SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)

Department of Aerospace Engineering

23AST101-Fundamentals of Aerospace Engineering

UNIT-4:
POWER PLANTS

Flight Instruments

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Flight instruments are the tools used by pilots to understand and control an aircraft's attitude, altitude, airspeed, direction, and other critical flight parameters. They are essential for safe operation, especially in conditions where visual cues are limited (e.g., clouds or night flying).

The Six Basic Flight Instruments (also known as the "Six-Pack"):

1. **Airspeed Indicator (ASI)**
    1. **Function**: Measures the aircraft's speed relative to the surrounding air.
    2. **Unit**: Knots (nautical miles per hour).
2. **Attitude Indicator (AI)**
    1. **Function**: Shows the aircraft's orientation relative to the horizon (pitch and bank).
    2. **Uses**: Crucial for instrument flight and maneuvering.
3. **Altimeter**
    1. **Function**: Displays the aircraft's altitude above mean sea level.
    2. **How**: Measures atmospheric pressure.
4. **Vertical Speed Indicator (VSI)**
    1. **Function**: Indicates rate of climb or descent (in feet per minute).
    2. **Use**: Helps manage altitude transitions smoothly.
5. **Heading Indicator (HI) / Directional Gyro**
    1. **Function**: Shows the aircraft's compass heading.
    2. **Note**: Requires periodic adjustment to align with the magnetic compass.
6. **Turn Coordinator**
    1. **Function**: Indicates rate of turn and coordination (whether the turn is slipping or skidding).
    2. **Important for**: Balanced, safe turns especially in low visibility.

Additional Modern Instruments:

- **Magnetic Compass**: Basic directional reference.
- **GPS Display**: Shows position, route, and more.
- **EFIS (Electronic Flight Instrument System)**:
- Replaces mechanical instruments with digital screens.
- **Flight Management System (FMS)**:
- Integrates navigation, performance, and
- aircraft control data.

Airspeed Indicator (ASI)

Airspeed Indicator (ASI) – Overview

The **Airspeed Indicator (ASI)** is one of the most essential instruments in an aircraft's cockpit. It tells the pilot how fast the aircraft is moving through the air, which is critical for maintaining control, performance, and safety.

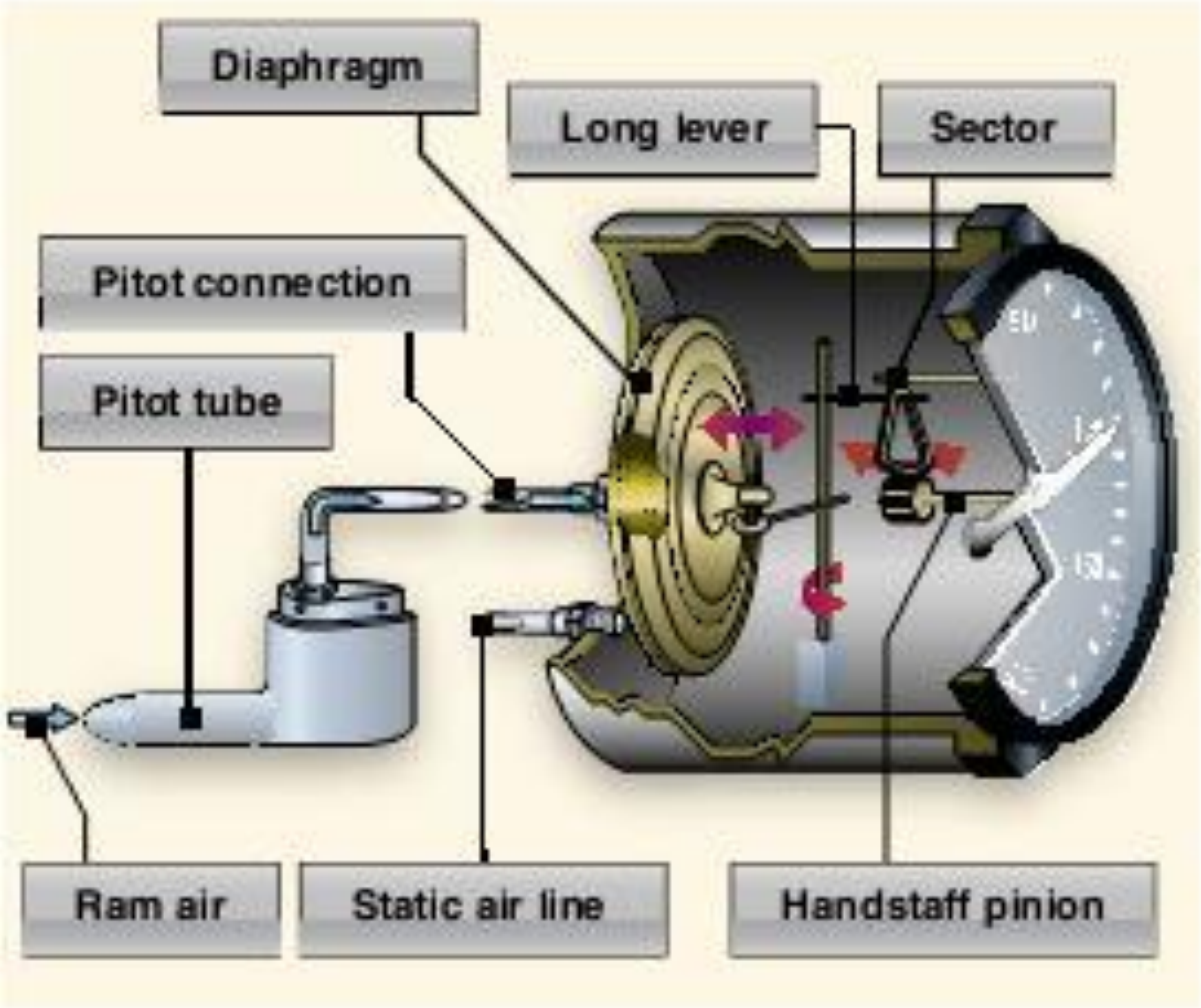
How It Works:

- The ASI measures **dynamic pressure**, which is the difference between:
  - **Pitot Pressure** (from the **pitot tube**, facing forward into the airflow)
  - **Static Pressure** (from static ports on the aircraft body)
- The formula used:

$$V = \sqrt{\frac{2(P_{pitot} - P_{static})}{\rho}}$$

Where:

- V = airspeed
- ρ = air density



📏 Units of Measurement:

•Typically in **knots (kt)** or **miles per hour (mph)**.

•Military or high-performance aircraft may use **Mach number** indicators for supersonic speeds.

📘 Types of Airspeed (Displayed or Derived):

1. **Indicated Airspeed (IAS)** – What the ASI directly displays.
2. **Calibrated Airspeed (CAS)** – IAS corrected for instrument and position errors.
3. **True Airspeed (TAS)** – CAS corrected for air density (altitude and temperature effects).
4. **Ground Speed (GS)** – TAS adjusted for wind; actual speed over the ground (not shown on ASI).

🎯 Key Speed Markings (Color Codes):

On the ASI dial, various colored arcs and marks indicate critical speeds:

Color	Meaning
White Arc	Flap operating range (from stall speed in landing configuration to r flap speed)
Green Arc	Normal operating range
Yellow Arc	Caution range (only in smooth air)
Red Radial Line	Never exceed speed (V_NE)
Blue Line (twin engines)	Safe single-engine climb speed (V_YSE)

🛩 Typical Uses in Flight:

- Takeoff and landing speeds
- Stall avoidance
- Turbulence penetration speed
- Climb and cruise performance
- Approach control

Attitude Indicator (AI) – Overview

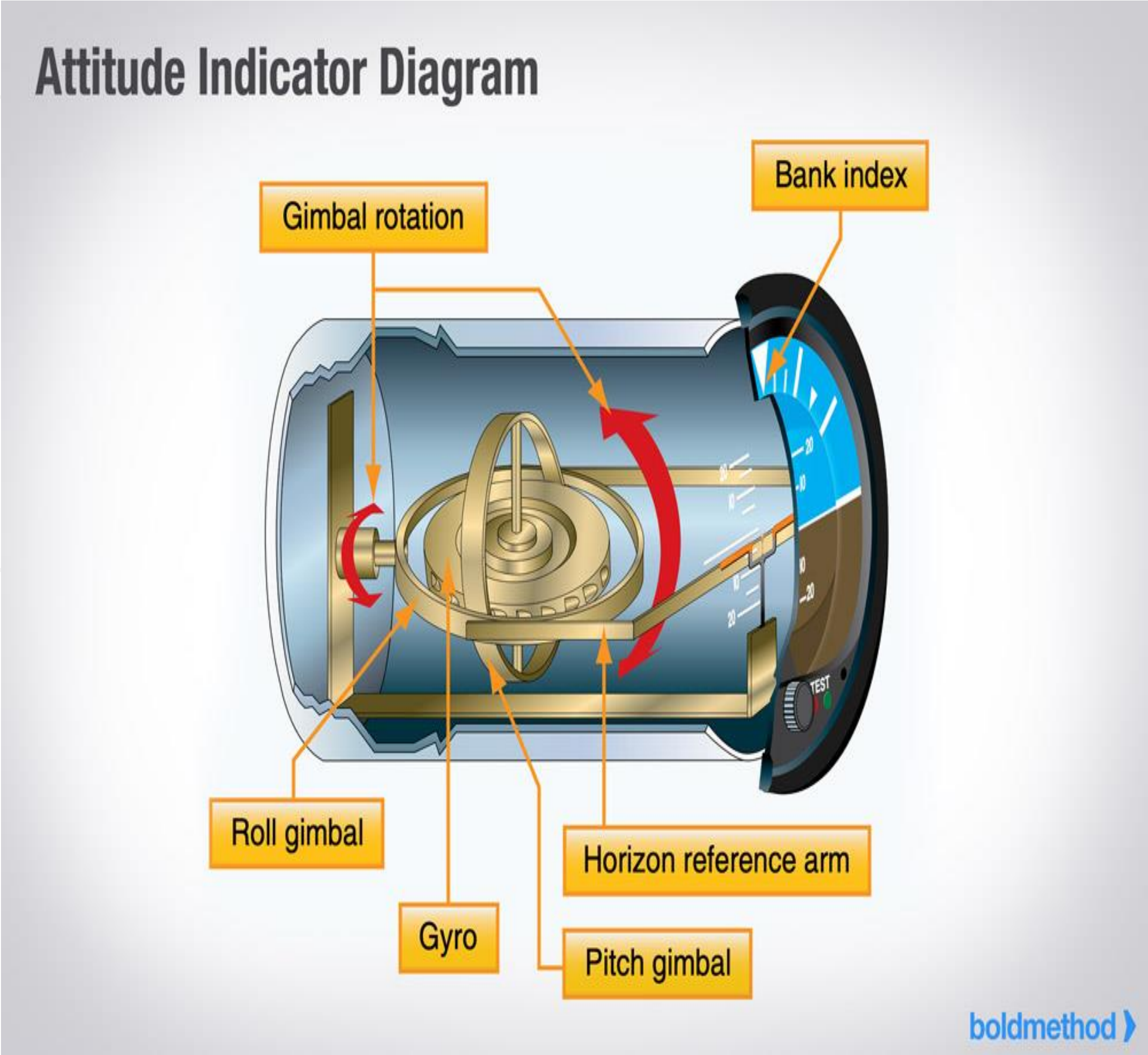
The **Attitude Indicator (AI)**—also known as the **Artificial Horizon**—is a critical flight instrument that shows the aircraft's orientation relative to the **natural horizon**, specifically its **pitch** (nose up/down) and **bank** (roll left/right).

🧭 Purpose:

The AI helps the pilot maintain spatial orientation, especially in **Instrument Meteorological Conditions (IMC)**, where the natural horizon is not visible (e.g., clouds, fog, or night).

🔧 How It Works:

- **Traditional AI** uses a **gyroscope** that maintains rigidity in space.
- The aircraft rotates **around** the gyroscope, and this relative motion is displayed visually on the instrument.
- Modern **Electronic Flight Instrument Systems (EFIS)** use **solid-state sensors** and digital displays (called PFDs – Primary Flight Displays).



🎨 Instrument Layout:

The display consists of:

- **Blue upper half** → Sky
- **Brown lower half** → Ground
- **Miniature airplane symbol** (fixed)
- **Moving horizon bar** rotates to show pitch and bank changes
- **Bank angle scale** (graduated in degrees, e.g., 10°, 20°, 30°, 60°)
- **Pitch scale** (usually marked every 5°)

🧠 Tip: The airplane symbol stays fixed while the background (horizon and pitch lines) move.

📏 Indications:

Parameter	How It's Displayed
Pitch	Horizon line moves up or down relative to the fixed airplane symbol.
Bank	Horizon rotates left or right, with marks showing degree of roll.

💡 Limitations (Mechanical AI):

- Typically limited to **±100° of pitch** and **±60° of bank**.
- Can tumble or give false readings under **high acceleration** or **abrupt maneuvers**.
- Requires power (vacuum system, electric motor, or digitally via AHRS in glass cockpits).

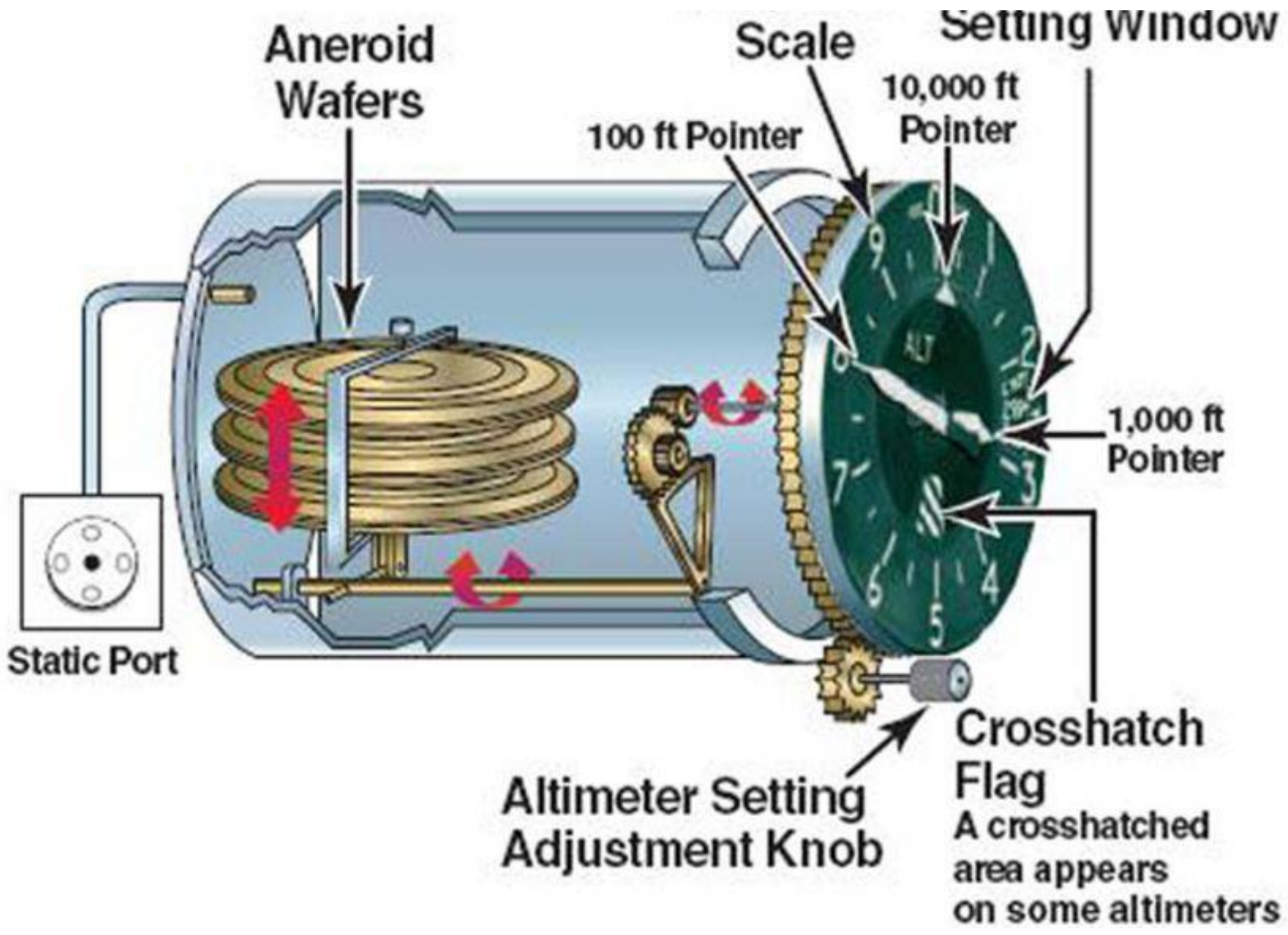
Altimeter – Overview

The **altimeter** is a crucial flight instrument that displays the aircraft's **altitude** above **mean sea level (MSL)** by measuring **atmospheric pressure**.

How It Works:

- It uses the **static pressure** from the **pitot-static system**.
- As the aircraft climbs, air pressure decreases; the altimeter senses this drop and converts it into an altitude reading.
- Based on the **International Standard Atmosphere (ISA)** model:
  - Pressure at sea level = **29.92 inHg (1013.25 hPa)**
  - Pressure decreases ≈ **1 inHg per 1,000 ft**

Internally, it contains a sealed, expandable **aneroid barometer** that expands/contracts with pressure changes. Mechanical linkages convert that motion into a pointer movement on the dial.



Altimeter Display:

- Typically has 3 **pointers** (like a clock):
  - **Short, wide hand**: tens of thousands of feet
  - **Medium hand**: thousands of feet
  - **Long, thin hand**: hundreds of feet
- **Kollsman Window**: A small dial where the pilot sets the current local **altimeter setting** (pressure at sea level).

📊 Types of Altitude:

Type	Definition
Indicated Altitude	What the altimeter shows, based on the current pressure setting
True Altitude	Actual height above mean sea level
Absolute Altitude	Height above ground level (AGL)
Pressure Altitude	Height above standard datum plane (29.92 inHg)
Density Altitude	Pressure altitude corrected for temperature – affects aircraft performance

⚙️ Importance of Setting the Altimeter:

- **Incorrect pressure setting** can lead to dangerous altitude misreadings.
- ATC provides local pressure settings (e.g., QNH or QFE) for pilots to dial into the Kollsman window.
- In high-altitude flight, standard pressure (29.92 inHg / 1013.25 hPa) is used above the **transition altitude.**

🚨 Altimeter Errors and Limitations:

- **Temperature deviations** from ISA cause **true altitude errors.**
- **Lag** due to mechanical movement.
- **Pressure changes in weather** affect readings if not updated.
- Does **not** measure AGL directly unless linked to a **radar altimeter.**

Vertical Speed Indicator

Vertical Speed Indicator (VSI) – Overview

The **Vertical Speed Indicator (VSI)** is a key flight instrument that shows the **rate of climb or descent** of an aircraft, usually in **feet per minute (ft/min)** or **meters per second (m/s)**.

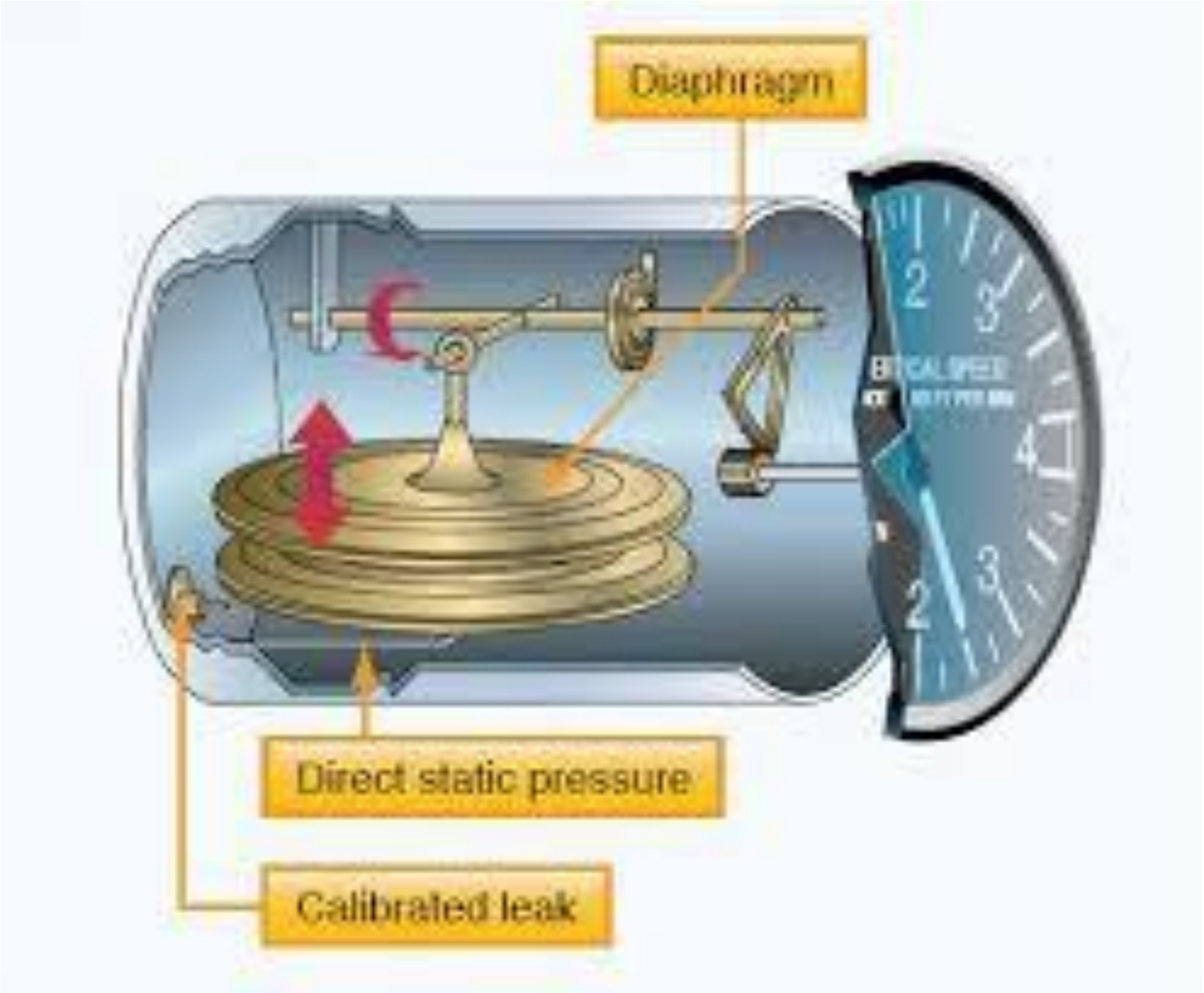
🔧 How It Works:

- The VSI uses **static pressure** from the pitot-static system.
- It compares **instantaneous pressure** to **delayed pressure** using a **calibrated leak**:
  - As the aircraft climbs or descends, pressure changes.
  - The VSI senses the **rate at which pressure is changing**, not just the absolute value.

> Essentially, it acts like a pressure rate-of-change meter.

📏 Typical Display:

- Circular dial with a **zero point** at the center.
- Markings to indicate climb (+) or descent (–) rates.
- Ranges usually:
  - Light aircraft: ±2,000 ft/min
  - Airliners: up to ±6,000 ft/min or more



⚠️ Lag and Limitations:

- **Mechanical VSI** has a **lag of 6–9 seconds**, making it less responsive to rapid altitude changes.
- More modern versions like the **Instantaneous VSI (IVSI)** use accelerometers to reduce lag.
- Not perfectly accurate in turbulence or abrupt maneuvers.

🚀 Pilot Use Cases:

Situation	VSI Use
Climbing/descending at constant rate	Monitor performance and smoothness
Leveling off	Know when to reduce vertical speed to prevent overshoot
IFR flying	Required for precise altitude changes
Approach and landing	Ensure stable descent path

🧠 Pilot Tip:

> VSI alone doesn't indicate **altitude** — always cross-check with the **altimeter**. It shows **rate**, not **position.**

Heading Indicator (HI) / Directional Gyro (DG) – Overview

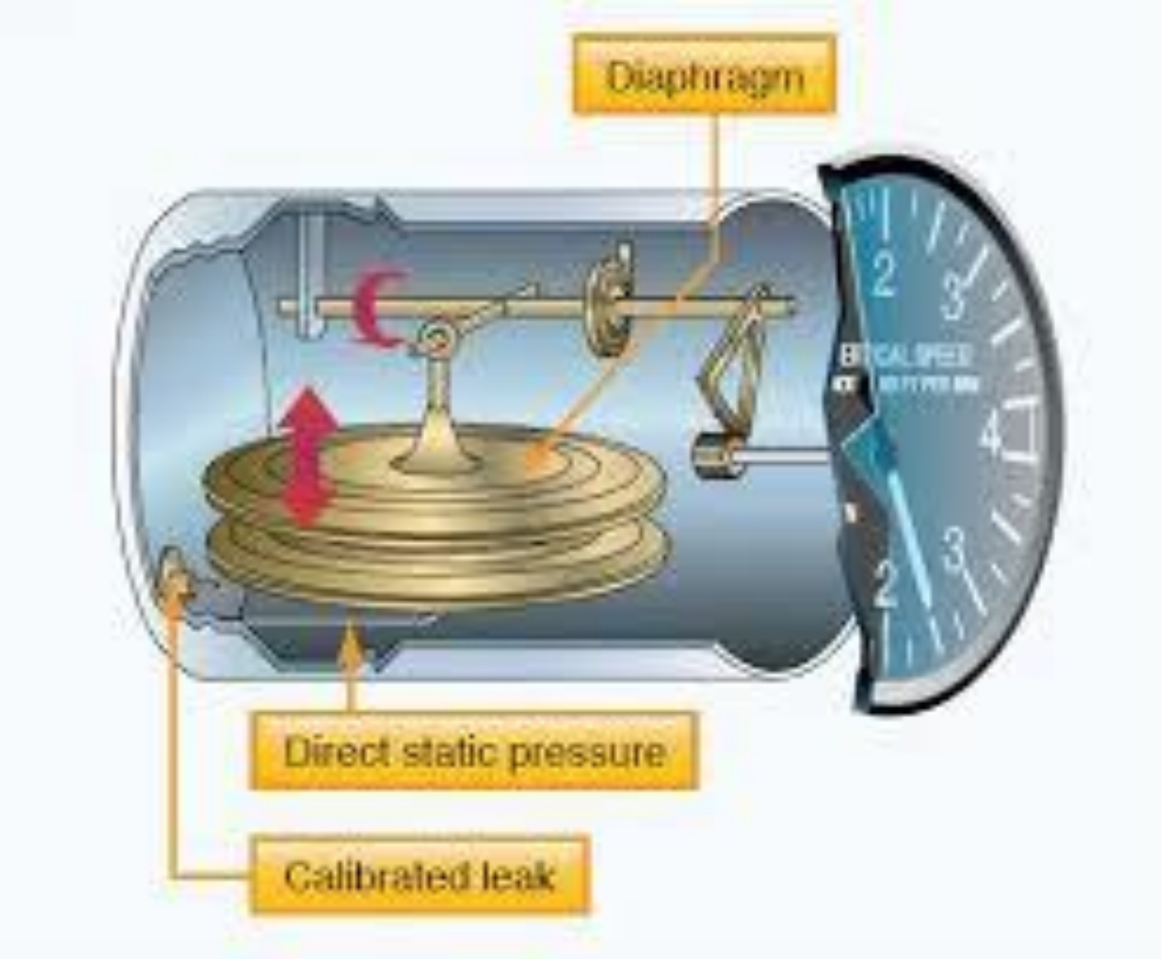
The **Heading Indicator (HI)**—also called the **Directional Gyro (DG)**—is a flight instrument that shows the aircraft's current **heading** (direction relative to magnetic north), providing a stable and accurate reference for navigation.

🧭 Why It's Needed:

- The **magnetic compass** is prone to errors (e.g., turning errors, acceleration/deceleration swings).
- The **HI/DG** provides a more **stable and accurate** directional reference by using a **gyroscope**, which resists changes in orientation due to gyroscopic rigidity.

🔧 How It Works:

- Uses a **spinning gyroscope** aligned with the aircraft's horizontal plane.
- The gyro maintains a fixed orientation in space.
- As the aircraft turns, the instrument case rotates around the gyro, and this movement is shown as a change in heading.



Heading Indicator

📏 Instrument Features:

- **Rotating compass card:** Marked in degrees from **000° to 360°**.
- **Lubber line:** Fixed reference mark at the top of the instrument indicating the current heading.
- **Knob:** Used to manually **align the HI with the magnetic compass**, since the gyroscope **drifts** over time.

> ⚠️ The HI does **not self-correct** for drift or precession—it must be **realigned every 15 minutes** or so.

🧭 Typical Use Cases:

Scenario	HI/DG Role
Straight and level flight	Maintain a consistent heading
Turns	Execute precise heading changes (e.g., turn to 270°)
IFR flight	Follow assigned headings accurately
Compass unreliability	Provides more stable directional information

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🧪 Limitations:

- Subject to **gyroscopic drift** and **precession** (especially in mechanical models).
- Requires **manual correction** based on magnetic compass.
- Powered by **vacuum**, **electric**, or **solid-state** systems depending on aircraft type.

Turn Coordinator – Overview

The **Turn Coordinator** is a flight instrument that helps the pilot monitor:

1. **Rate of Turn** – how quickly the aircraft is turning (usually in degrees per second), and
2. **Turn Coordination** – whether the turn is properly balanced (not slipping or skidding).

Function and Display:

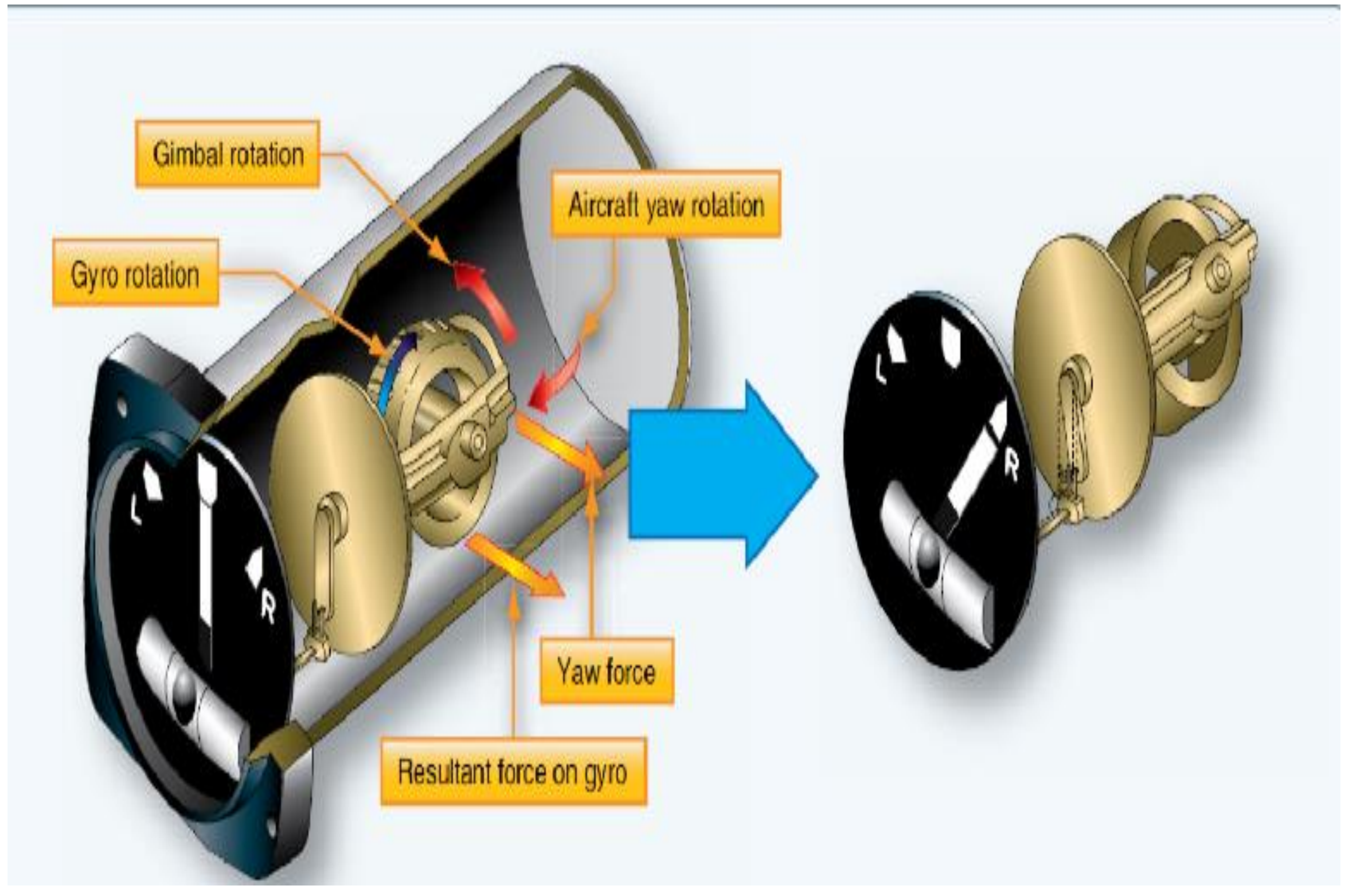
The turn coordinator includes **two components:**

1. **Miniature Airplane Symbol (Turn Indicator)**
   - Shows **rate and direction** of the aircraft's roll and turn.
   - Canted gyro (mounted at an angle) detects both **yaw and roll** movements.
   - When wings of the miniature airplane align with the marks (usually one needle-width), it indicates a **standard rate turn:**

$$3^\circ \text{ per second} \Rightarrow 360^\circ in 2 minutes$$

→ Called a "**2-minute turn**".

2. **Inclinometer (Slip-Skid Ball)**
   - **A ball in a curved glass tube** (also known as the "ball").
   - Indicates **lateral balance** of the turn:
     - Ball centered → Coordinated turn ✅
     - Ball inside the turn → **Slip**
     - Ball outside the turn → **Skid**



Turn Indicator

✈️ How to Use It (Turn Coordination):

Ball Position	Meaning	Fix
Centered	Coordinated	All good ✅
Inside the turn	Slipping	Too little rudder
Outside the turn	Skidding	Too much rudder

> Mnemonic: **"Step on the ball"** (apply rudder on the same side the ball is on to center it).

🔧 How It Works:

- Uses a **gyroscope** powered by **electric or vacuum** system.
- **Inclinometer** is gravity- and acceleration-based, not gyroscopic.

🌐 Variants:

- **Turn-and-Slip Indicator** (older): Shows **yaw rate only**, no roll information.
- **Turn Coordinator** (newer): Also detects **roll rate**, offers earlier indication of turns.

🧠 Use Cases:

Flight Condition	Use of Turn Coordinator
IFR conditions	Maintain precise heading changes
Training	Teach proper turn coordination
Engine-out (multi-engine)	Monitor slip/skid to maintain control
Instrument failure	Backup for spatial awareness

THANK YOU!