CPL Theory
Aircraft Systems (CSYA)

CSYA 12 – Flight Instruments

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3. Disclaimer

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TYPES OF INSTRUMENTS

Types of Instruments

Engine Instruments:

- Oil Temperature & Pressure Gauges
- Fuel Quantity & Pressure Gauges
- CHT & EGT Gauges
- Tachometer
- Manifold Pressure Gauge (for aircraft with MPPC)

Navigation Instruments:

- Magnetic Compass
- Clock
- Radio Navigation Aid Instruments e.g. NDB, VOR

Flight Instruments:

- Pressure Instruments
  - Airspeed Indicator, Altimeter, Vertical Speed Indicator

- Gyroscopic Instruments
  - Attitude Indicator, Directional Indicator, Turn Coordinator

Types of Instruments

Pressure Flight Instruments:

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

} **Powered by the Pitot-Static System**

Gyroscopic Flight Instruments:

- Attitude Indicator (or Artificial Horizon)
- Directional Indicator (or Directional Gyro)

} **Powered by the Vacuum System**

- Turn Coordinator

} **Powered electrically**

MAGNETIC COMPASS

Magnetic Compass

How it Works:

- Also known as the direct-indicating compass, it is powered by the Earth's local magnetic field and aligns with the magnetic poles

- Your magnetic heading can be read from the compass card under the lubber line on the face of the instrument

Magnetic Compass

How it Works:

- You may notice that your compass is filled with a clear liquid
- This is an alcohol and helps to decrease friction and compass oscillations, making it more accurate and easier to read in flight
- This is known as a “wet compass”

Magnetic Compass

Deviation Error and Compass Correction Card:

- The metal structure of the aircraft, rotating parts of the engine and aircraft radios all generate their own magnetic fields
- The effect of all of these fields on the compass' ability to align with the earth's magnetic field an error known as Magnetic Deviation
- To overcome this error, a Compass Correction Card is fitted
- Note that this will not overcome the effect of you placing magnetic objects such as headsets, pens, clipboards etc. near the compass

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

Magnetic Compass

Acceleration Error:

- In the southern hemisphere, compass acceleration error can be summarised by the “SAND” pneumonic:

“South – Accelerate”

When accelerating east OR west, the compass will show an apparent turn to the south

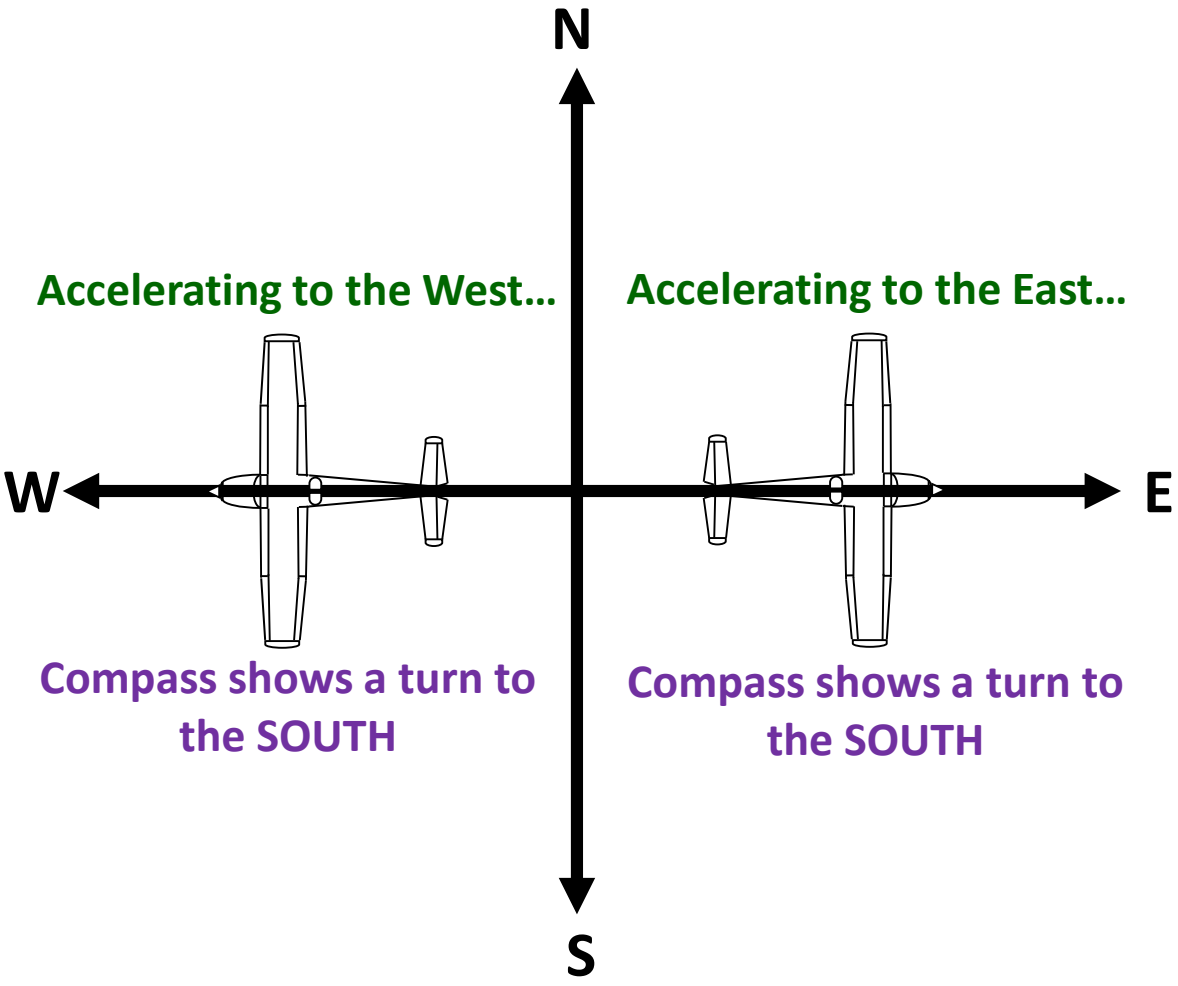
“North – Decelerate”

When decelerating east OR west, the compass will show an apparent turn to the north

Magnetic Compass

Acceleration Error:

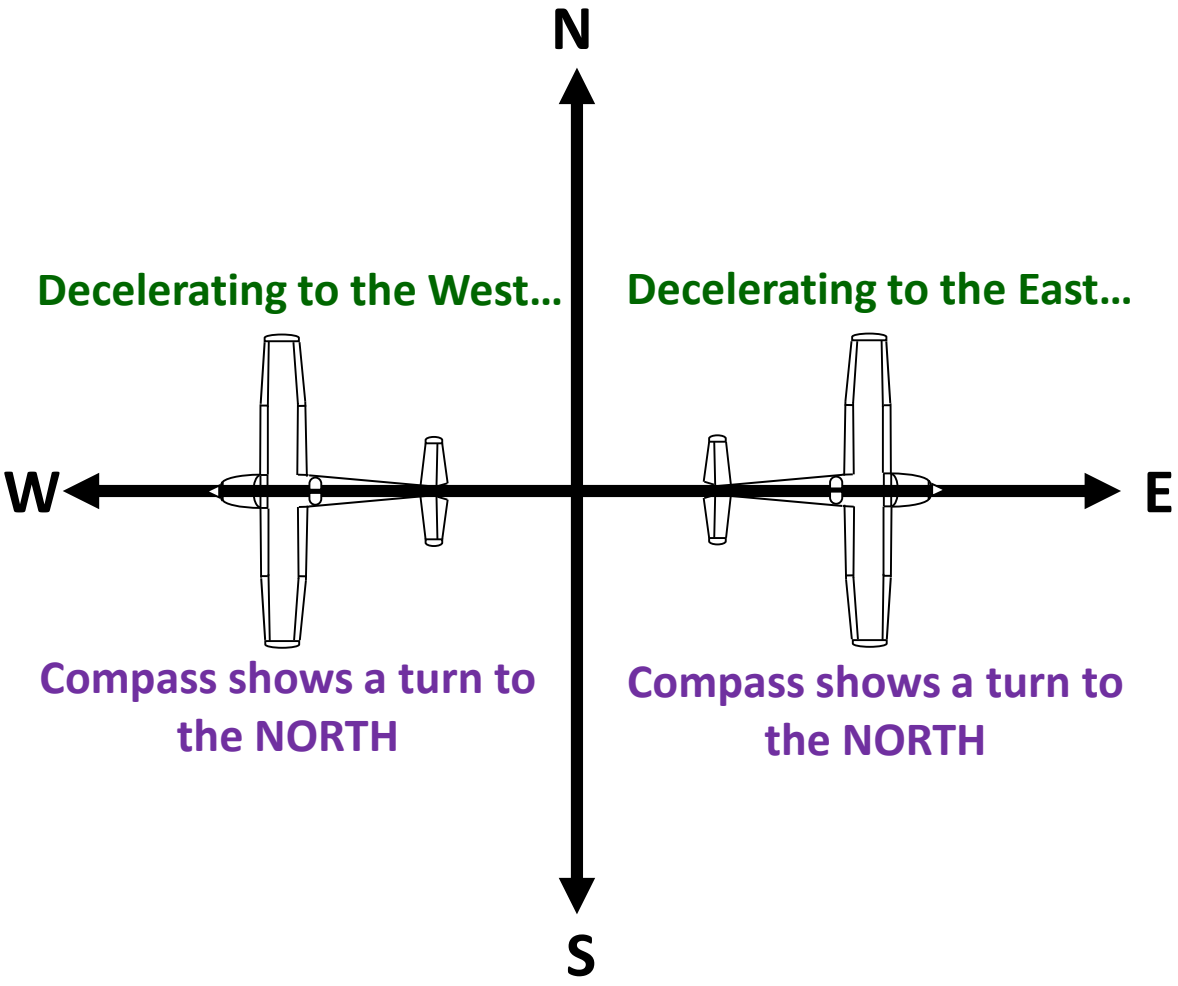
"SAND"



Magnetic Compass

Acceleration Error:

"SAND"



Magnetic Compass

Turning Error:

- In the southern hemisphere, the compass rotates too fast as a turn through north is made and too slow as a turn through south is made:

- In other words, the compass is:

“Nippy on North”

“Sluggish on South”

- To overcome this, the pilot should ‘ONUS’:

“Overshoot North”

“Undershoot South”

- The over/undershoot should be about 10° per 30° of turn

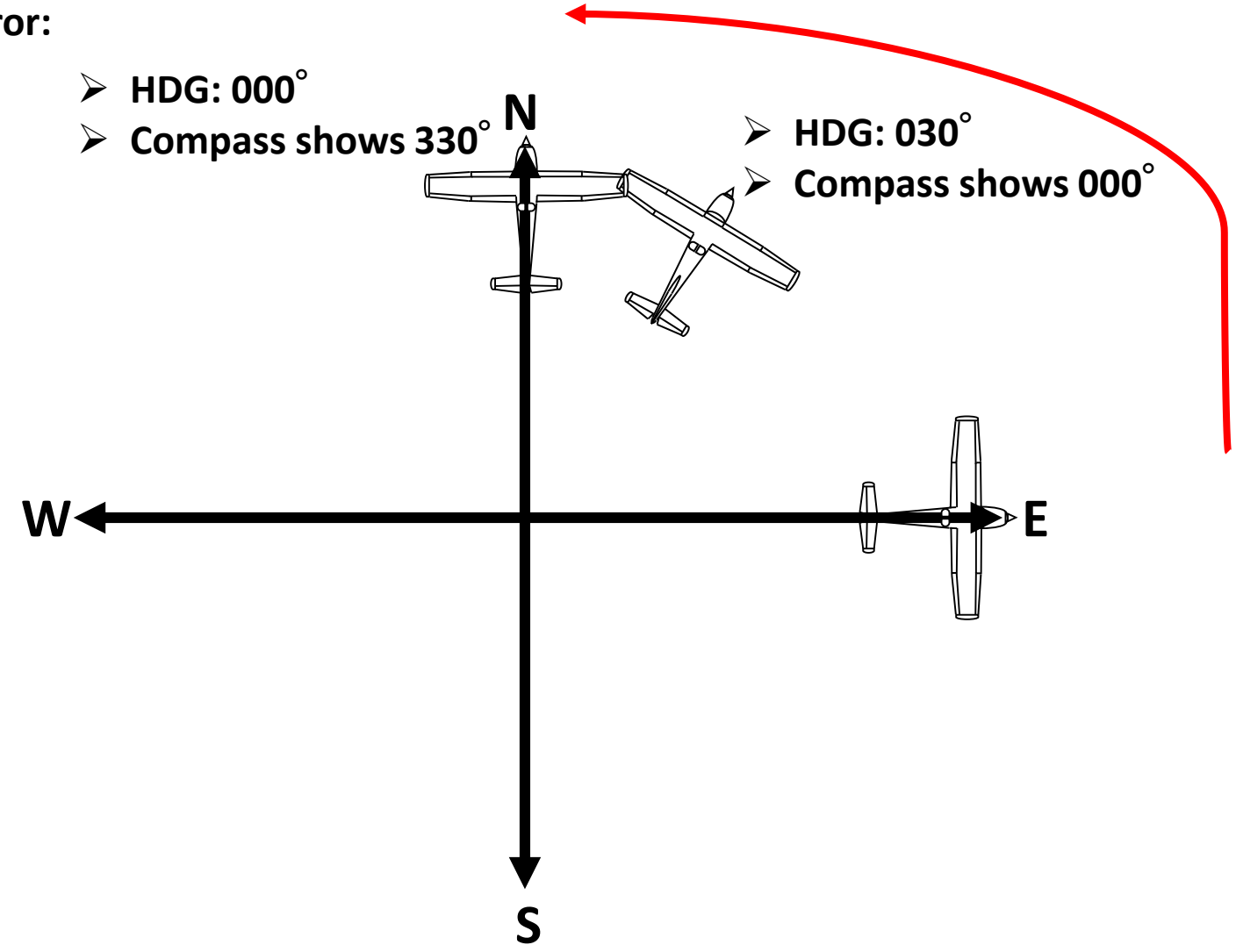
Magnetic Compass

Turning Error:

"ONUS"

- **HDG: 000°**
- **Compass shows 330°**

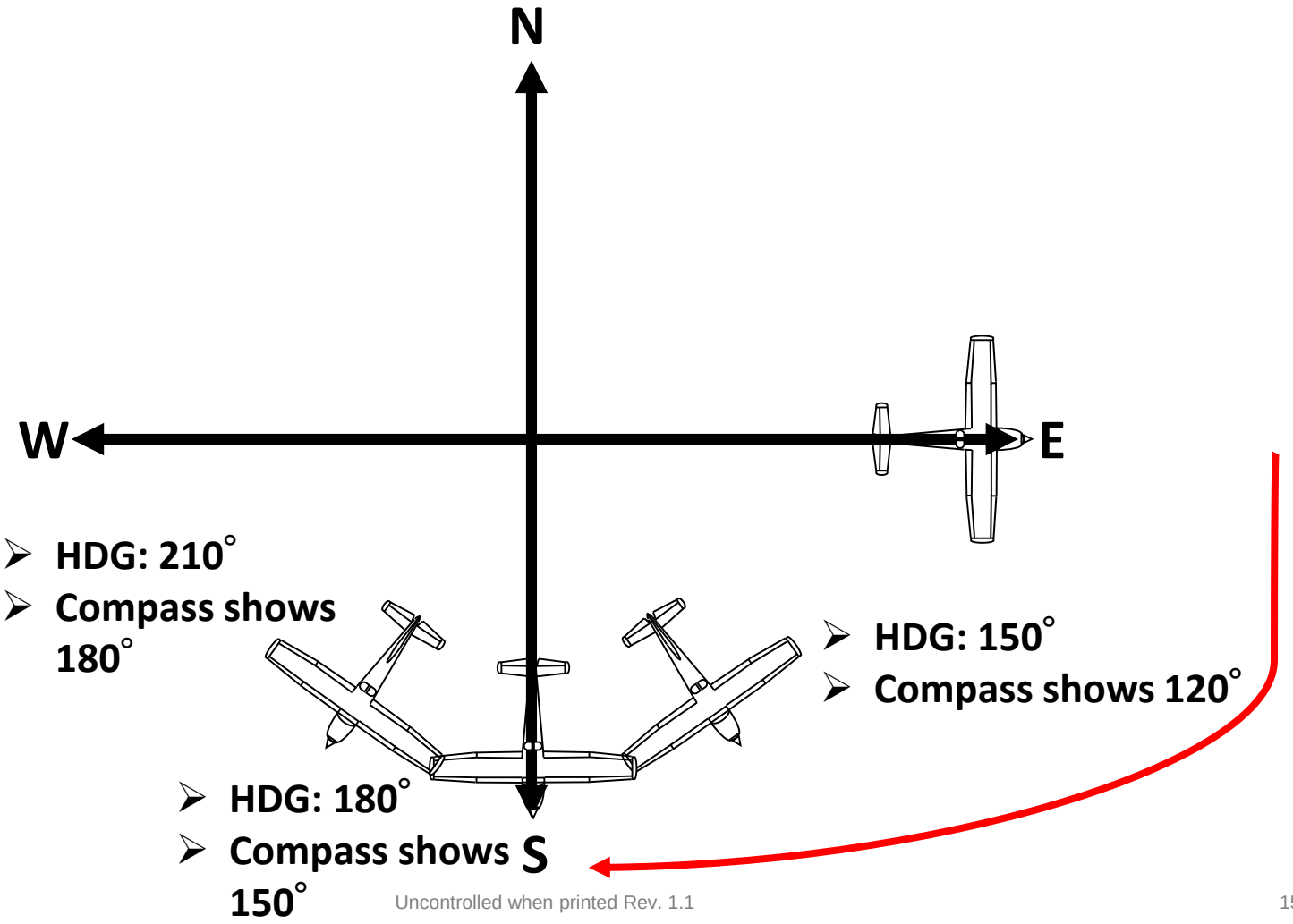
- **HDG: 030°**
- **Compass shows 000°**



Magnetic Compass

Turning Error:

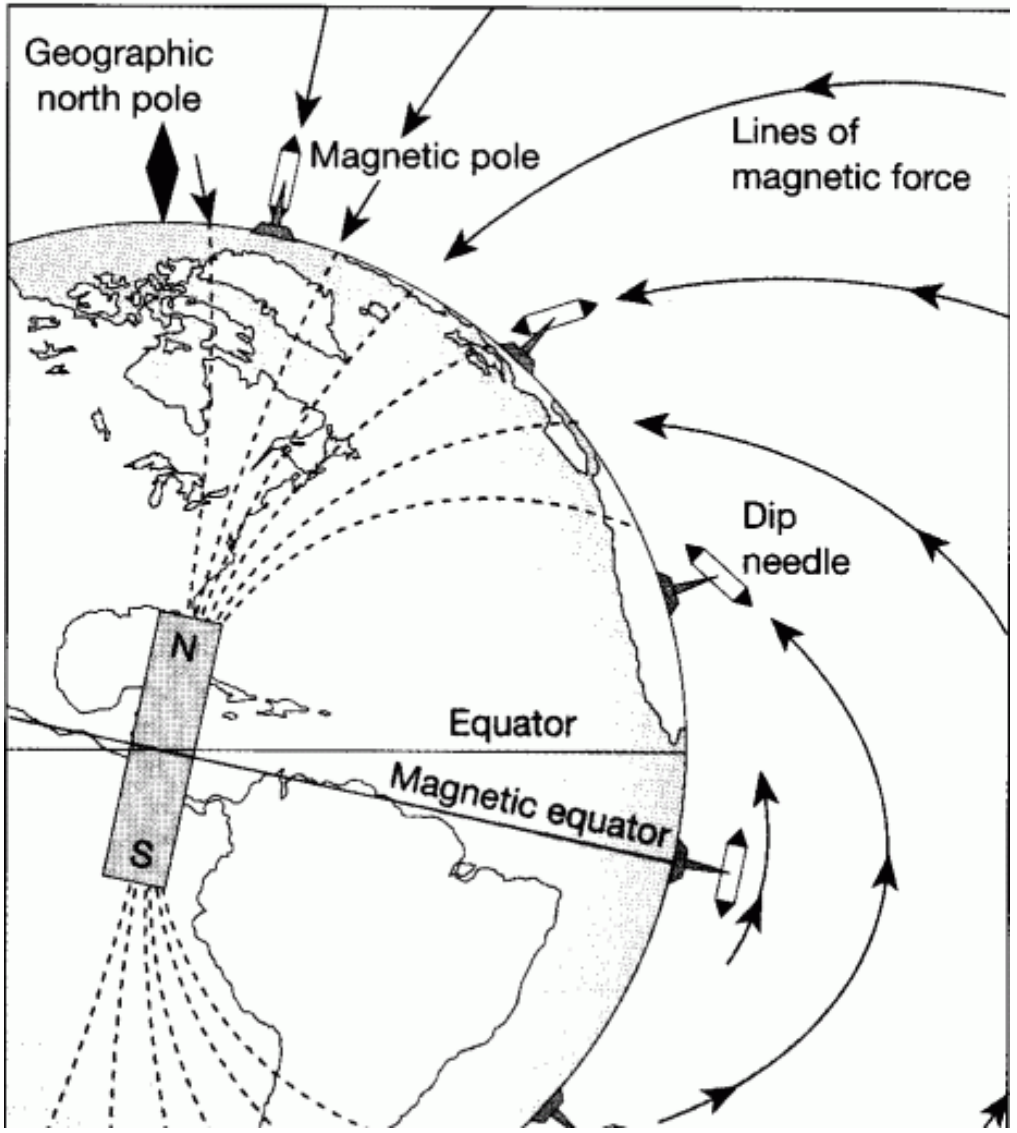
"ONUS"



Magnetic Compass

Magnetic Dip:

- The magnet inside the compass will want to align itself with the magnetic field lines
- In the southern hemisphere, the north end of the compass needle will point slightly upwards
- This causes errors during banked turns and airspeed changes



Magnetic Compass

Determining Serviceability:

- Your compass should indicate within 10° to be serviceable
- This can be tested by aligning the aircraft with a feature of known magnetic direction e.g. a runway
- Every so often, a 'compass swing' is carried out as part of the maintenance schedule to ensure it is within limits
- Serviceability of the compass is also checked during taxi

"Turning left, Balance Ball skidding right, AI is erect and wings level, DG is decreasing, Compass is following"

PRESSURE INSTRUMENTS

Pressure Instruments

ASI

ALT

VSI

Airspeed Indicator (ASI)

System:

- Pitot-Static System

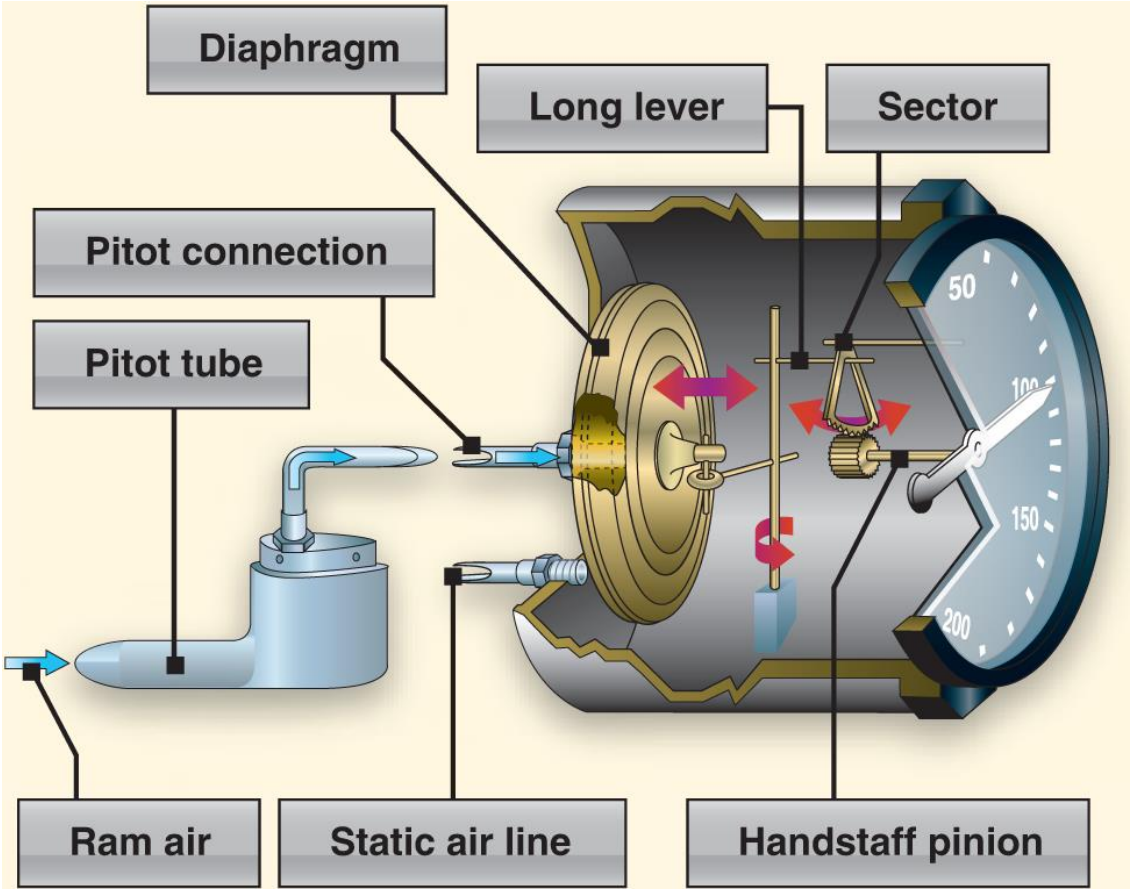
Powered By:

- Pitot Tube & Static Ports

How it Works:

- ASI measures the aircraft's dynamic pressure, calibrated in knots

- The instrument compares total pressure supplied by the pitot tube with the static pressure from the static ports



(Pdynamic = Ptotal – Pstatic)

Airspeed Indicator (ASI)

Associated Errors:

1. Instrument Error and Position Error

2. At altitude, IAS will be less than TAS

3. Windshear (increase in headwind) → IAS increases then returns to normal

4. Windshear (increase in tailwind) → IAS decreases then returns to normal

5. Blockage of the pitot tube or static port e.g. due icing

- Remember **PUDSUC**!

Airspeed Indicator (ASI)

If the **P**itot Tube becomes blocked, the ASI will…

Under-read

During a **D**escent (and therefore over-read on climb)

Airspeed Indicator (ASI)

If the **S** tatic Port becomes blocked, the ASI will…

U nder-read

During a **C** limb (and therefore over-read on descent)

Airspeed Indicator (ASI)

Associated Errors:

1. Instrument Error and Position Error

2. At altitude, IAS will be less than TAS

3. Windshear (increase in headwind) → IAS increases then returns to normal

4. Windshear (increase in tailwind) → IAS decreases then returns to normal

5. Blockage of the pitot tube or static port e.g. due icing
   - Remember **PUDSUC**!

Pilot Actions to Rectify Errors:

- If the pitot tube is blocked due to ice → select pitot heat

- If the static port is blocked due to ice → select alternate static

- If alternate static is selected, air will be drawn from inside the cabin. Because this air is at a slightly lower air pressure than that outside, the ASI will **over read** slightly

Altimeter

System:

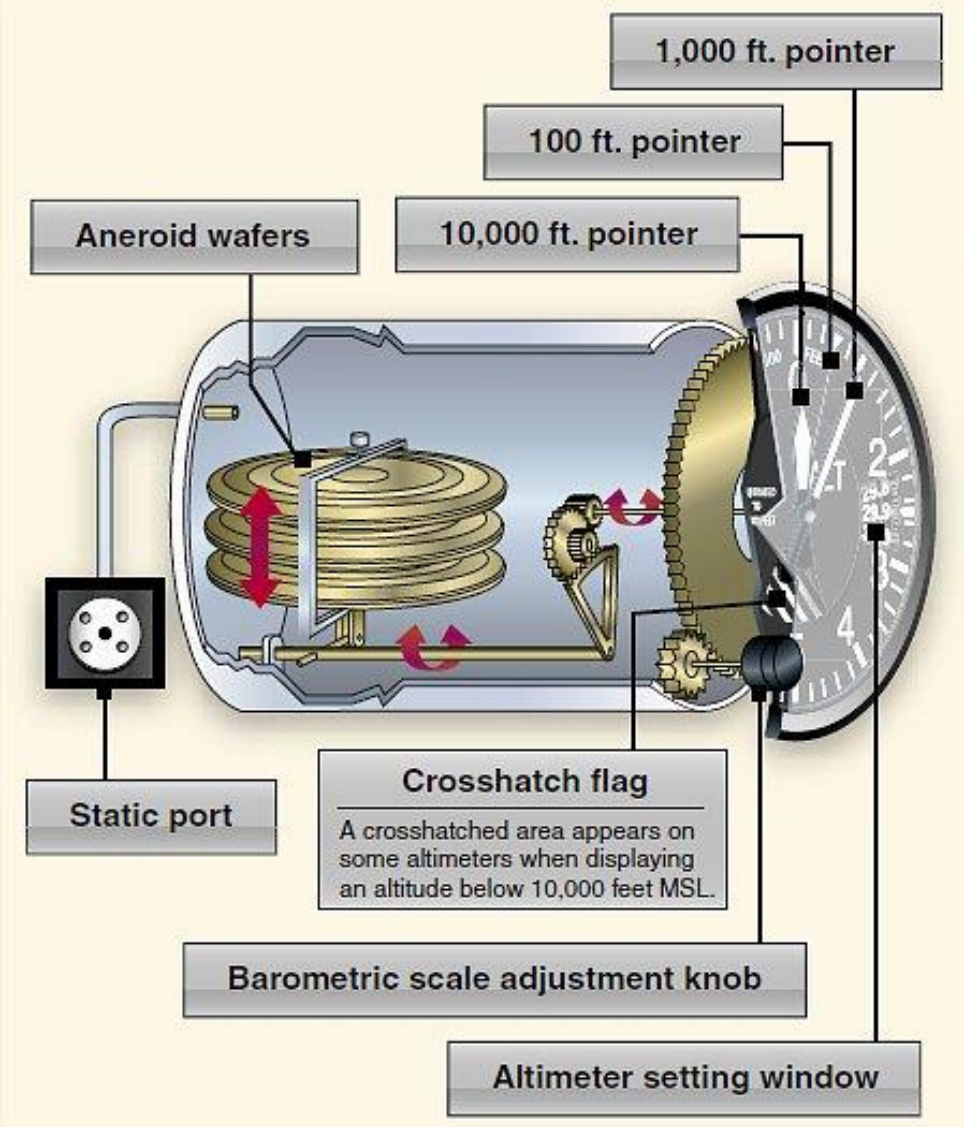
- Pitot-Static System

Powered By:

- Static Ports only

How it Works:

- Contains a sealed, flexible capsule called an aneroid that contains air
- As you climb, the static pressure surrounding the aneroid decreases, so the aneroid expands
- The aneroid is connected via a mechanical linkage to the needle of the altimeter, which moves as the aneroid expands and contracts



Altimeter

Associated Errors:

1. Instrument Lag, Instrument Error and Position Error

2. Pilot setting the wrong QNH on the subscale
   - Remember: Wind on QNH → Wind on Height

3. Blockage of the static port → Altimeter will remain fixed on the altitude at which the port became blocked

Pilot Actions to Rectify Errors:

- Set and cross-check your QNH to ensure correct setting
- If the static port is blocked due to ice → select alternate static
- If alternate static is selected, the altimeter will over read slightly

Vertical Speed Indicator (VSI)

System:

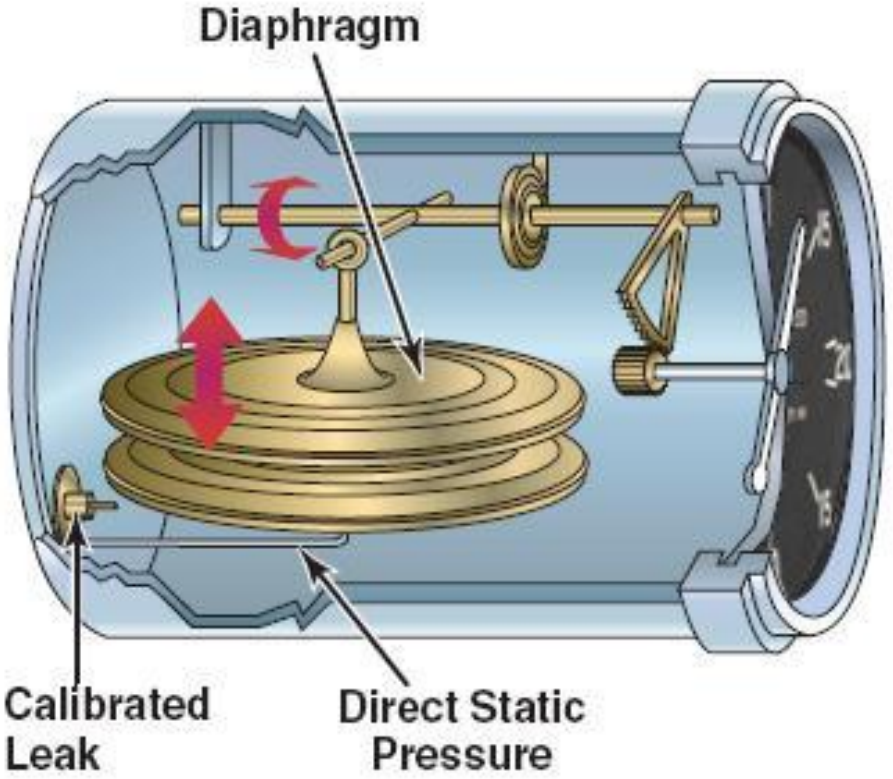
- Pitot-Static System

Powered By:

- Static Ports only

How it Works:

- Measures a rate of change of static pressure and converts this to a rate of change of altitude
- Static pressure is introduced into a diaphragm and also a surrounding chamber (but with slight delay)
- The time taken for the chamber pressure to “catch up” to the diaphragm is converted to a RoC/RoD



Vertical Speed Indicator (VSI)

Associated Errors:

1. Instrument Lag, Instrument Error and Position Error

2. Blockage of the static port → Vertical Speed Indicator will read 0

Pilot Actions to Rectify Errors:

- If the static port is blocked due to ice → select alternate static

- Although alternate static uses the slightly lower-than-ambient cabin pressure, the VSI merely measures a **rate of change of static pressure**, and thus will not be subject to any error

GYROSCOPIC INSTRUMENTS

Gyroscopic Instruments

DG

AH

TC

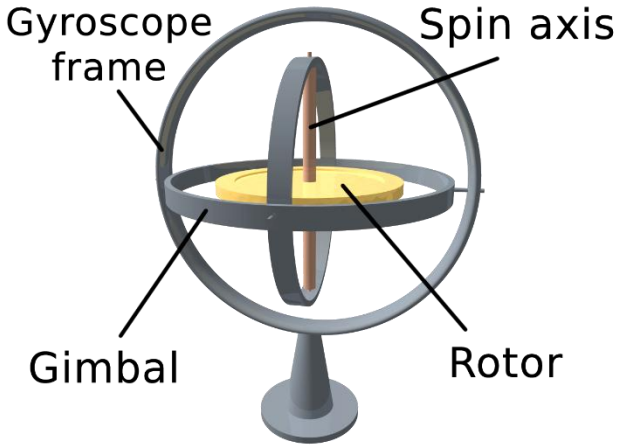
Gyroscopic Instruments

- A gyroscope is a spinning wheel mounted so that its axes can turn freely in one or more directions

- There are two important properties of gyroscopes:

1. Rigidity in Space

2. Precession



- **Rigidity:** A gyroscope is capable of maintaining the same absolute direction in space despite what goes on around it e.g. the AH remains fixed and the aircraft moves around it

- **Precession:** If a force is applied, the change of direction brought about by the force will be displayed 90° further in the direction of rotation. This is the cause of several errors in the gyros

Attitude Indicator/Artificial Horizon

System:

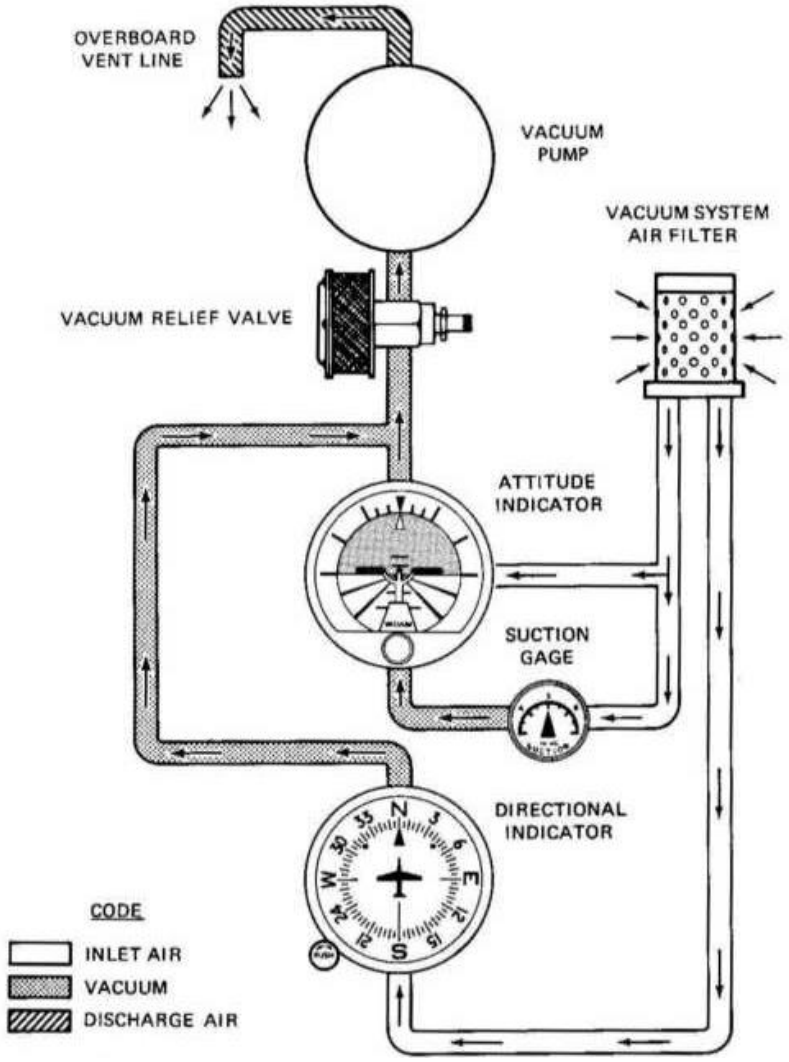
- Vacuum

Powered By:

- Vacuum Pump (engine-driven)

How it Works:

- Air is sucked through a filter and delivered onto the buckets of the gyro, causing it to spin in excess of 20,000 RPM
- This causes the gyro to become rigid in space
- The AH gyro is mounted to two gimbals, allowing it to indicate pitch and bank information



Attitude Indicator/Artificial Horizon

Associated Errors:

1. Toppling – unstable tumbling motion caused by extreme manoeuvres

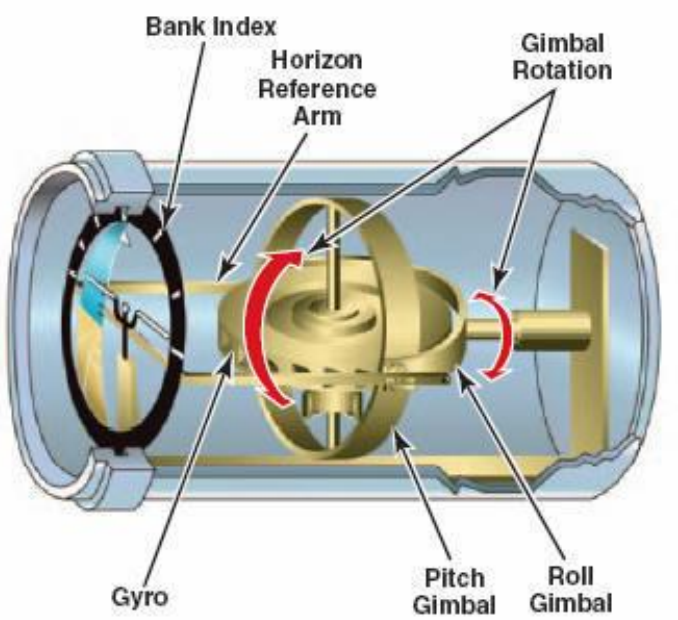
2. Turn Error – AH will precess in a turn
   E.g. Rolling out of a 180° steep turn to the right, the AH will show a slight climb and left turn. This is no more than 5° and corrects itself

3. Acceleration/Deceleration Error – during acceleration, horizon bar moves down indicating a pitch up attitude (opposite effect for deceleration)

Pilot Actions to Rectify Errors:

- In some aircraft, the AH has a 'cage' knob allowing the pilot to lock the gyro in place and prevent it from toppling

- Some modern gyros will actually re-erect by themselves



Directional Indicator/Directional Gyro

System:

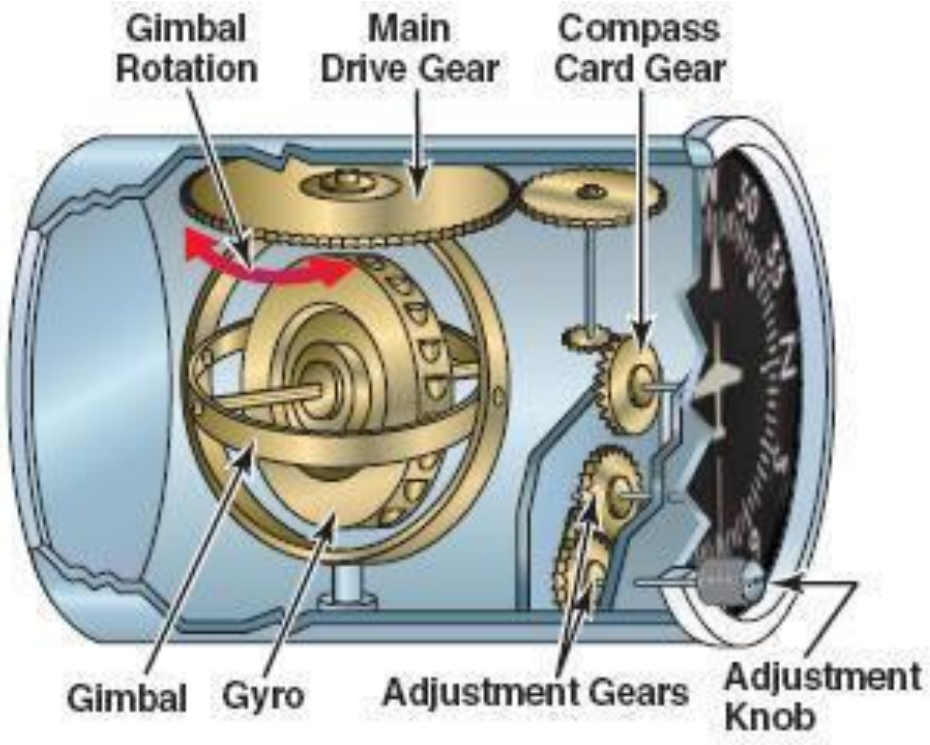
- Vacuum

Powered By:

- Vacuum Pump (engine-driven)

How it Works:

- Same as AH – the vacuum system allows the DG to become rigid
- The DG has no idea where north is
- We use the magnetic compass to set the DG so that the gyro has a reference
- As the aircraft moves around the rigid gyro, our heading change will be displayed



Directional Indicator/Directional Gyro

Associated Errors:

1. Toppling (DG will spin rapidly and eventually stop, misaligned)

2. Earth Rate & Transport Wander → causes precession

3. Friction/Mechanical Drift → causes precession

- Errors 2. and 3. cause the DG to drift about 10° of heading every hour (max. 30 before classified as unserviceable)

Pilot Actions to Rectify Errors:

- Every 15-20 minutes, the DG should be realigned with the compass
- After toppling, simply realign the DG with the magnetic compass
- Make sure the aircraft is in straight & level flight at constant speed when aligning the DG to avoid any compass errors

Turn Coordinator

System:

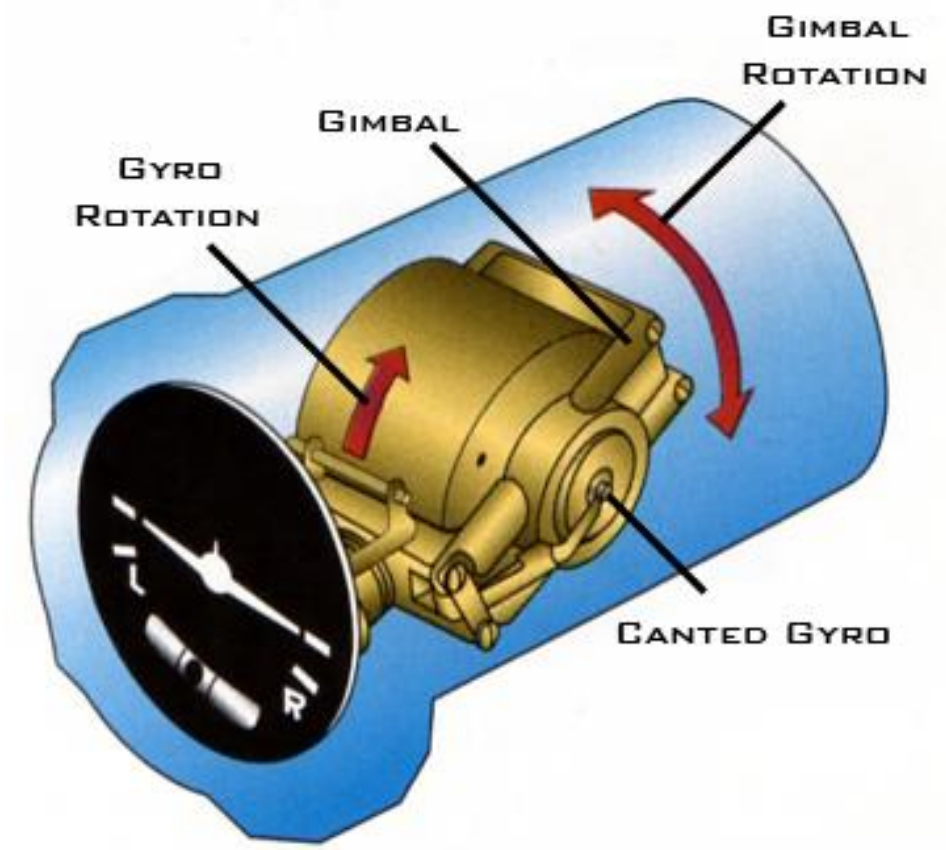
- Electrical

Powered By:

- DC Electricity

How it Works:

- Provides yaw and roll information and is a backup for the AH
- It is usually electric so that not all gyroscopic instruments are lost if the vacuum pump fails
- It is an electrically driven rate gyro which senses yaw and roll rates
- Note that it is different to a Turn Indicator, which only indicates yaw



Turn Coordinator

Associated Errors:

1. Human Error → Whilst the TC can be a backup to the AH, it will NOT show pitch information

Pilot Actions to Rectify Errors:

- If using the TC when the AH has failed, a positive scan incorporating the Altimeter and VSI must be conducted to ensure the correct level is being maintained

Balance Ball

- The balance ball is not part of the gyro
- It is a separate mechanical device indicating the combined effect of the earth's gravity force and any turning forces acting on the aeroplane
- It requires no power source
- Remember → step on the ball !