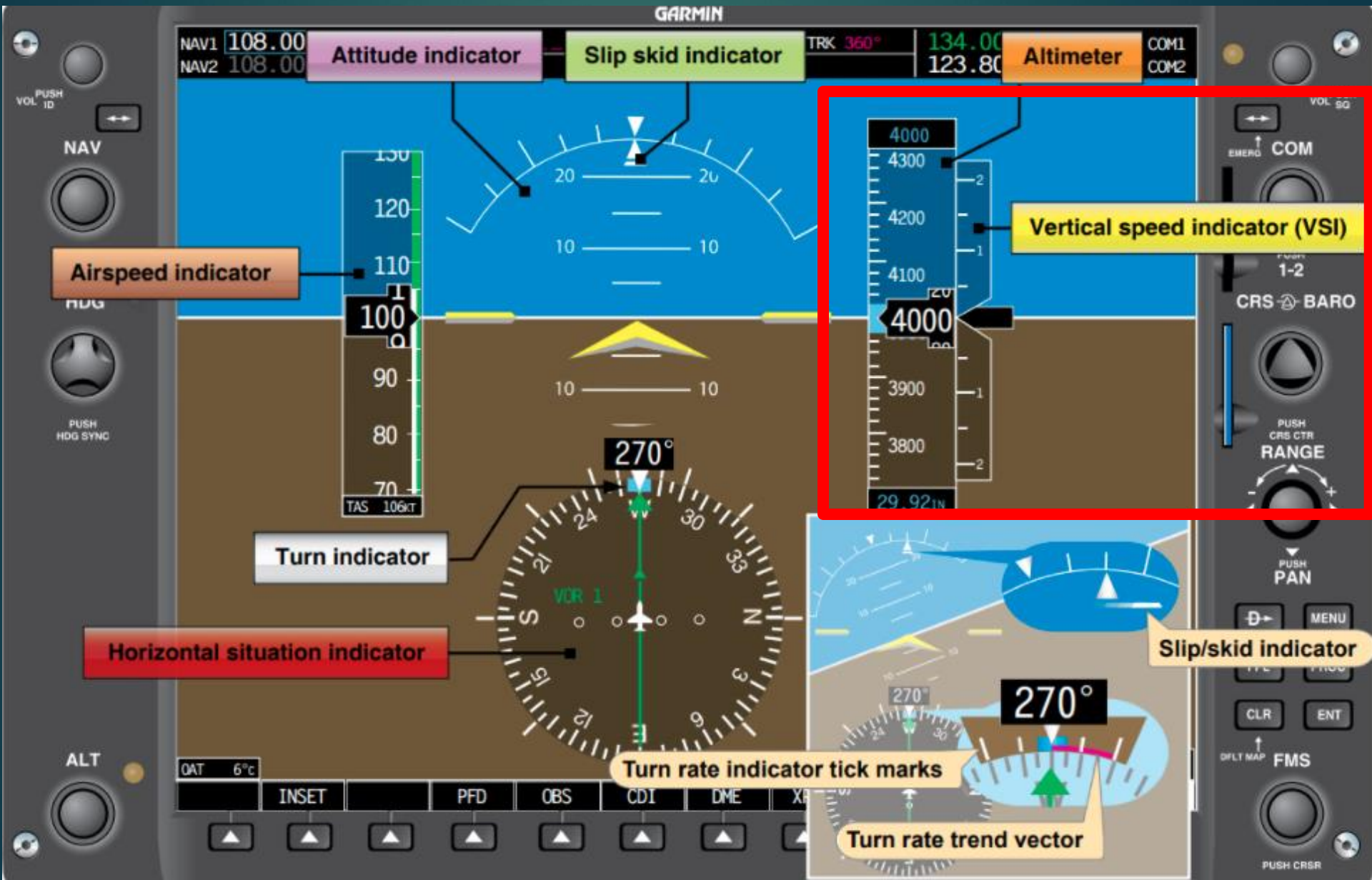
Pitot-Static Instruments

- Airspeed Indicator (ASI)
- Altimeter
- **Vertical Speed Indicator (VSI)**

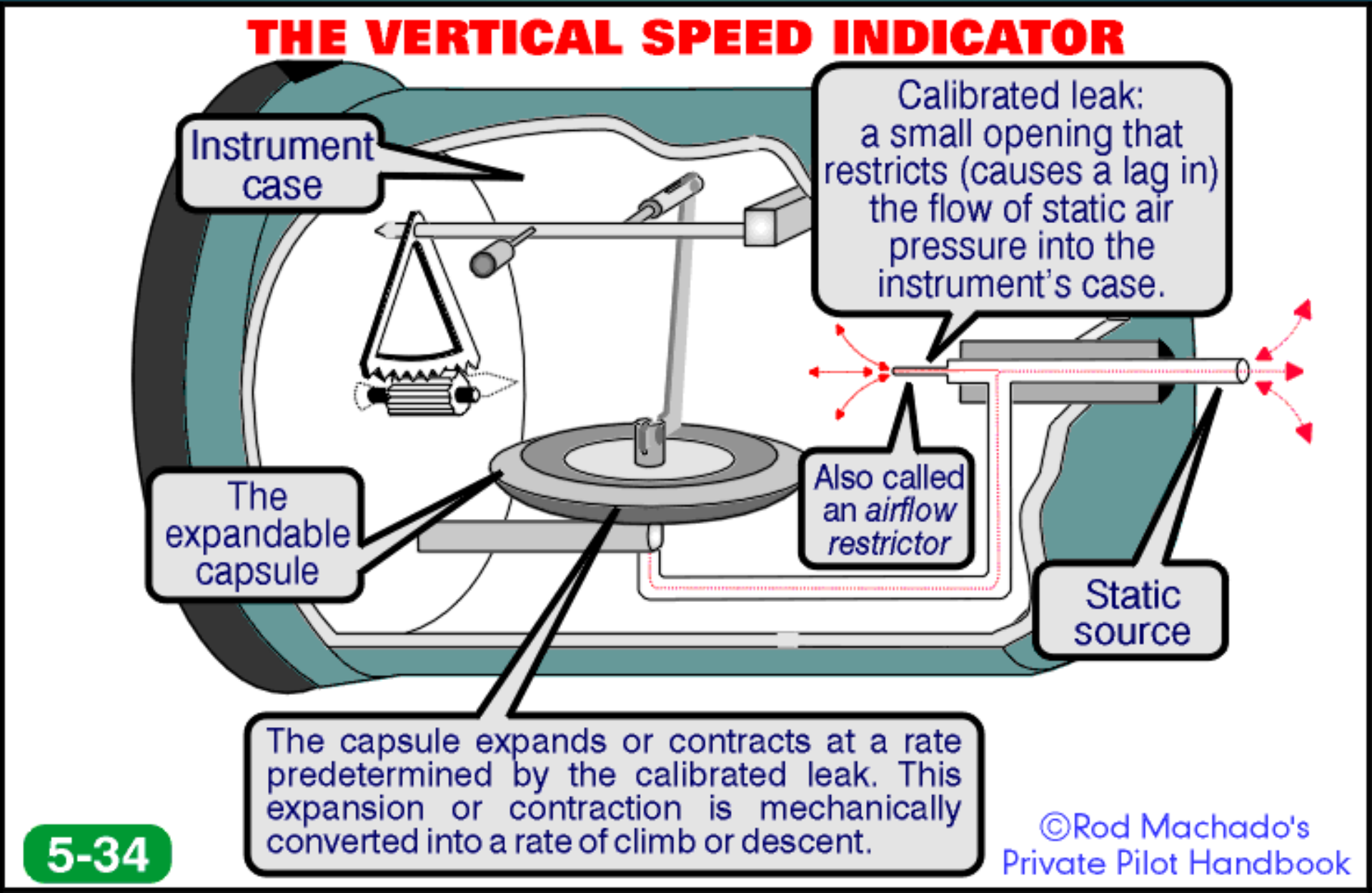
VSI – Steam Gauge



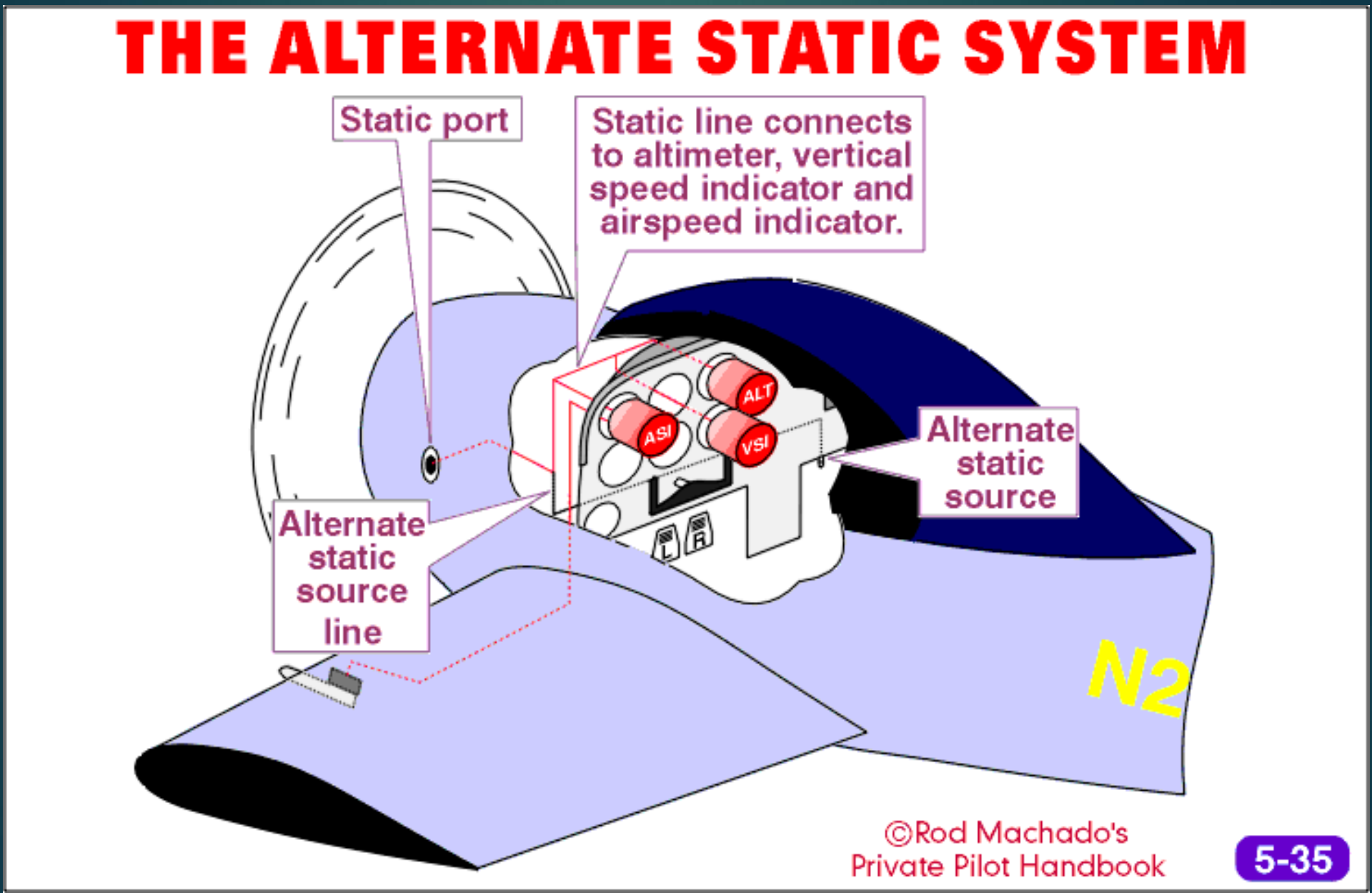
VSI - Glass


GARMIN
NAV1 108.00
NAV2 108.00
Attitude indicator
Slip skid indicator
TRK 360°
134.00
123.80
Altimeter
COM1
COM2
Airspeed indicator
Vertical speed indicator (VSI)
4000
4300
4200
4100
4000
3900
3800
29.92IN
120
110
100
90
80
70
TAS 106KT
270°
Turn indicator
Horizontal situation indicator
VOR 1
Slip/skid indicator
Turn rate indicator tick marks
Turn rate trend vector
OAT 6°C
INSET
PFD
OBS
CDI
DME
NAV
HDG
ALT
COM
CRS
BARO
RANGE
PAN
MENU
CLR
ENT
FMS

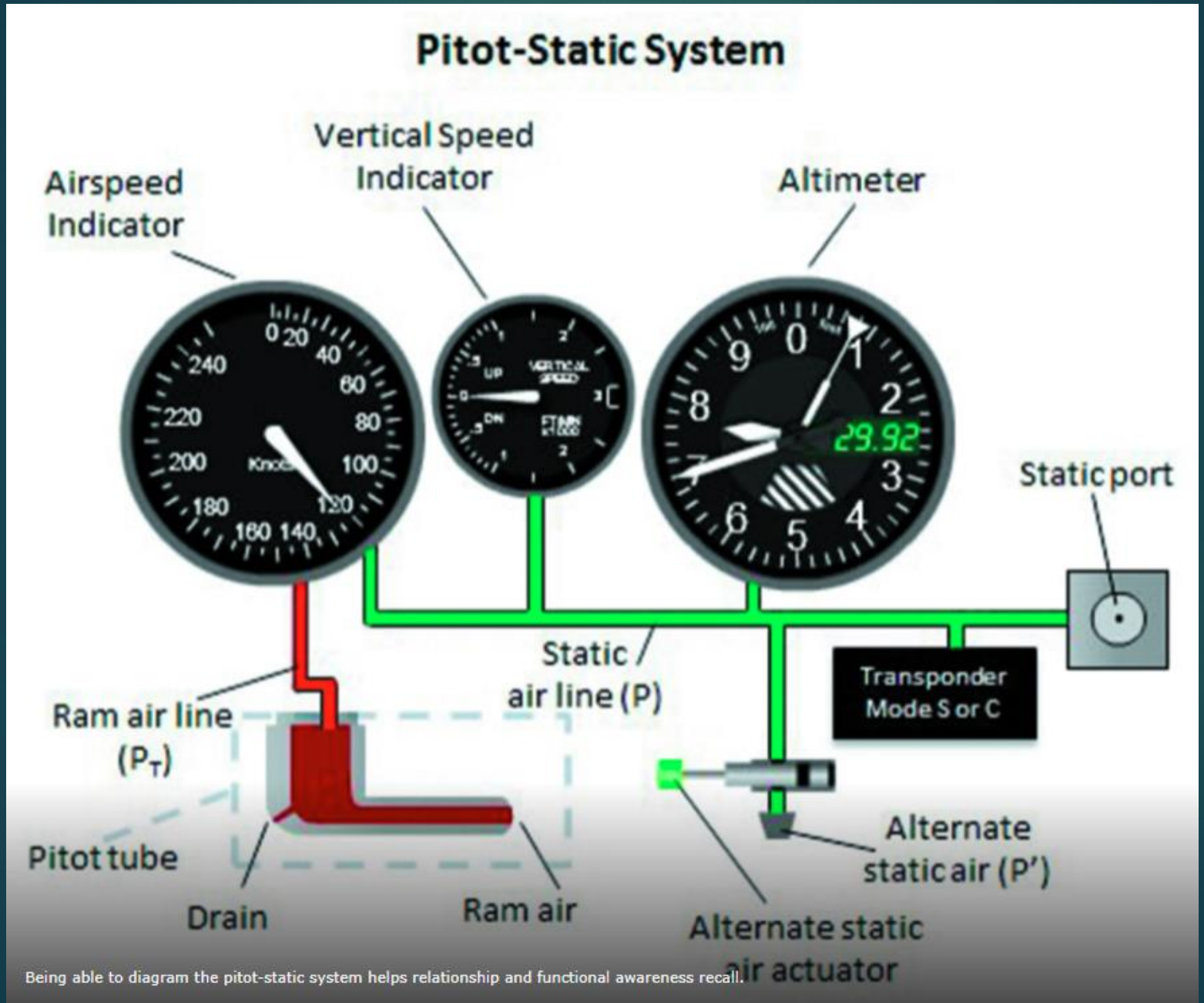
Vertical Speed Indicator (VSI)



Vertical Speed Indicator (VSI)



Failure Modes of Pilot-Static Instruments



Gyroscopic Instruments:

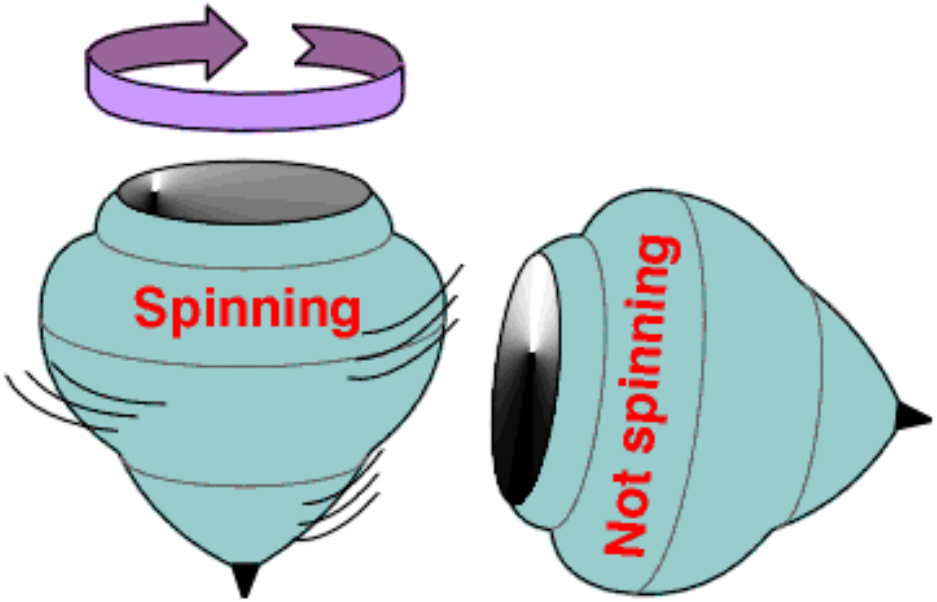
- Attitude Indicator
- Heading Indicator
- Turn Coordinator

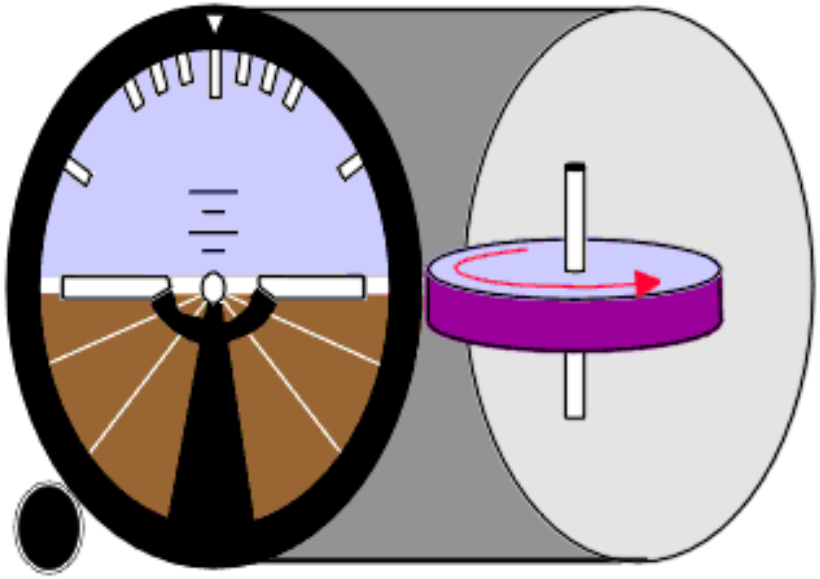
Gyroscope Principles

GYROSCOPIC RIGIDITY IN SPACE

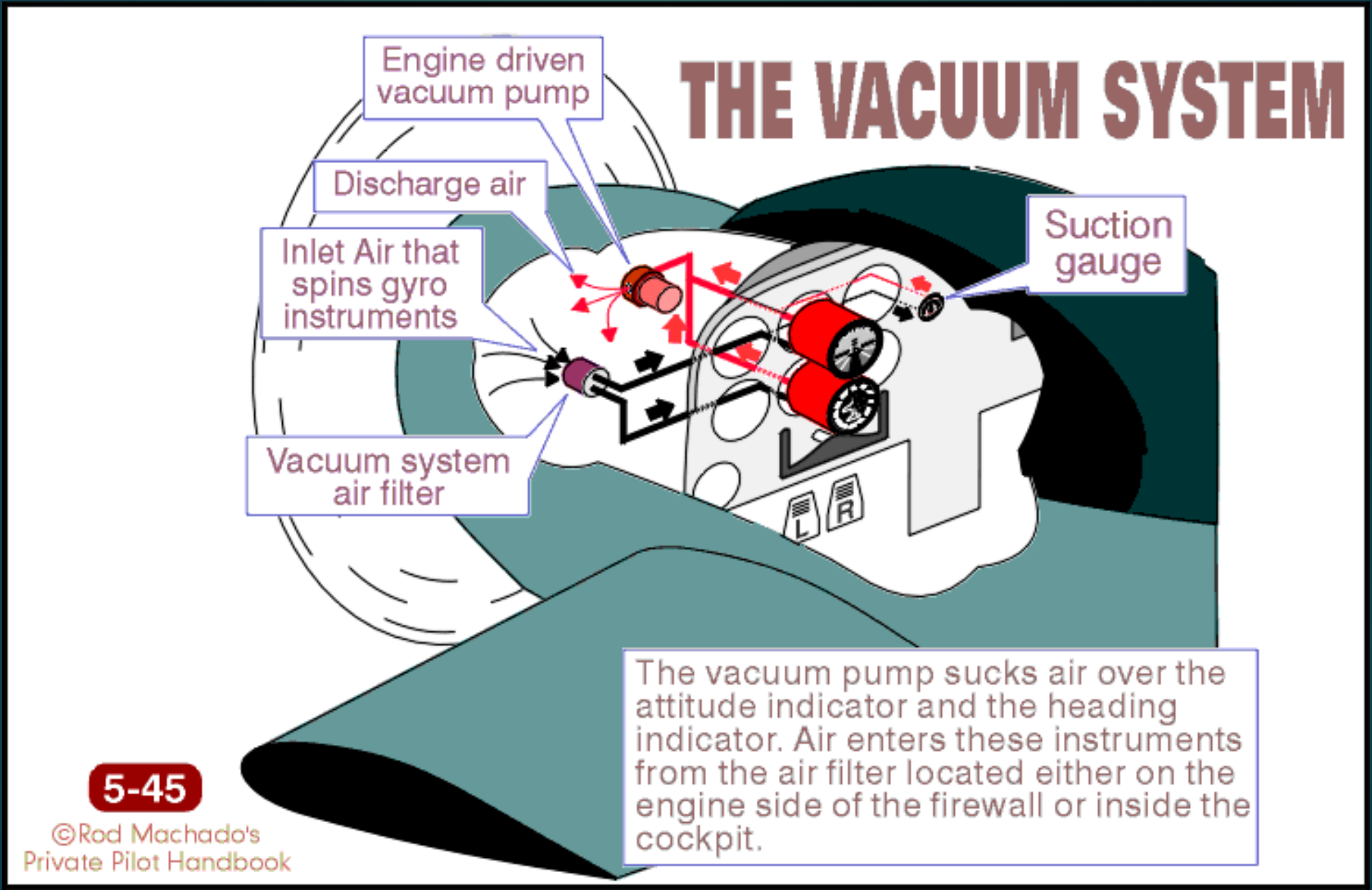
A child's toy top stays vertical or rigid in space when spun. When not spun, it easily falls to its side.

The same principle applies to modern day gyro instruments. A spinning gyro remains fixed in space allowing the airplane to rotate around it.

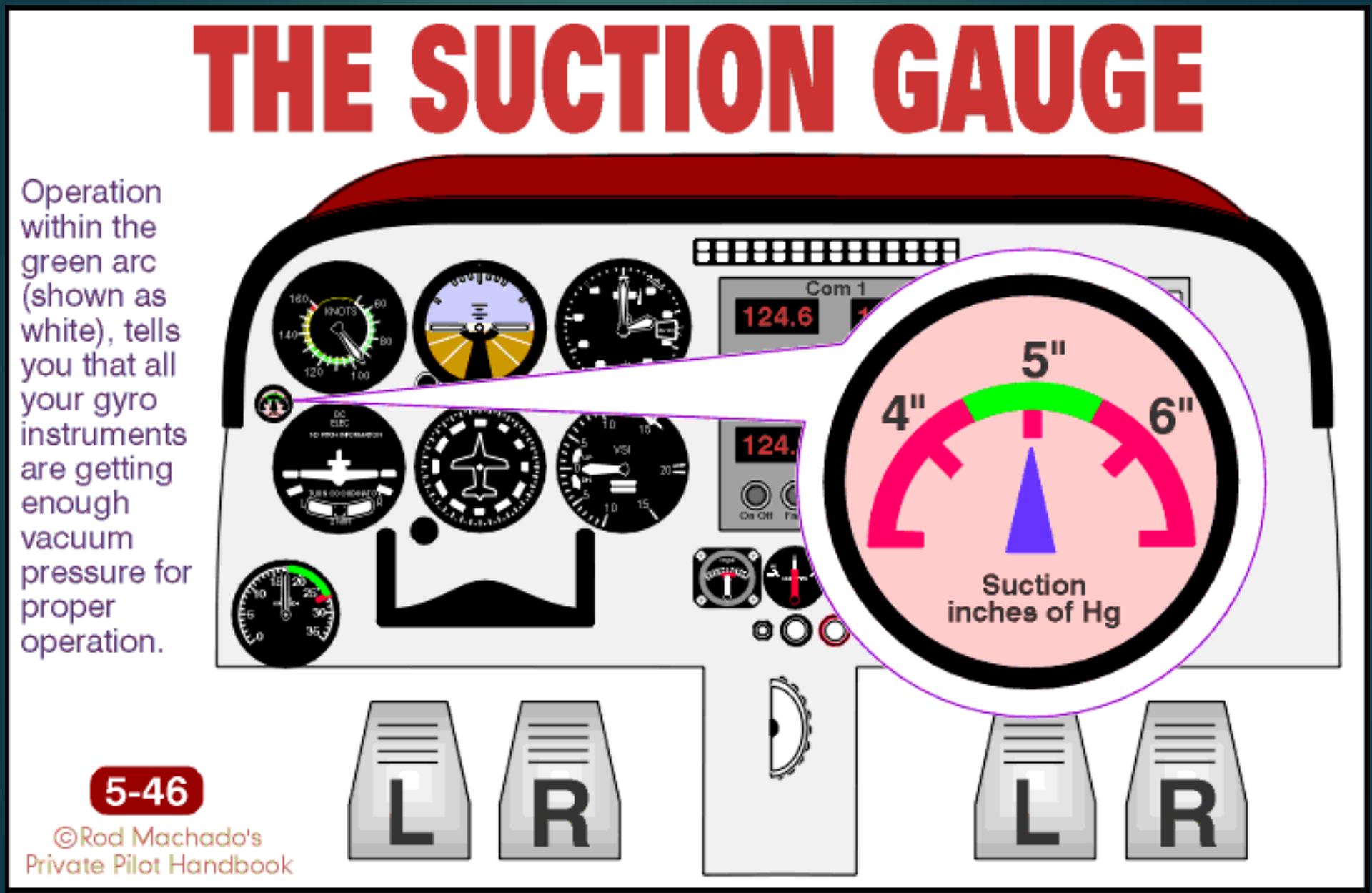




Gyroscope Principles



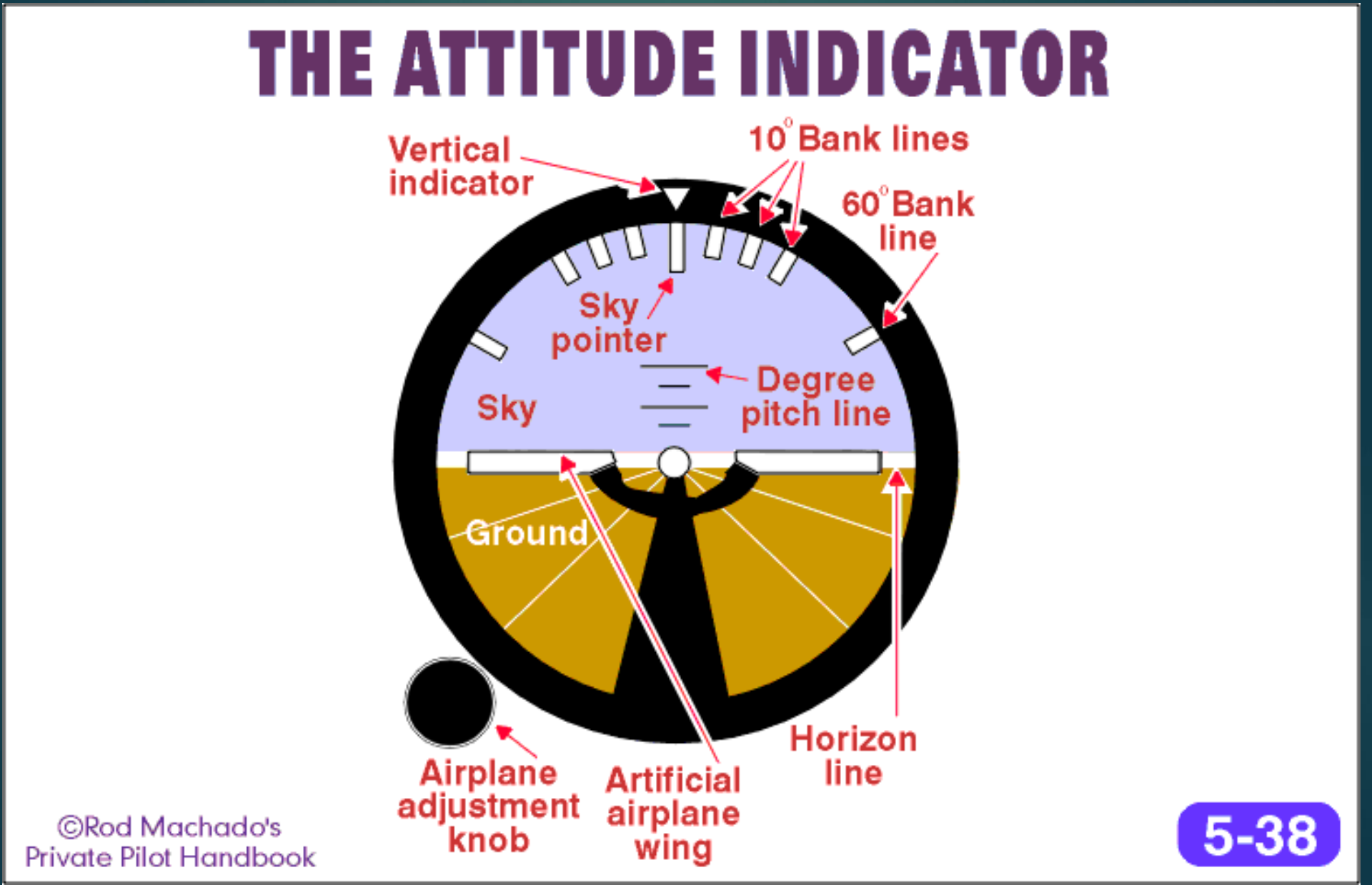
Gyroscope Principles



Gyroscopic Instruments:

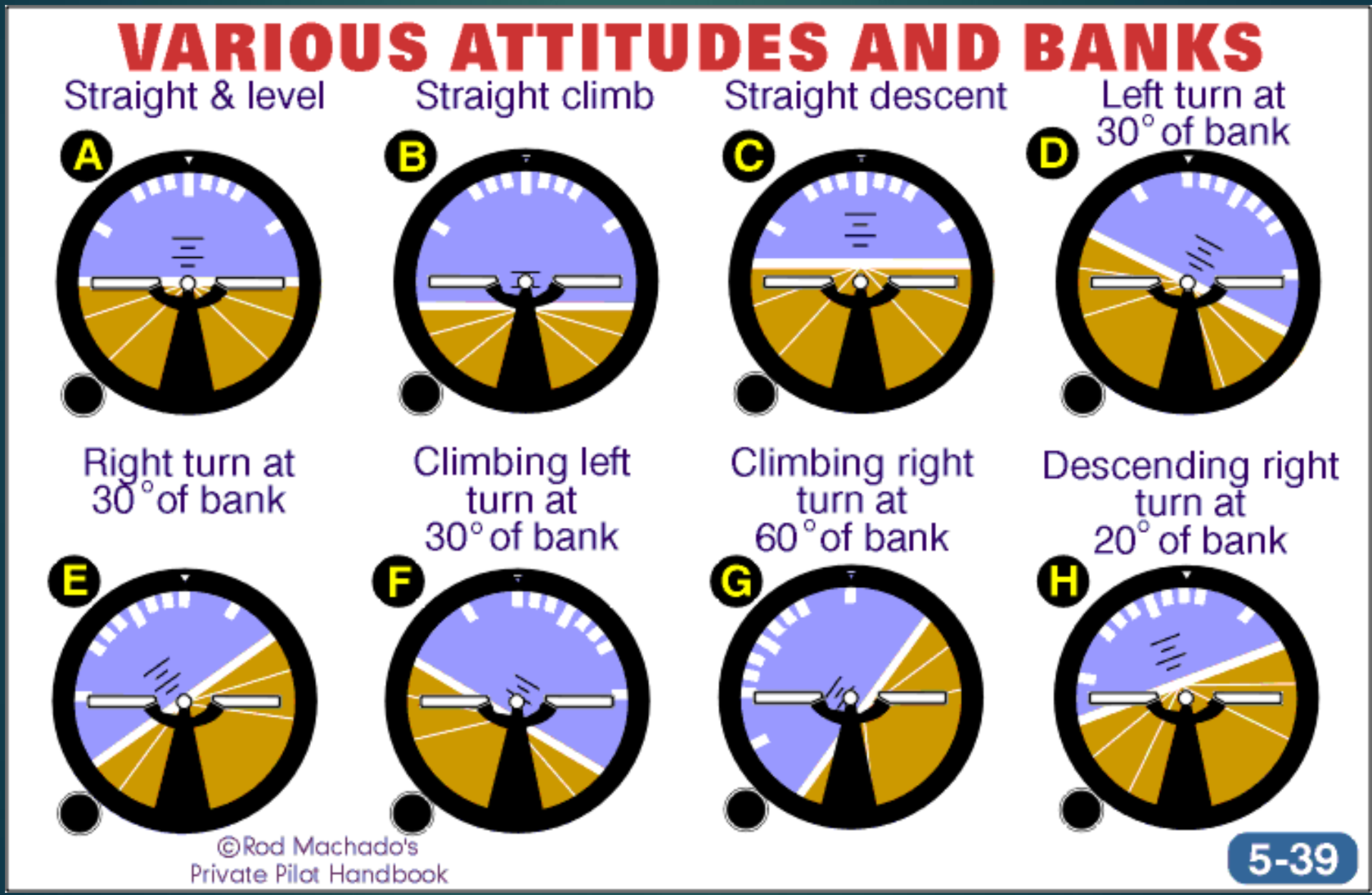
- **Attitude Indicator**
- Heading Indicator
- Turn Coordinator

Attitude Indicator: Steam Gauge

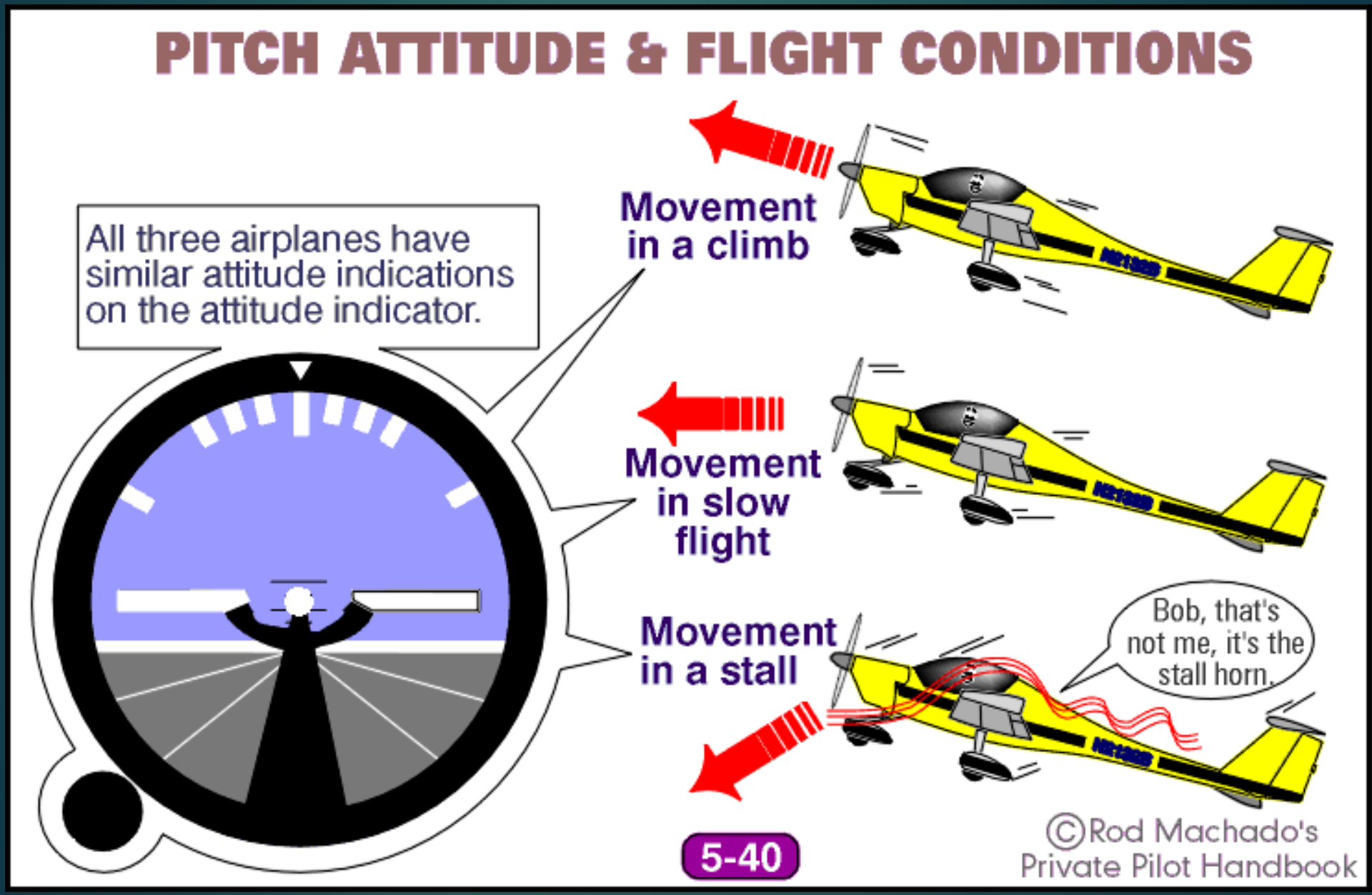


Attitude Indicator: Glass

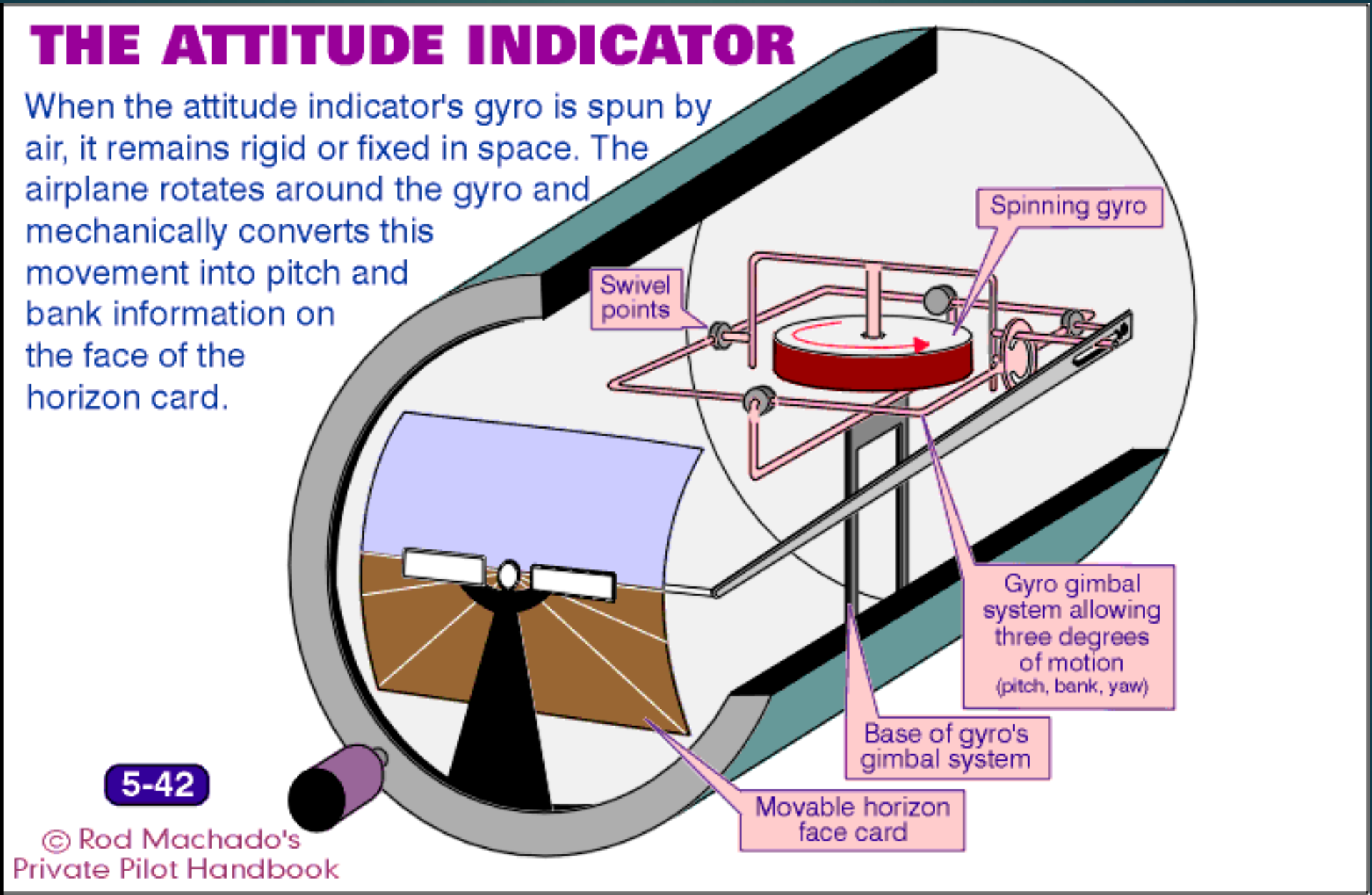
Attitude Indicator



Attitude Indicator



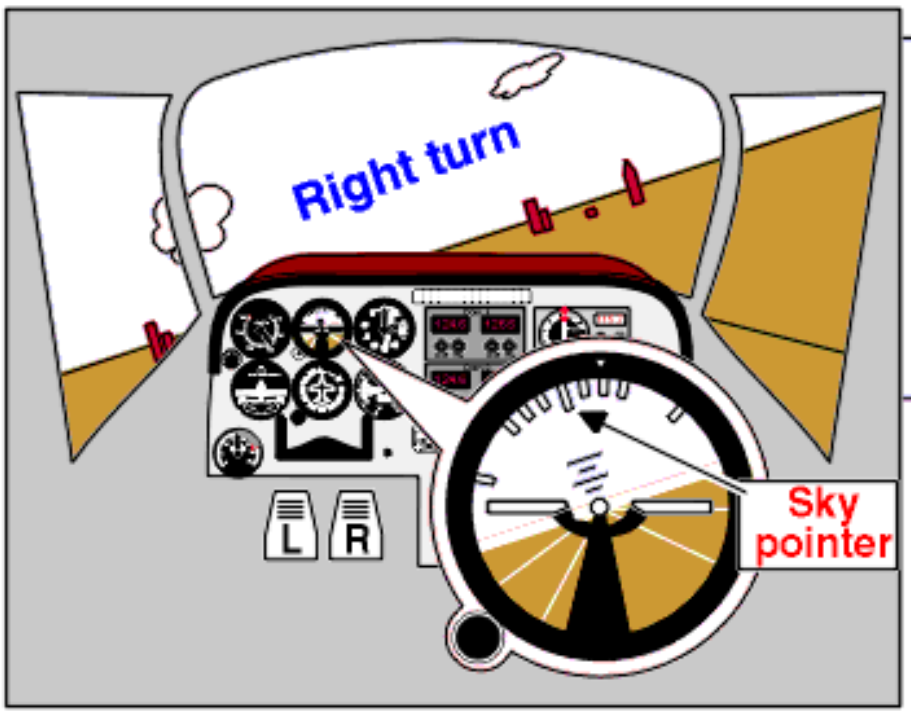
Attitude Indicator

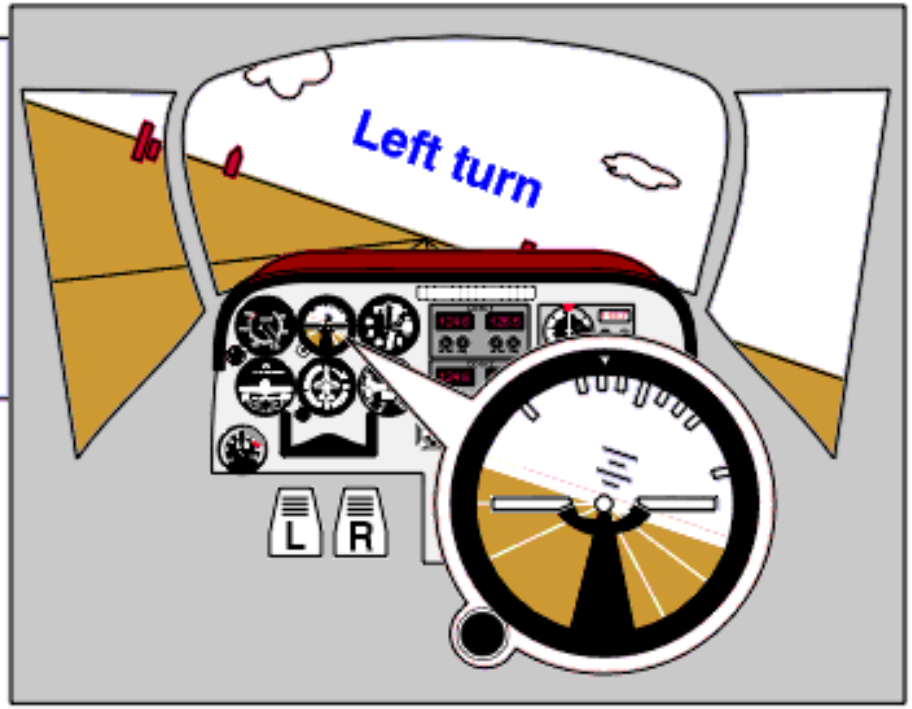


Attitude Indicator

THE HORIZON LINE

The attitude indicator's horizon line remains parallel to the earth's surface at all times and the sky pointer always points upward to the sky.

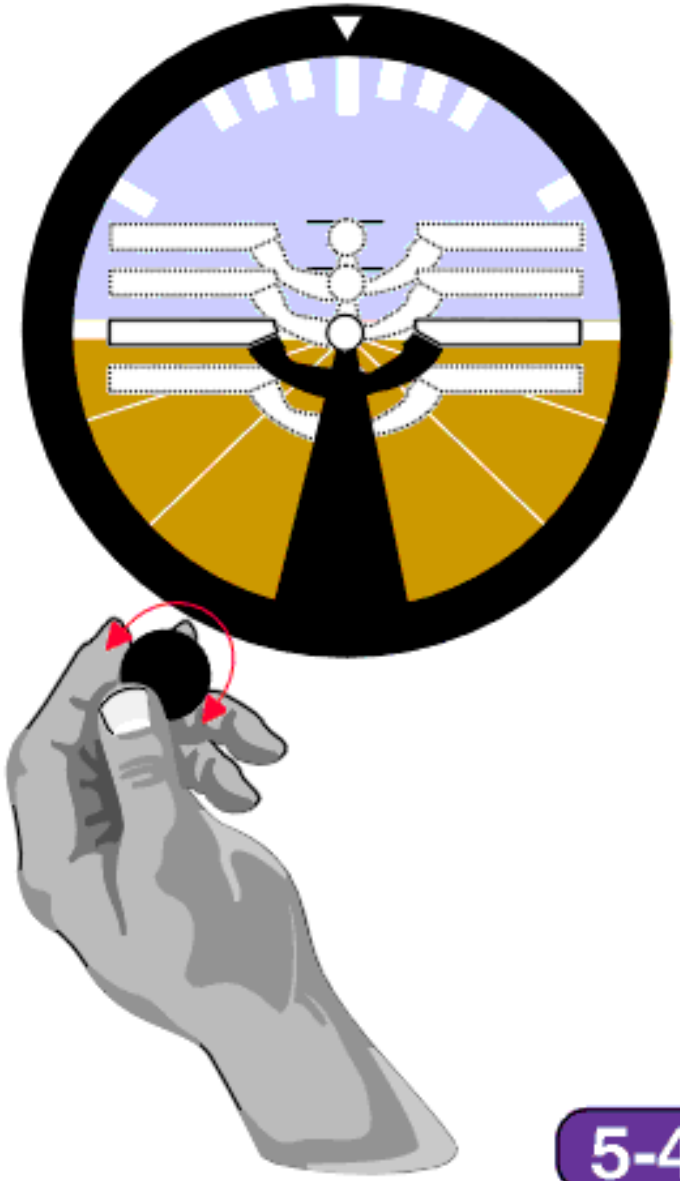




Attitude Indicator

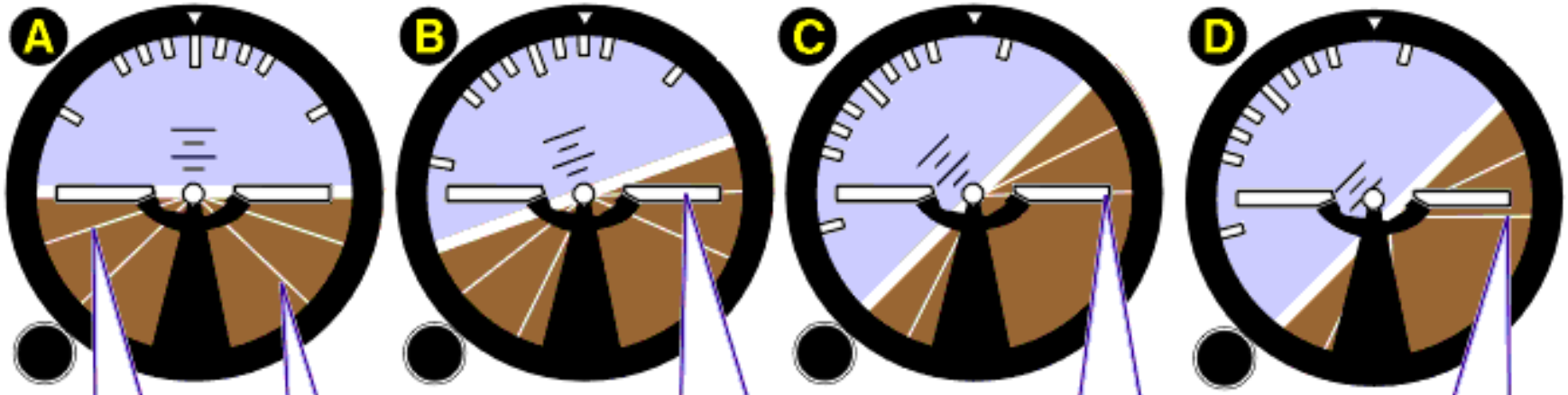
ATTITUDE INDICATOR ADJUSTMENT KNOB

Turning the adjustment knob allows you to reset the small airplane's position. You may need to do this to show the straight & level position when flying at variable weights & speeds since this changes your angle of attack.



Attitude Indicator

THE ATTITUDE INDICATOR'S DIAGONAL BANK LINES



These are the attitude indicator's 20° & 45° bank lines (sometimes it's a 15°bank line vs. a 20°bank line).

The airplane's wings are parallel to the first white line which produces a 20° bank.

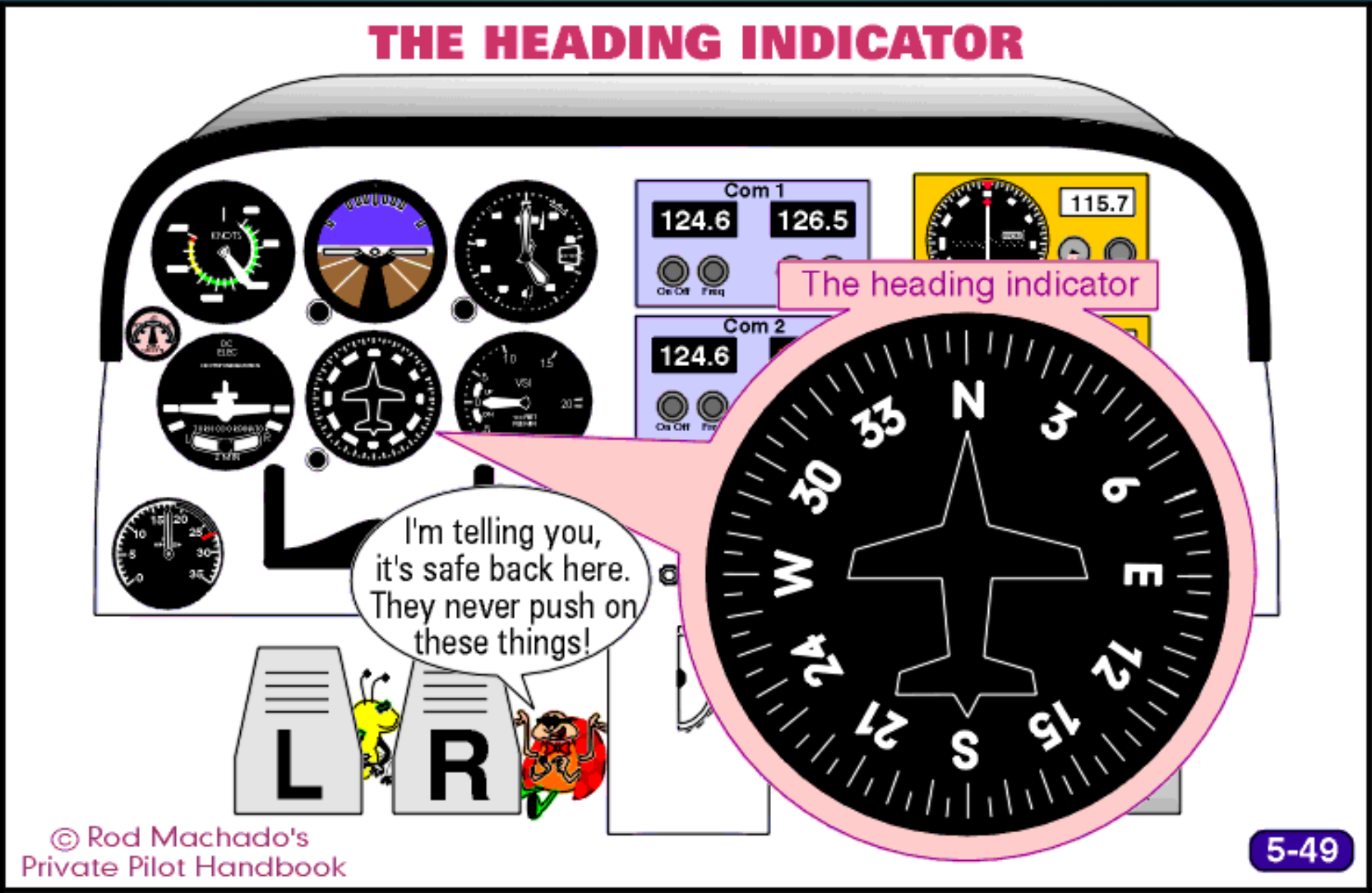
The airplane's wings are parallel to the second white line which produces a 45°degree bank.

The wings are above & parallel to the 45° bank line. The airplane is in a nose-up atttitude at a 45° bank.

Gyroscopic Instruments:

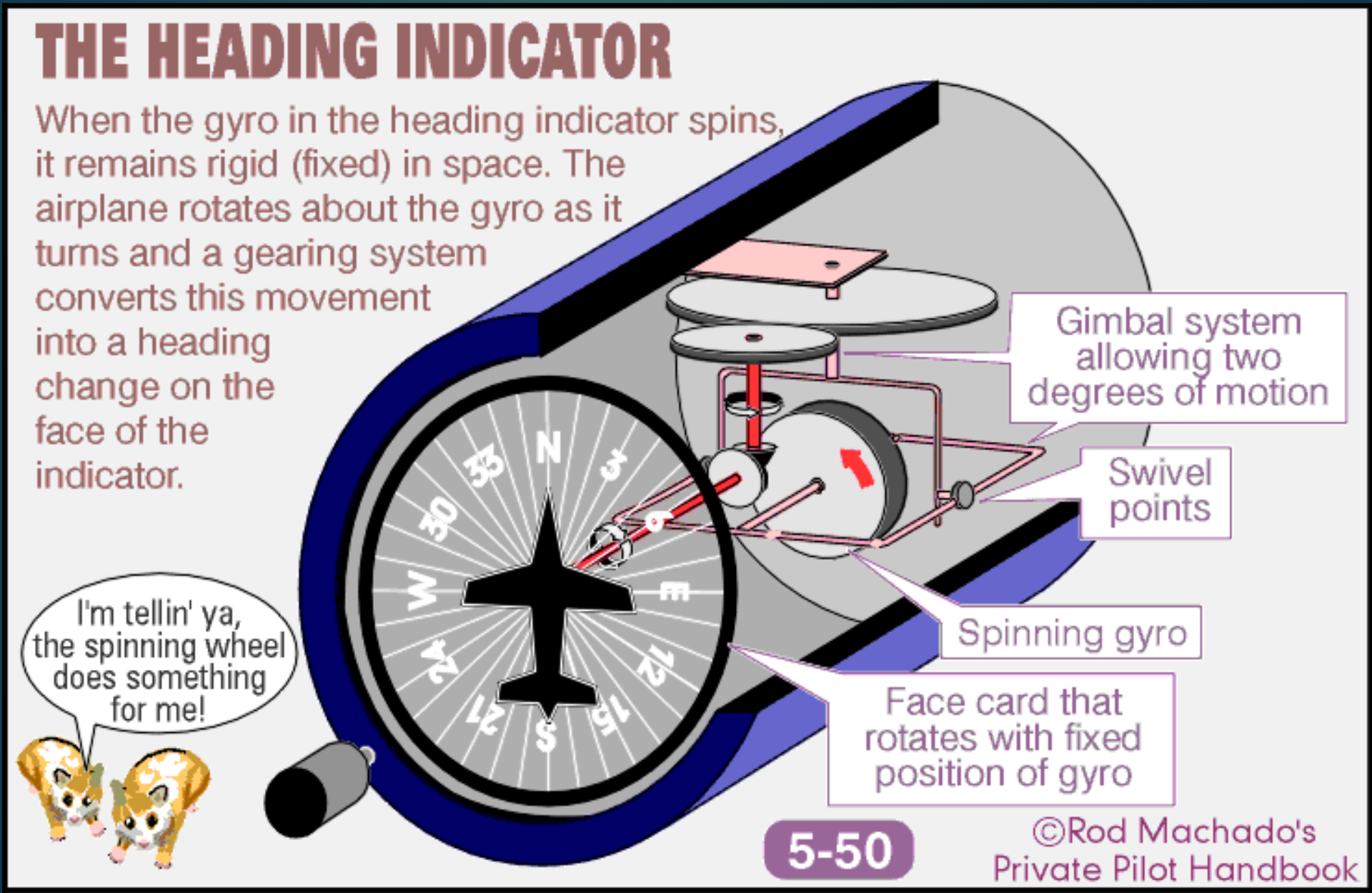
- Attitude Indicator
- **Heading Indicator**
- Turn Coordinator

Heading Indicator – Steam Gauge



Heading Indicator – Glass

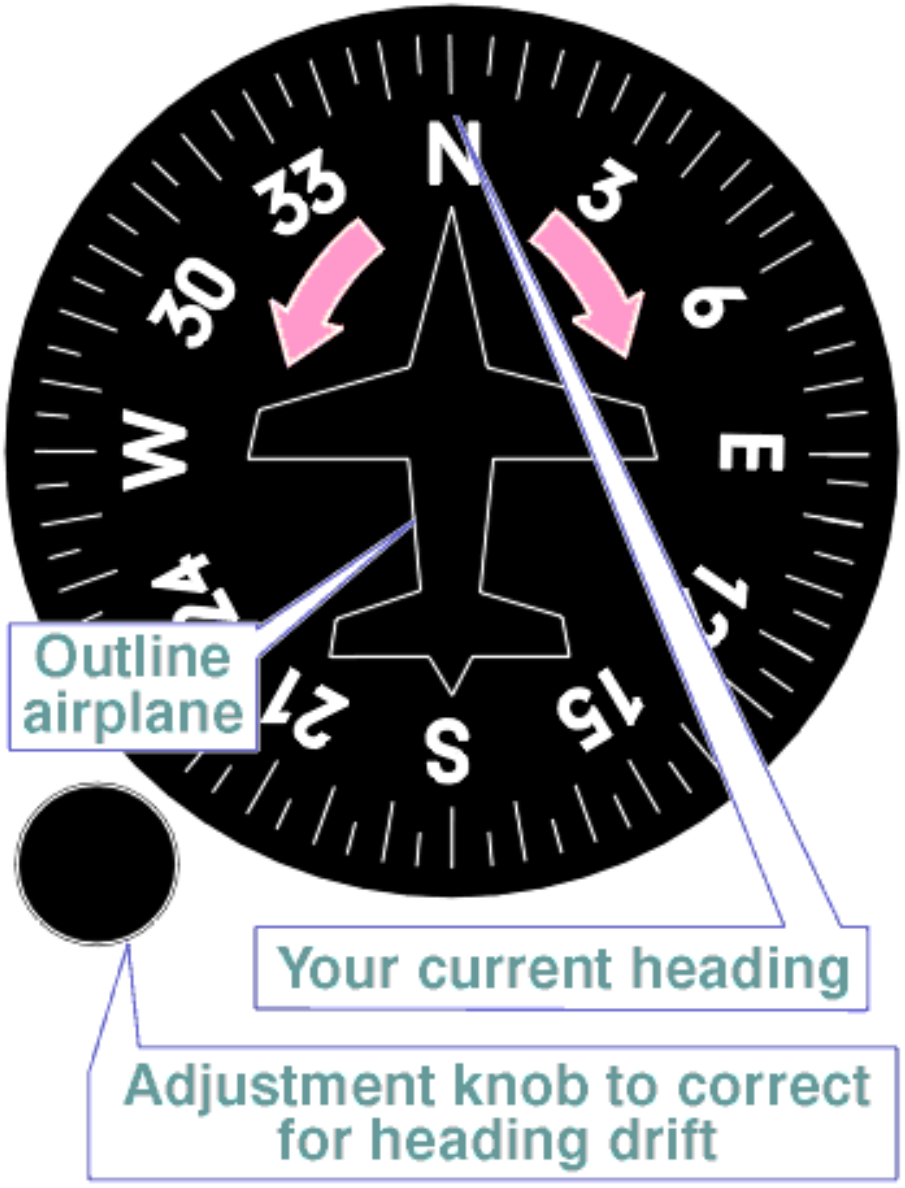
Heading Indicator



Heading Indicator

HEADING INDICATOR

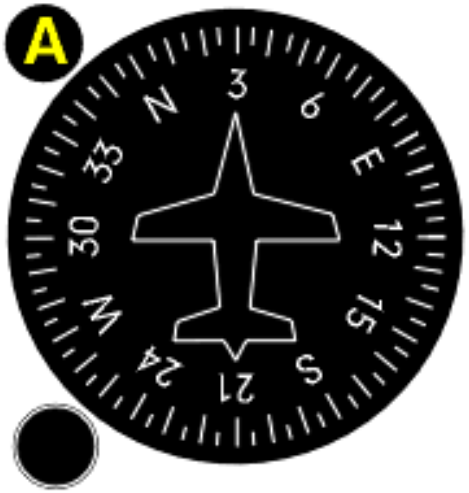
The outline airplane's nose in the heading indicator points to the actual airplane's magnetic heading. As the airplane turns, the numbered disk rotates under the outline airplane allowing your new heading to appear on top.



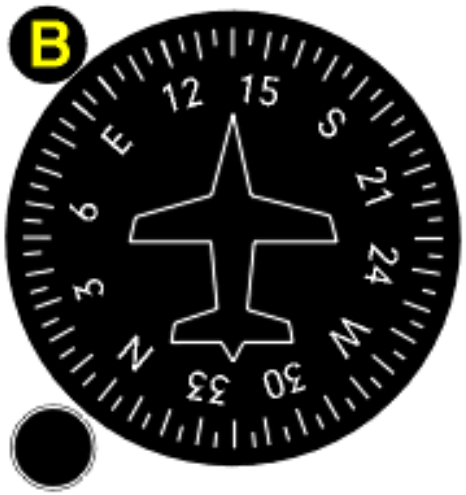
Heading Indicator

DIFFERENT HEADINGS

Heading "zero-three-zero"



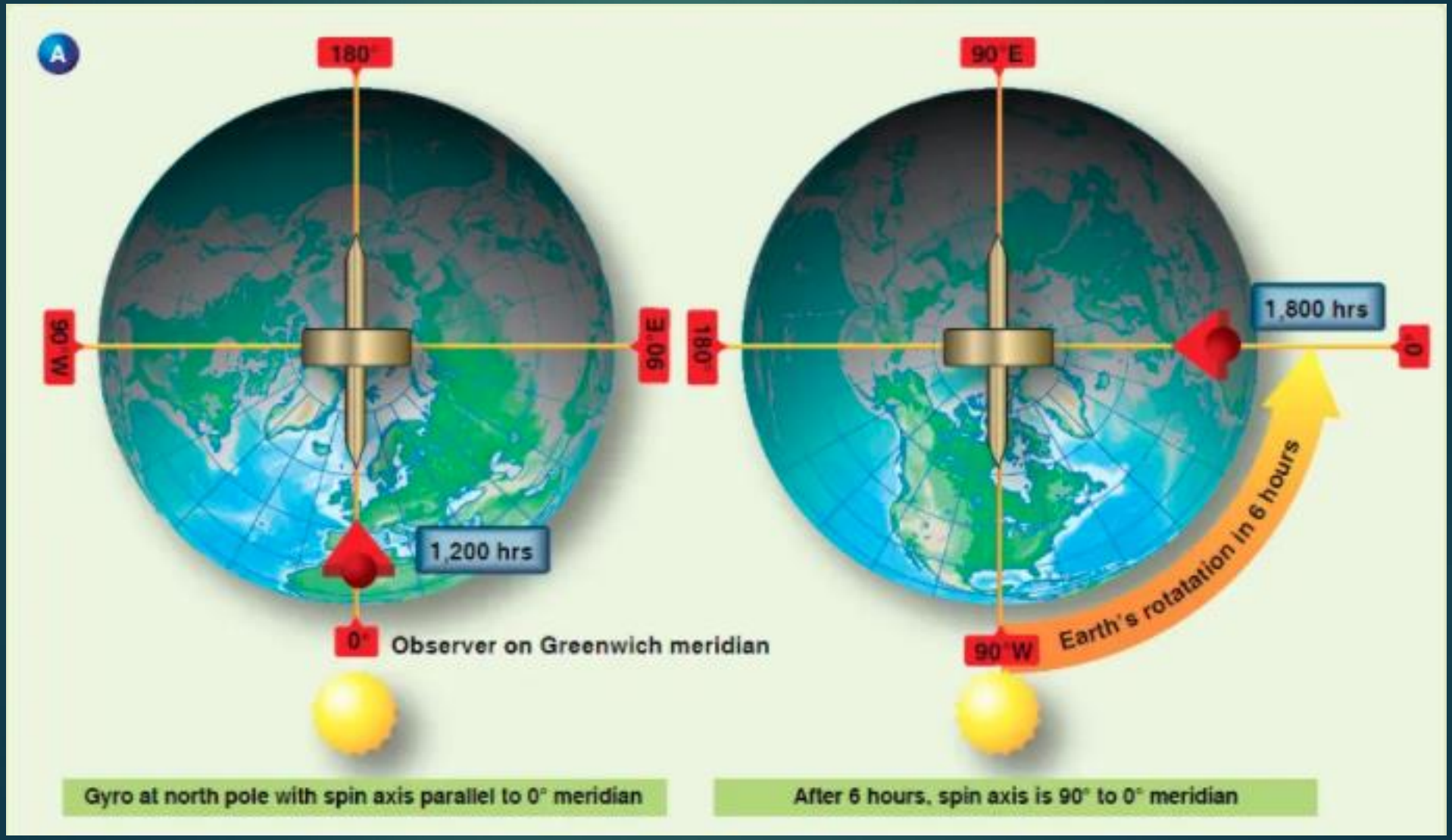
Heading "one-four-zero"



Heading "three-zero-zero"

Heading "three-zero-five"

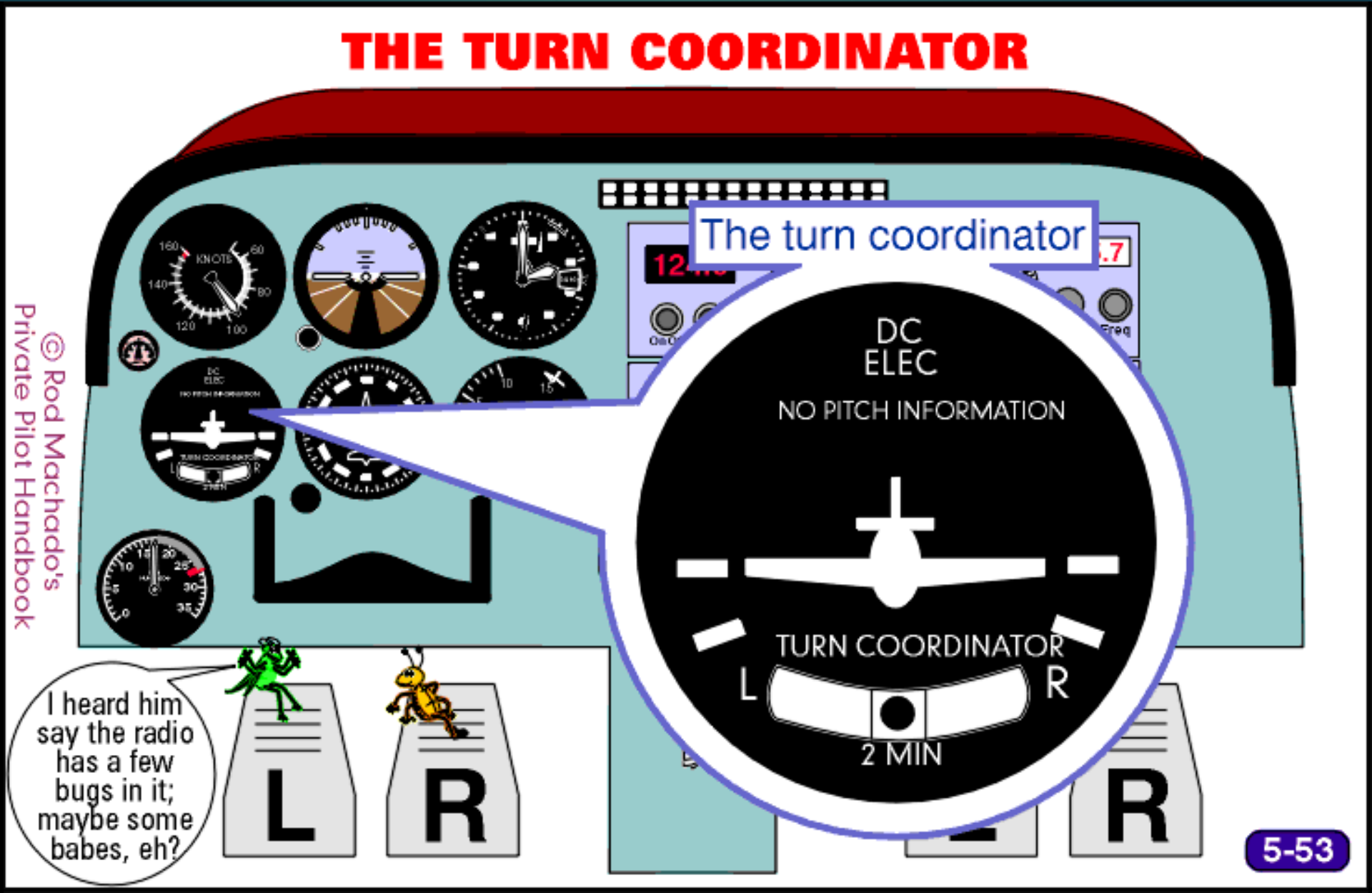
Gyroscopic Precession of HI



Gyroscopic Instruments:

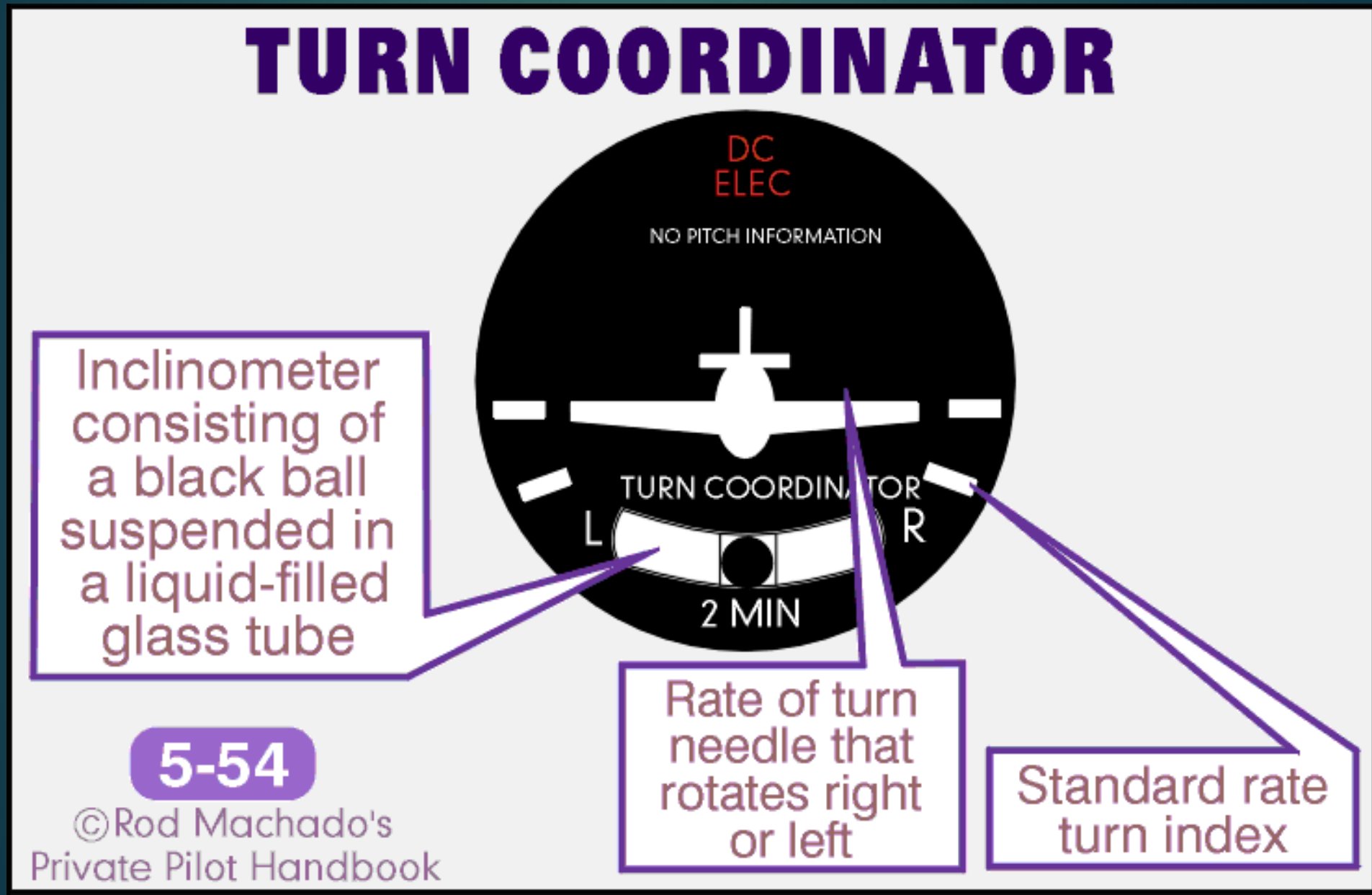
- Attitude Indicator
- Heading Indicator
- **Turn Coordinator**

Turn Coordinator: Steam Gauge

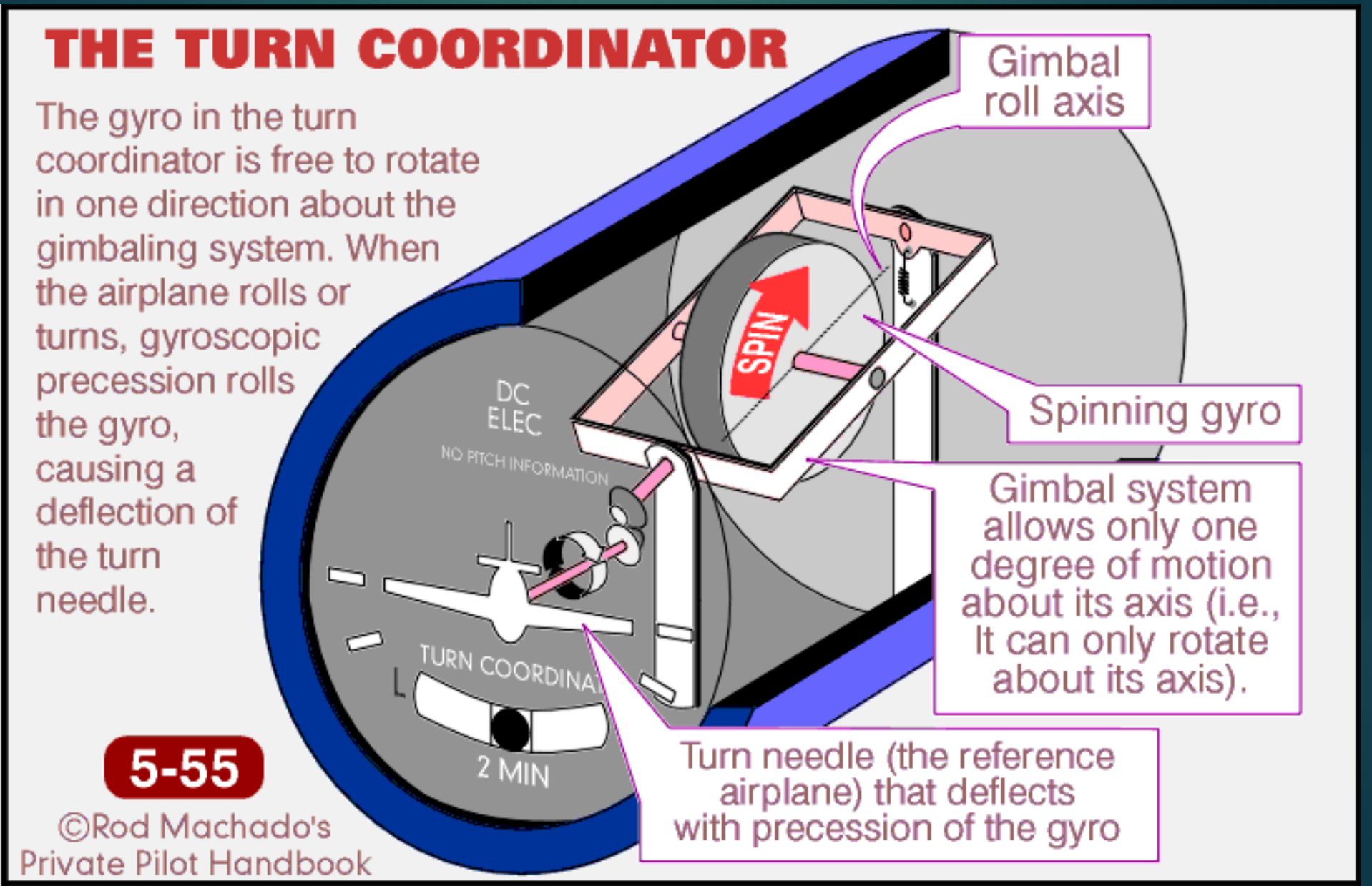


Turn Coordinator: Glass

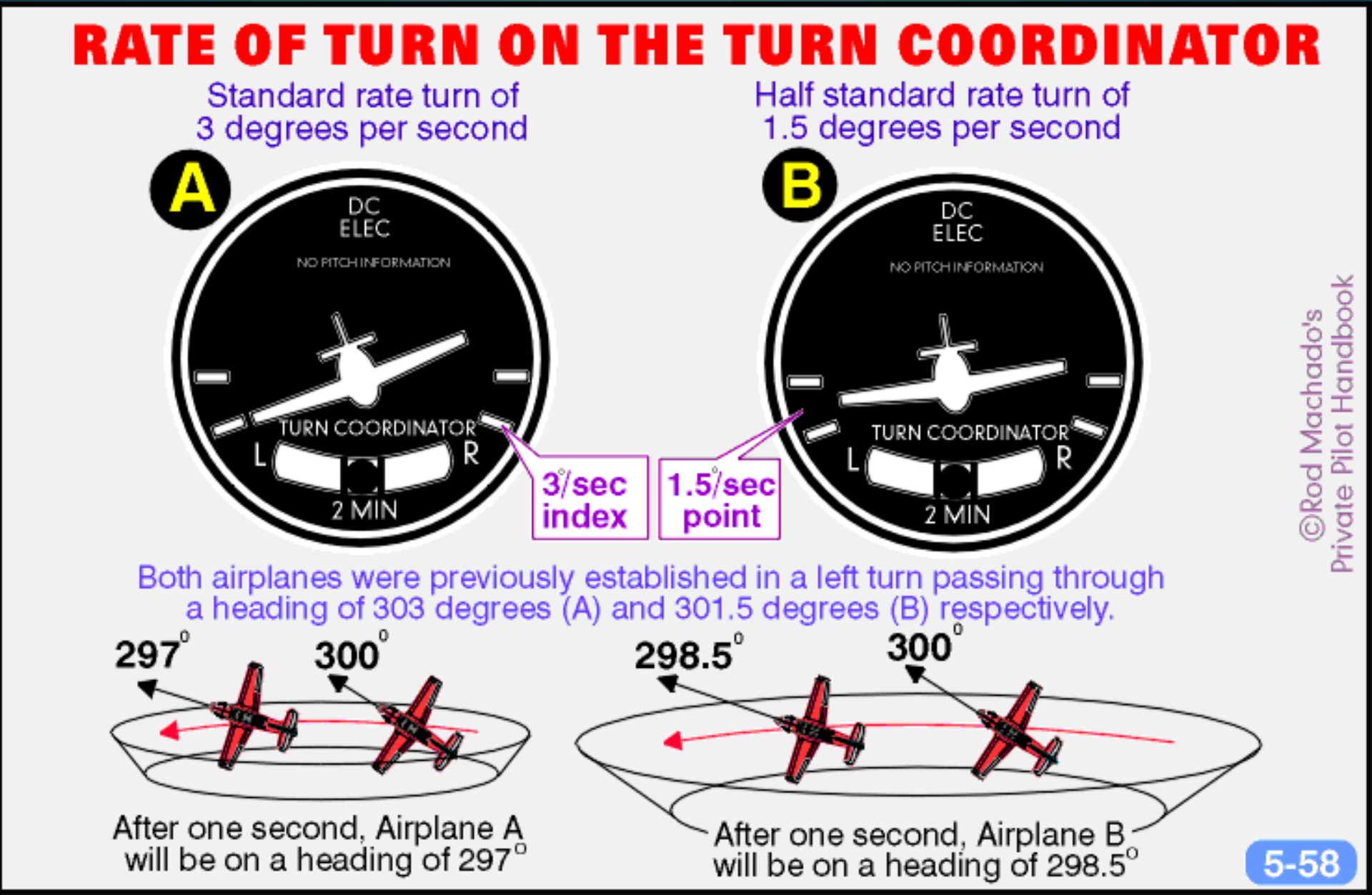
Turn Coordinator



Turn Coordinator

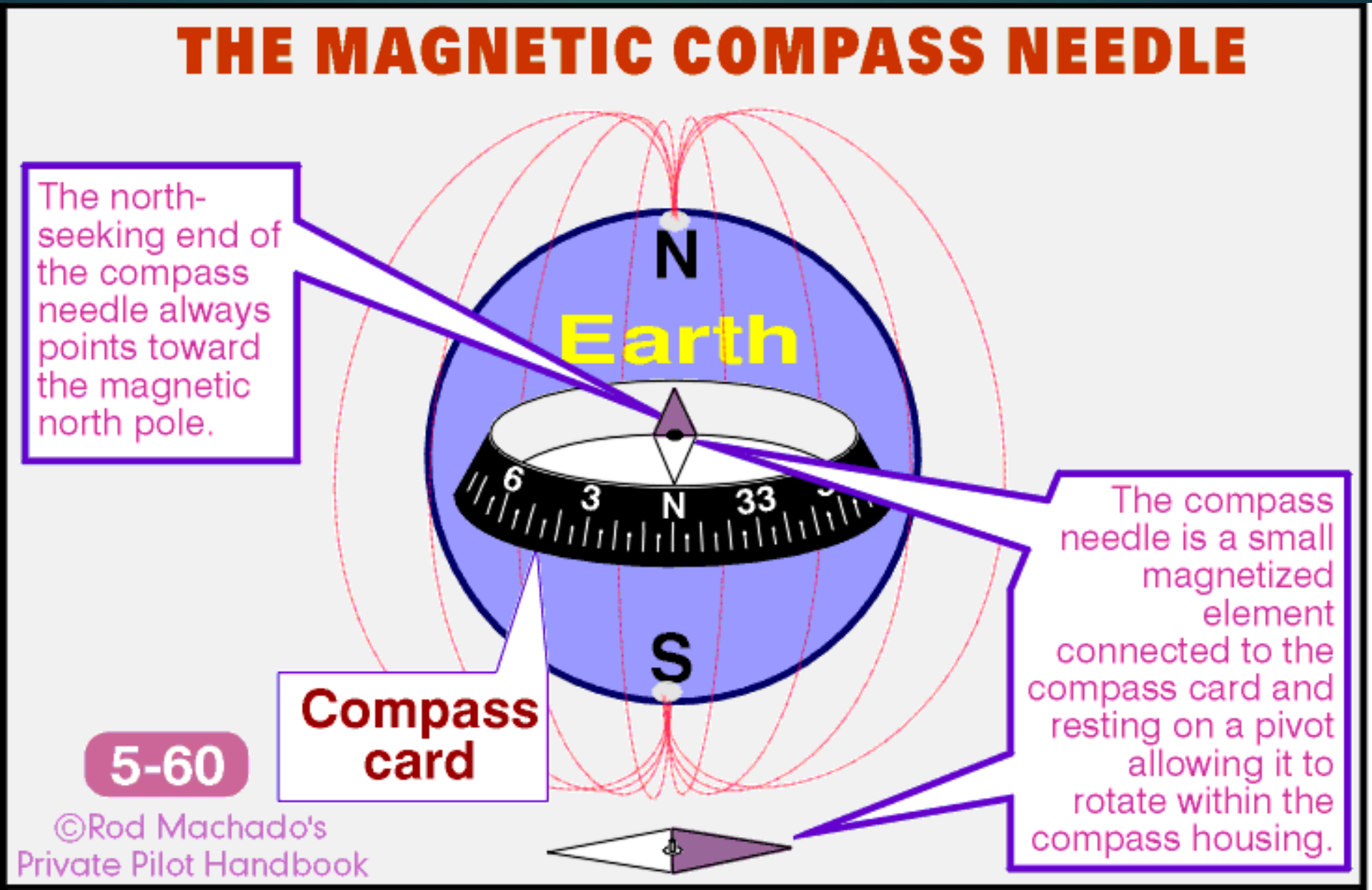


Turn Coordinator

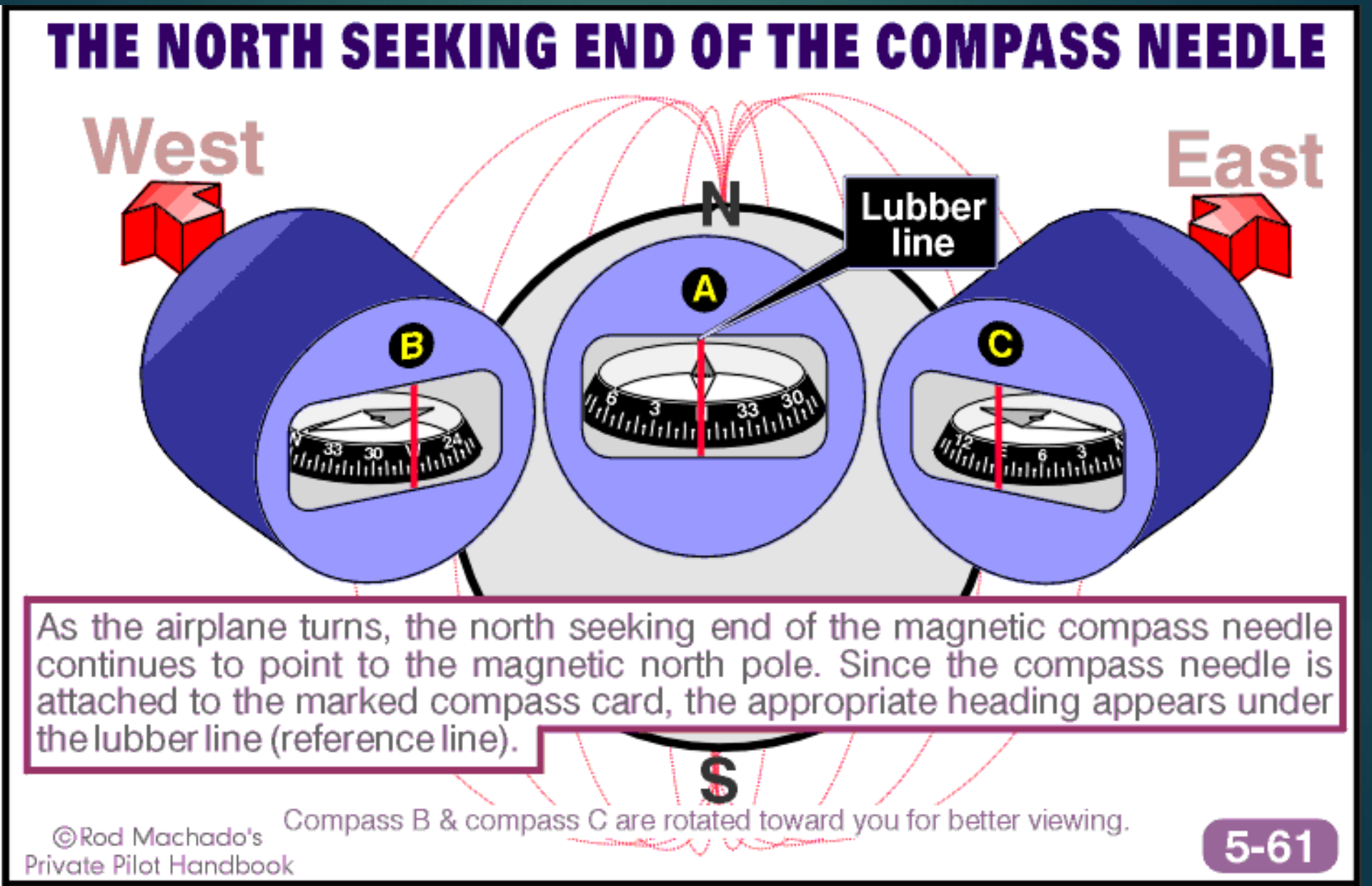


Magnetic Compass

Magnetic Compass

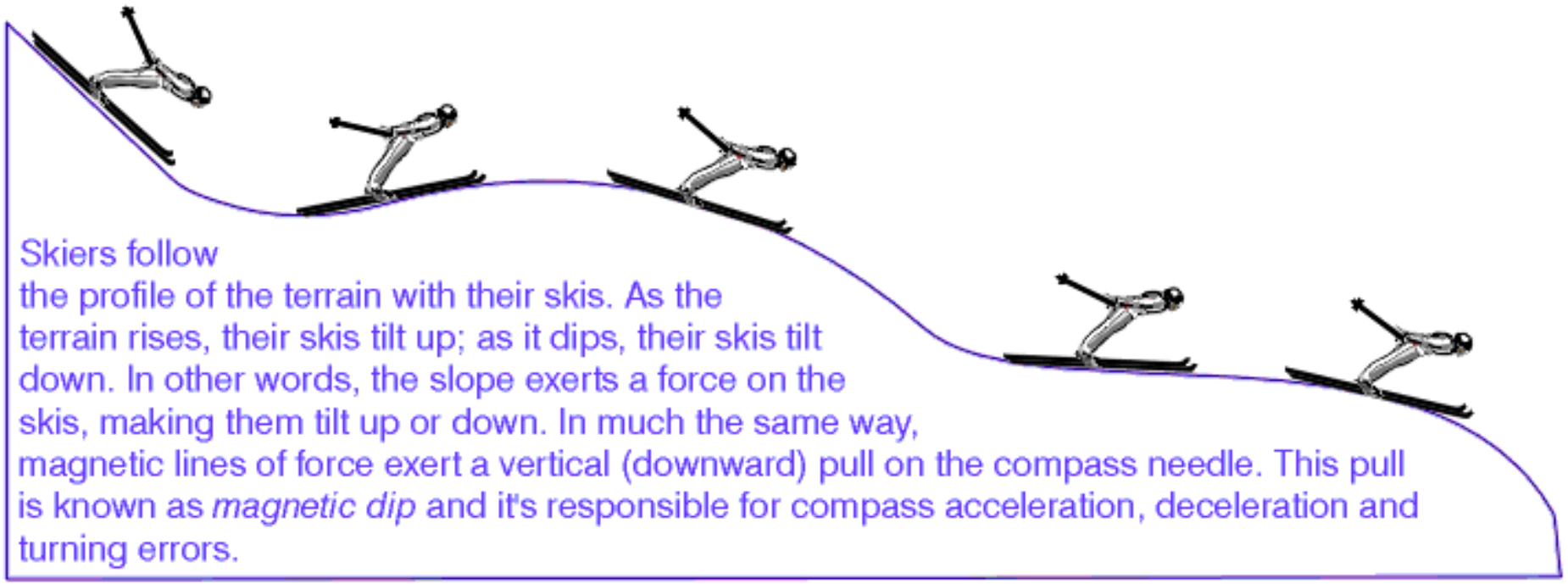


Magnetic Compass



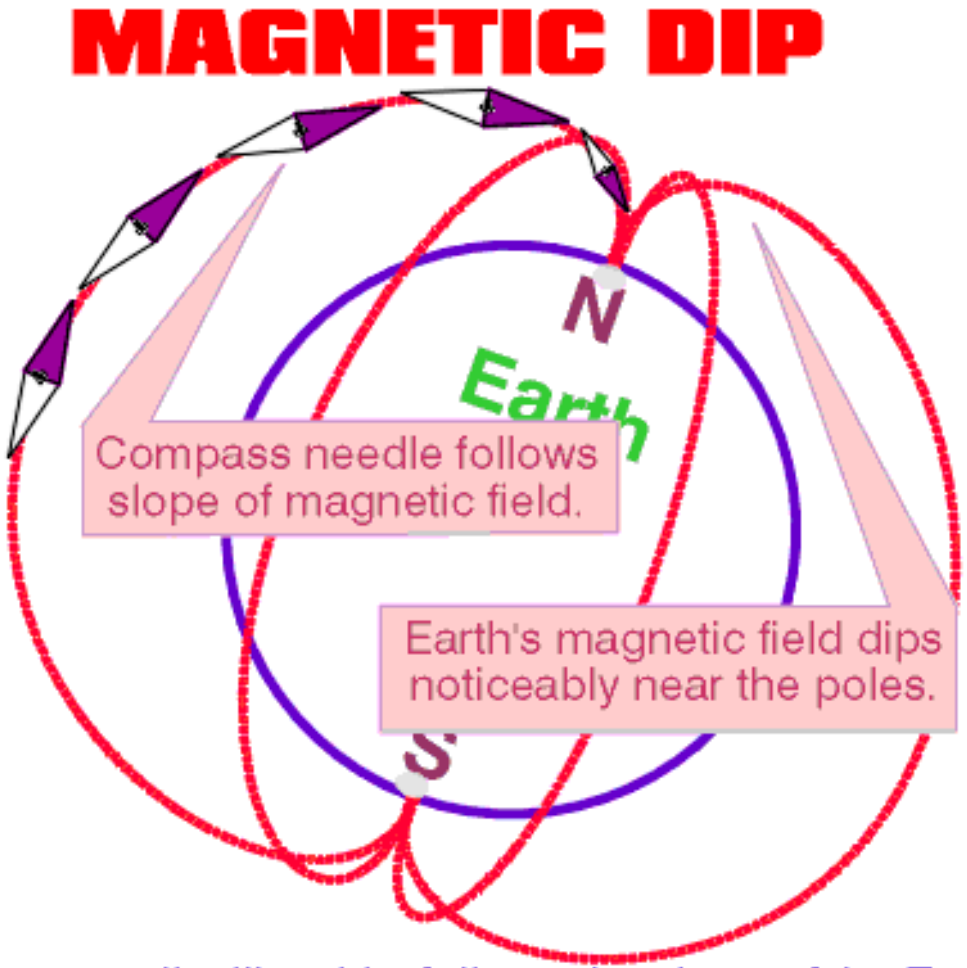
Magnetic Compass

SKI SLOPES & THE MAGNETIC COMPASS



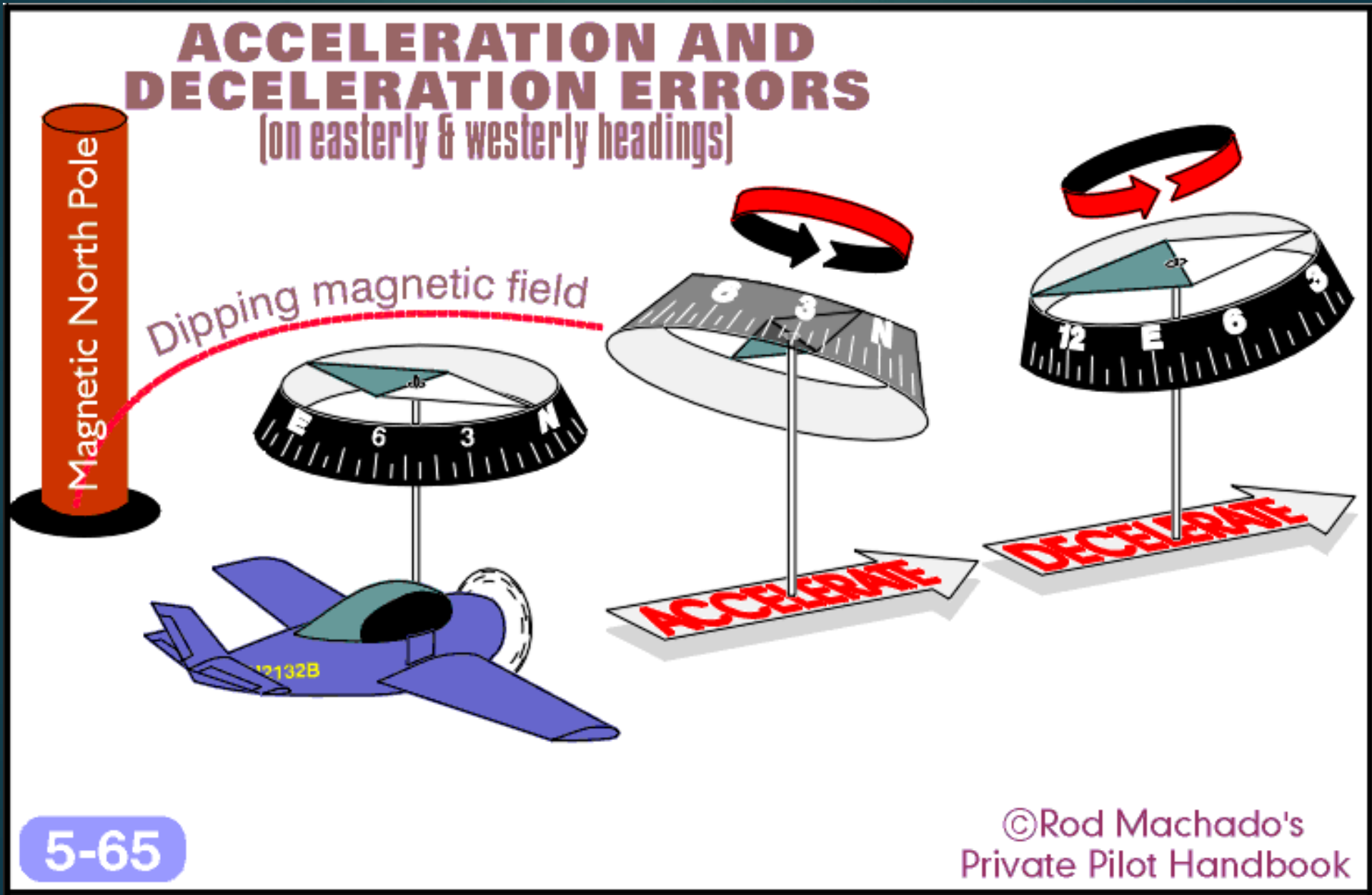
Skiers follow the profile of the terrain with their skis. As the terrain rises, their skis tilt up; as it dips, their skis tilt down. In other words, the slope exerts a force on the skis, making them tilt up or down. In much the same way, magnetic lines of force exert a vertical (downward) pull on the compass needle. This pull is known as *magnetic dip* and it's responsible for compass acceleration, deceleration and turning errors.

Magnetic Compass

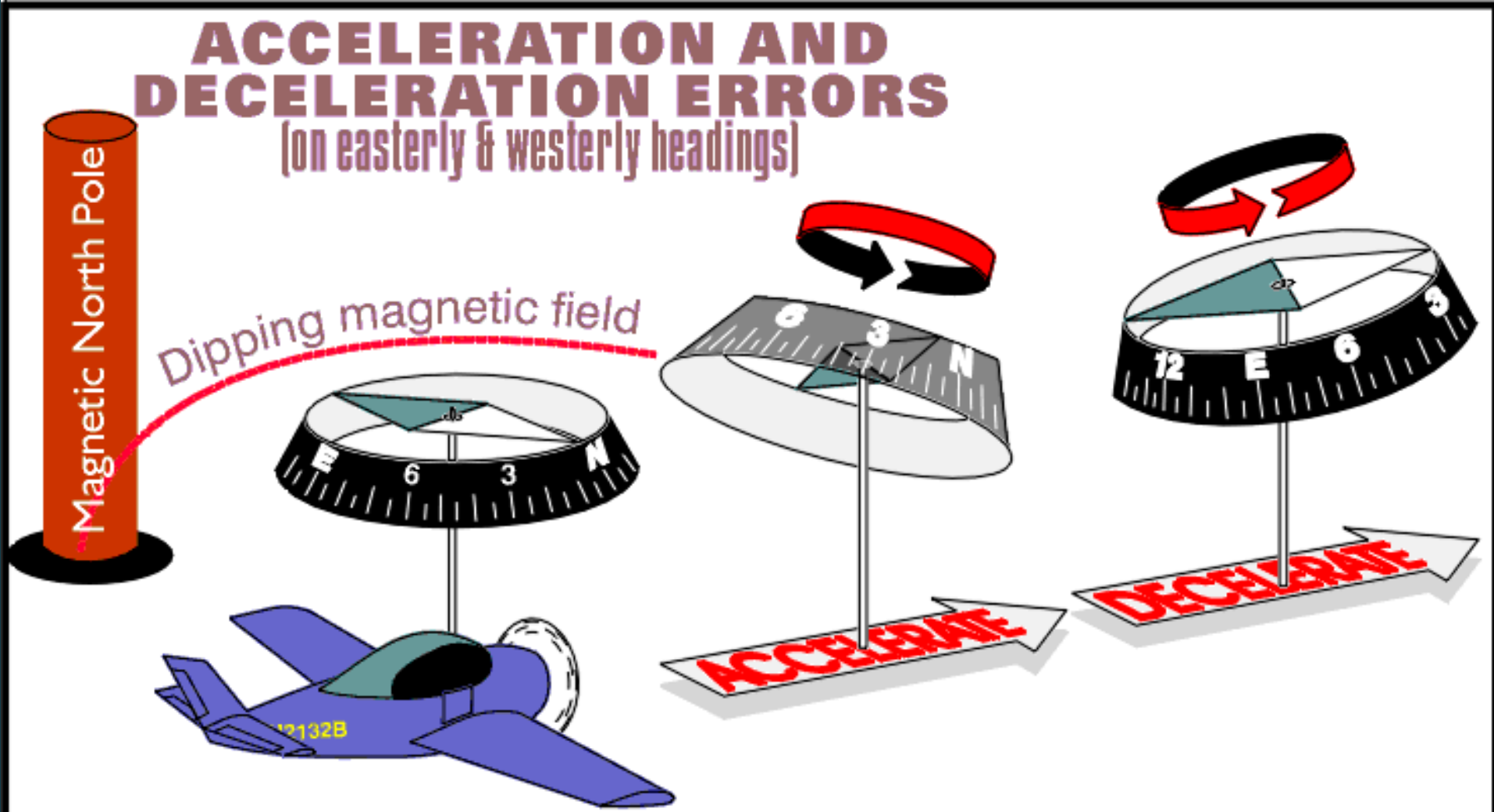


The magnetic compass needle, like skis, follows the slope of the Earth's magnetic field. Where the slope dips downward (near the poles), the compass needle also dips. This phenomena is known as magnetic dip.

Magnetic Compass

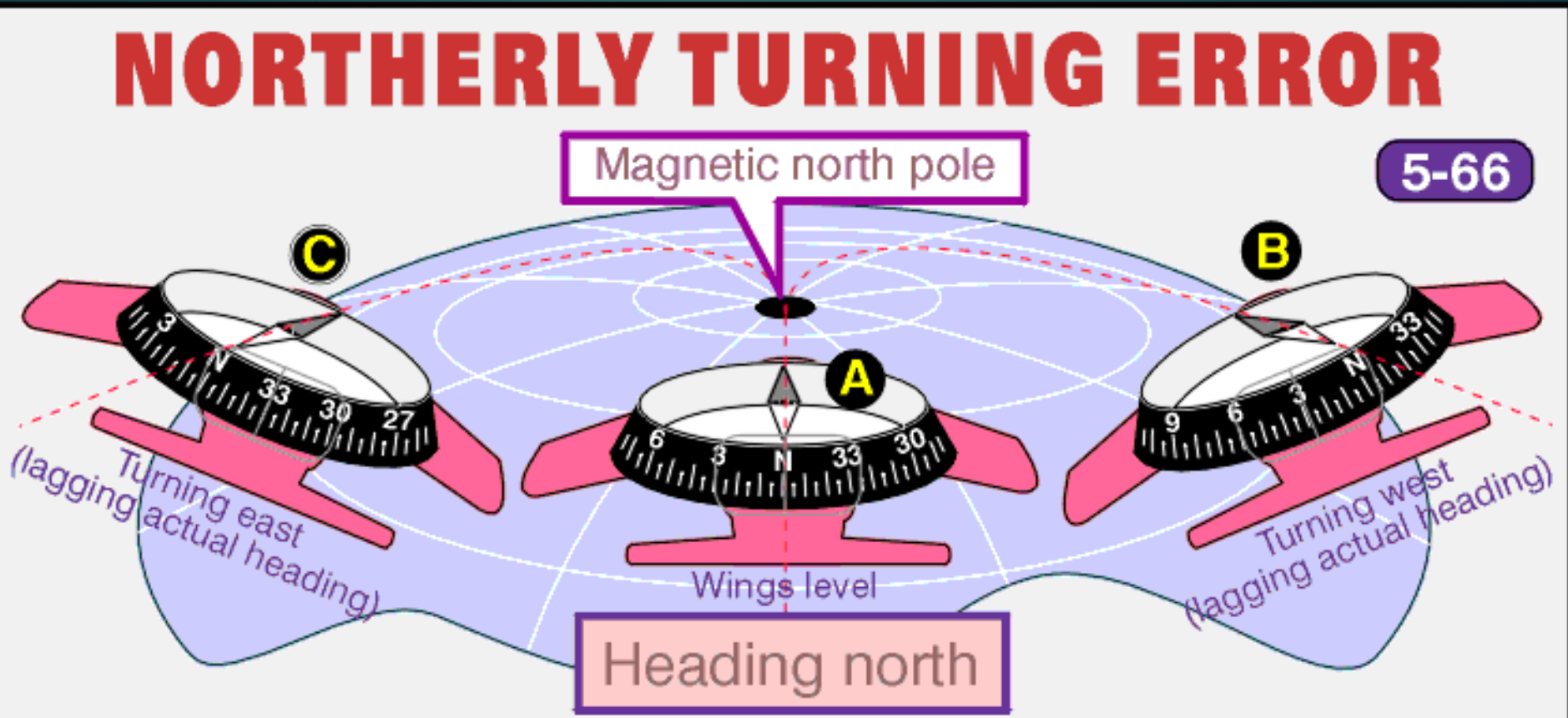


Magnetic Compass

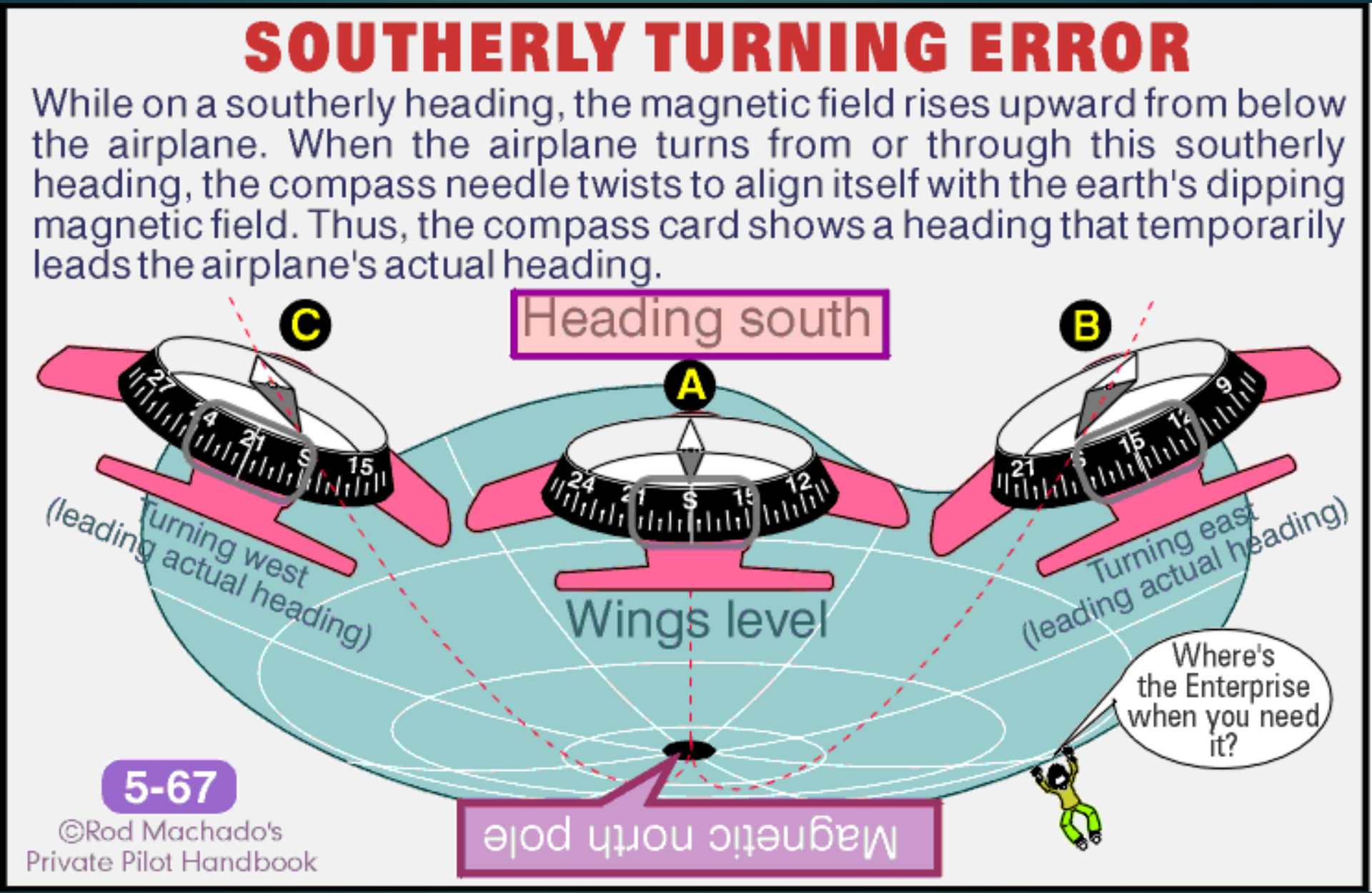


Accelerate North, Decelerate South = ANDS

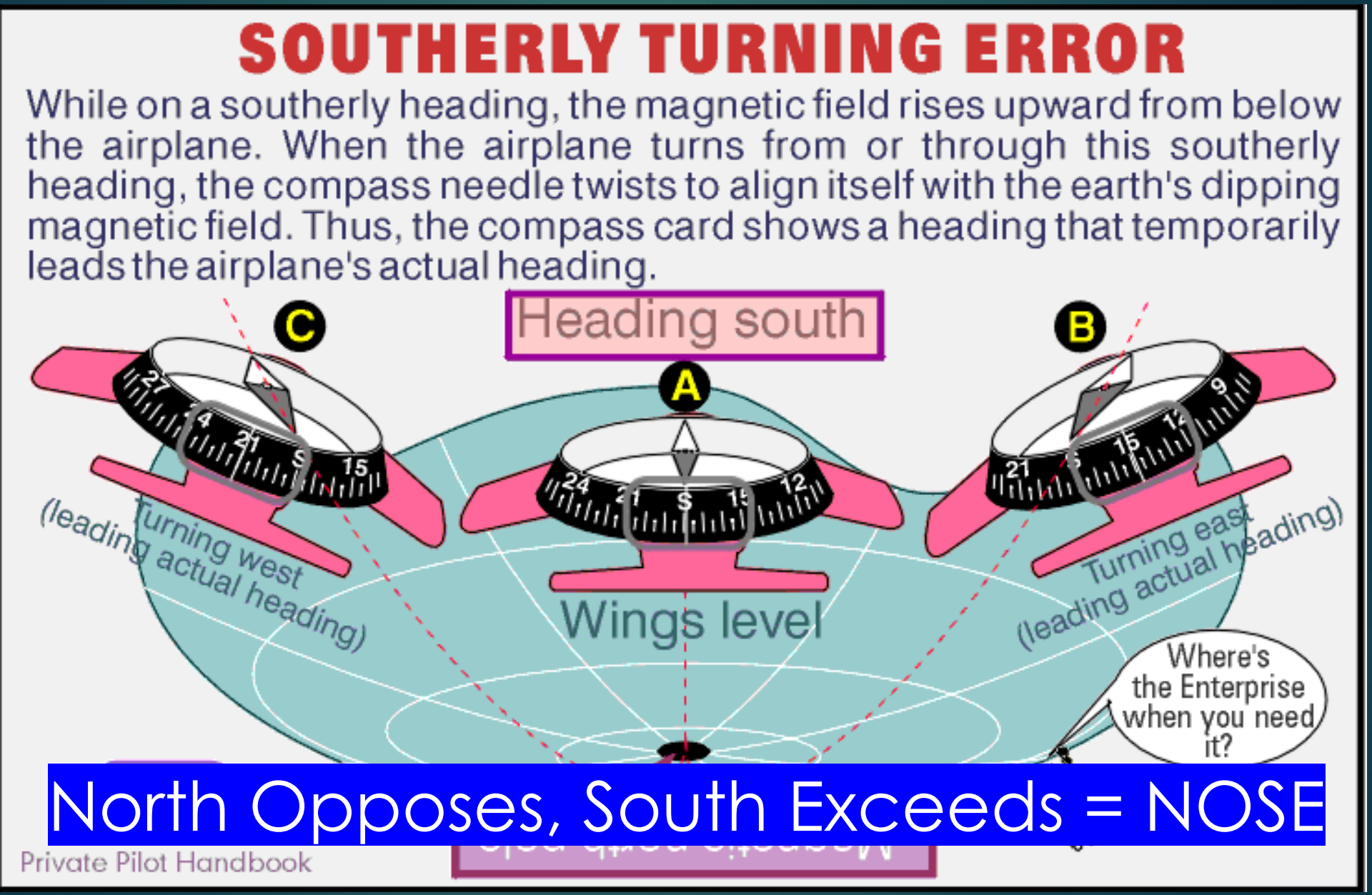
Magnetic Compass



Magnetic Compass



Magnetic Compass



North Opposes, South Exceeds = NOSE

ANDS: **A**ccelerate **N**orth, **D**ecelerate **S**outh
UNOS: **U**ndershoot **N**orth, **O**vershoot **S**outh
NOSE: **N**orth **O**pposes, **S**outh **E**xceeds

Next Session: Feb 12

- Quiz: Aerodynamics of Thrust & Drag
- Presentation: Airspace
- Reading:
  - Machado Chapter 9
  - Pilot's Handbook Chapter 15