

# BRONZE LECTURES

## INSTRUMENTS

- ASI
- Altimeter
- Vario (Mech & Elec)
- Compass
- Turn & Slip, Horizon
  
- Radio - another lecture

# INSTRUMENTS

## References

- **ASI – S&G Aug/Sept 2009**
- **Altimeter – S&G Oct/Nov 2009**
- **Vario (Mech & Elec) – S&G Aug/Sep + Oct/Nov 2012 + Feb/Mar 2011**
- **Turn & Slip – Dec09/Jan 10**
- **Compass– Feb/Mar + Apr/May 2010**
- **Also Trevor Thom Vol 4 Chs 25 & 26**
  
- **Radio - another lecture**

# INSTRUMENTS

- Construction
- Operation
- Limitations
- Modes of failure & symptoms

# INTERNATIONAL STANDARD ATMOSPHERE (ISA)

- Standard sea level pressure and temperature are defined as:-
  - 1013.25 millibars pressure
  - +15 °C
- In the lower atmosphere changes are defined as:-
  - Pressure falls by 30mb for every 1000 ft (approx)
  - Temp falls by 2°C for every 1000ft (approx)\*
- Actual definition is more complicated!

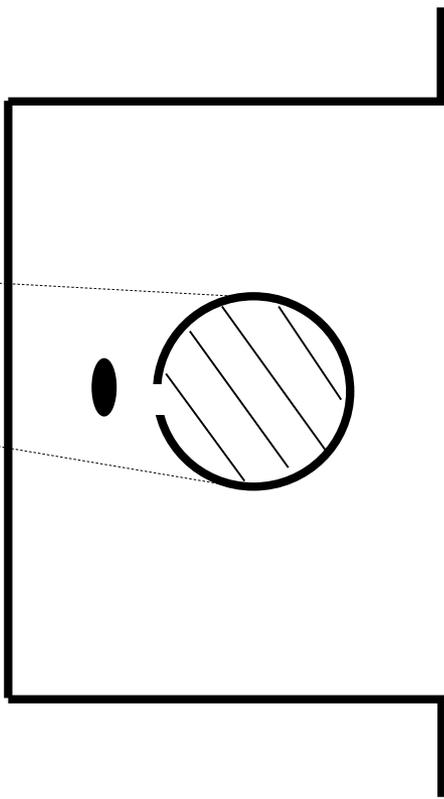
\* Actually ELR of 6.5°C per km. Nothing to do with DALR (3°C) or SALR (1.5°C)

# STATIC VENT

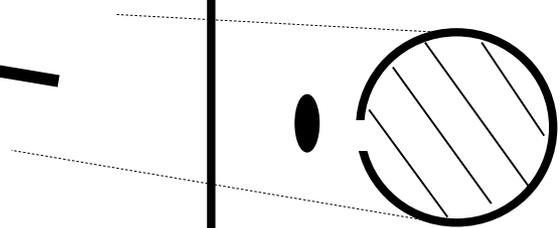
- Provides AMBIENT PRESSURE
- A tube end opening so placed as to be unaffected by the airflow
- often found one on each side of the tail boom (or nose) so combined they reduce effects of yaw
- usually very small – like a pin prick
- External vents used because cockpit pressure may be different e.g. open/close DV panel!
- Note manufacturer's specifications
  - position, use etc

# PITOT

- Provides DYNAMIC PRESSURE
- A tube end opening facing into the airflow\*
- gives a pressure which increases with the increasing airflow into it
  - also see 'Pot pitot'

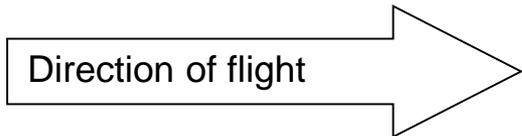


to static



To reduce risk of blockage

e.g. K13



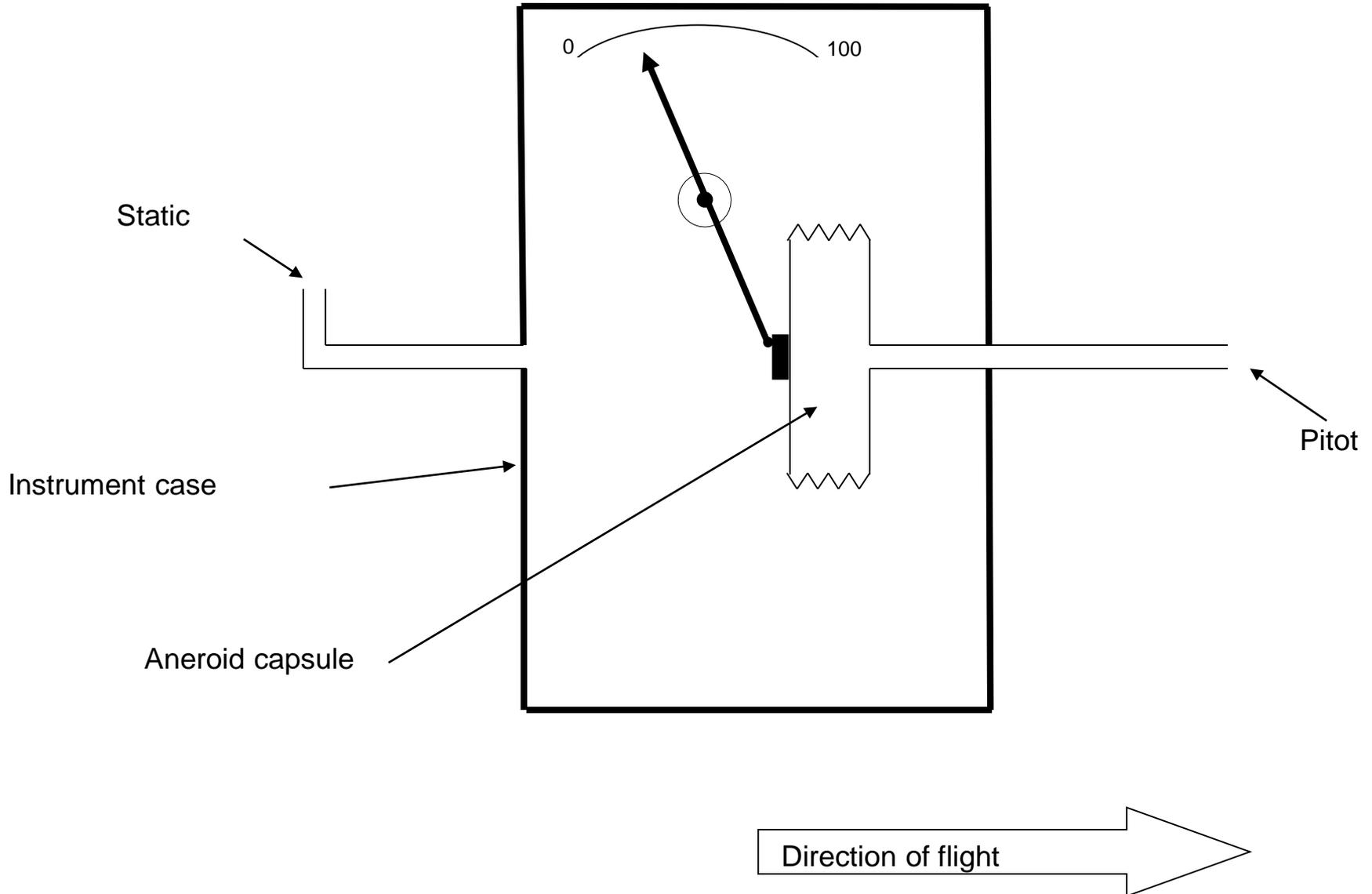
Direction of flight

# PORTS

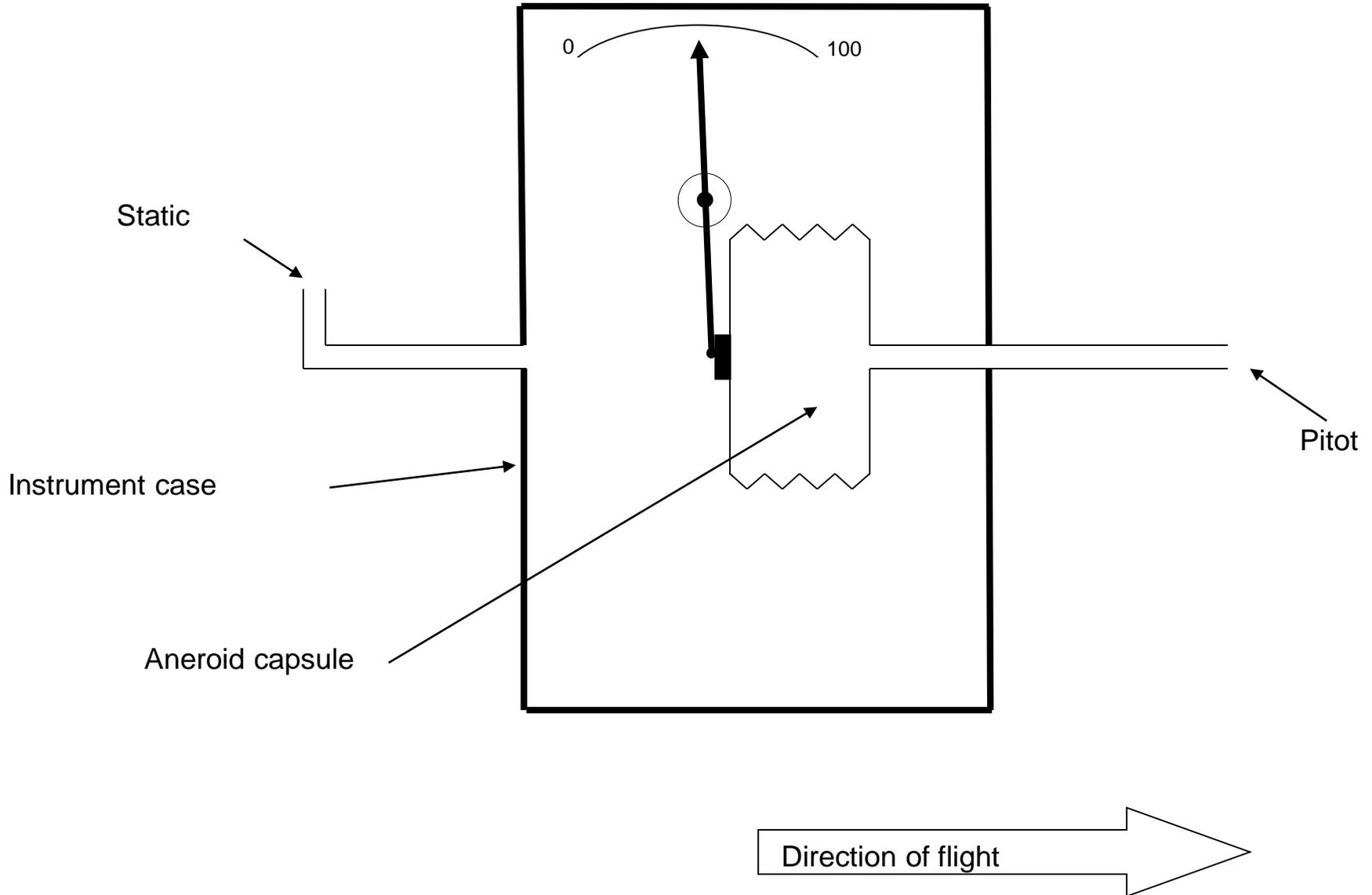
- Total Energy
  - A backward facing hole used for 'suck' to compensate for 'stick lift' (see varios)
  - Brunswick Tube, Schleicer 'multi-probe' etc

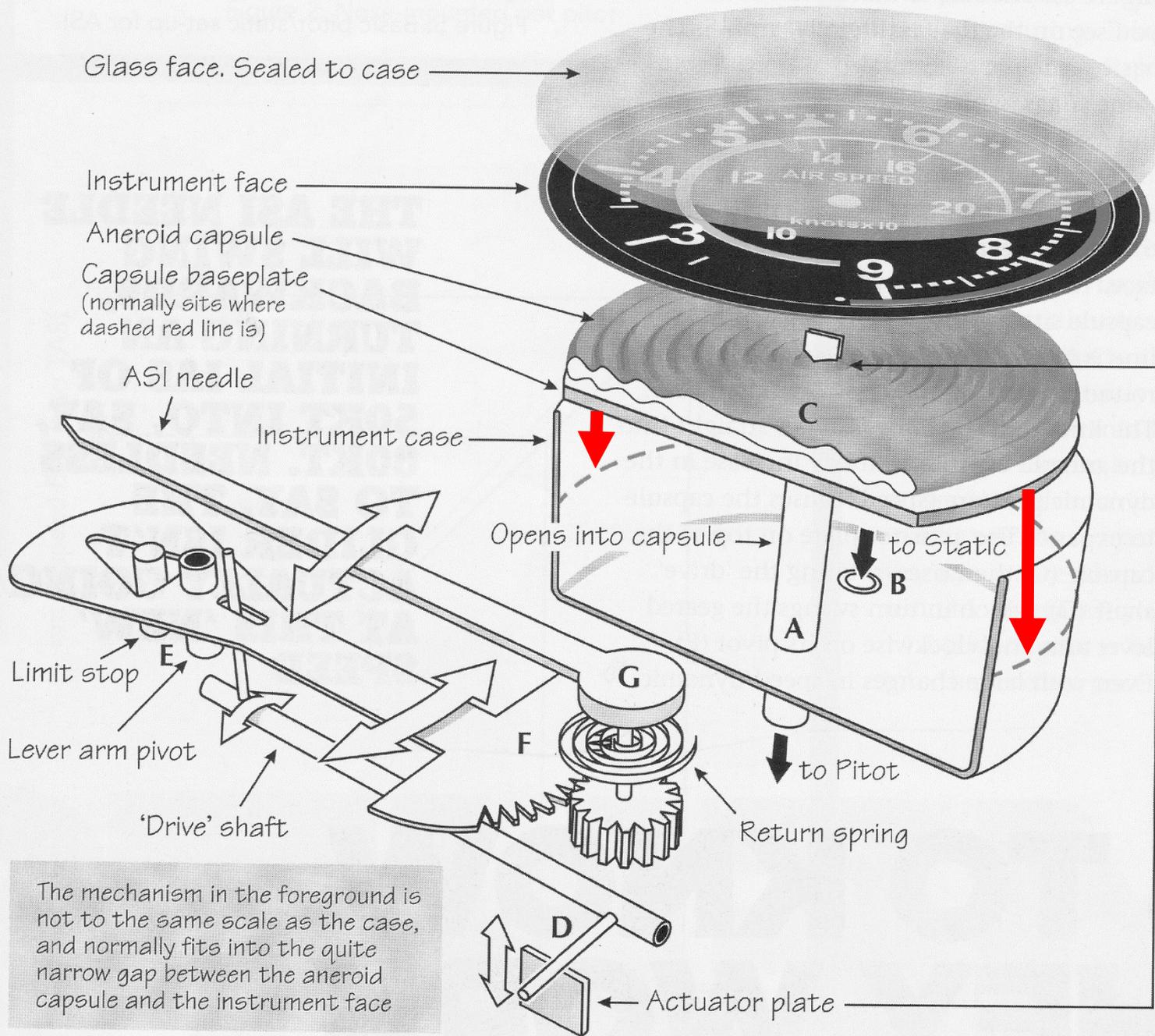
# AIRSPEED INDICATOR

# ASI – principle of operation



# ASI – principle of operation





The mechanism in the foreground is not to the same scale as the case, and normally fits into the quite narrow gap between the aneroid capsule and the instrument face

# ASI

- Note:-
  - the glass may be part of the ‘case’ and if cracked or broken may cause false readings
    - Hence “no cracked or broken glasses” in pre-flight checks

# ASI colour sectors

- Green – from stall to  $V_a$
- Yellow – from  $V_a$  to  $V_{ne}$
- Red bar –  $V_{ne}$
- Any White arcs relate to flap settings
- The Yellow triangle is min approach speed (but beware)



From S&G

# ASI errors

- The ASI measures increased air pressure due to airflow into the pitot and this is interpreted as airspeed
  - Pressure is a reflection of the number & speed of air molecules hitting a surface
- This measurement is affected by air density
  - The lower the density the fewer the number of molecules and therefore the lower the pressure
- So as altitude increases the ASI under- reads
- What the ASI shows is called INDICATED AIR SPEED (IAS)

# ASI errors

- Actual speed through the air (molecules) is called TRUE AIRSPEED (TAS)
- The ASI is calibrated for the ISA/msl and only shows TAS in these conditions
- TAS can be calculated from IAS (maths, slide rule, graph, app)
- Rule of thumb is  $TAS = \text{approx } IAS + 2\%$  per 1000ft
  - 5,000ft -> +10%,
  - 10,000 -> +20% !!

# ASI errors

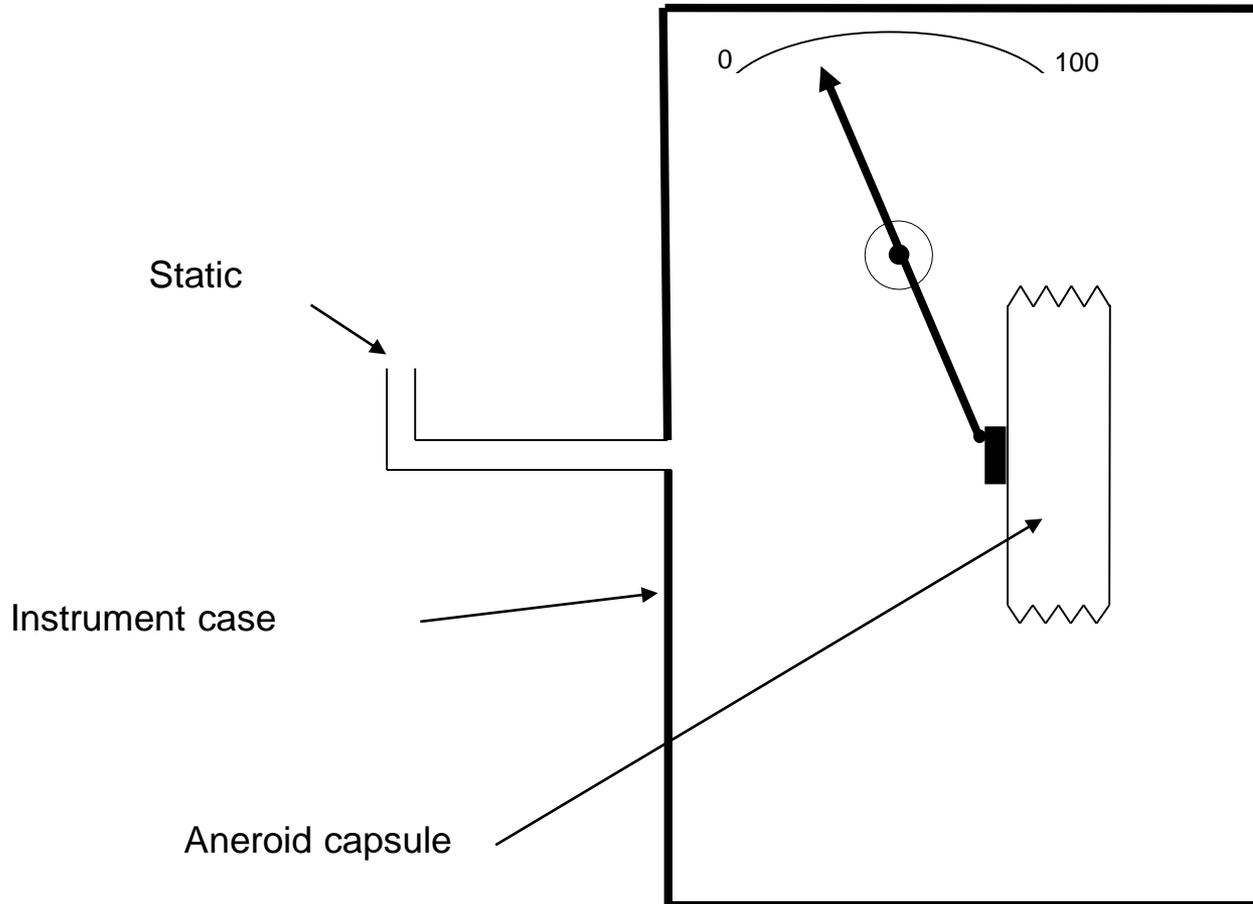
- You will stall etc at the relevant IAS
  - Note if landing at high altitudes TAS is greater than IAS and it is the IAS you need for an approach
  - Don't be tempted to slow down
  - and you are going to need a longer field to land in
  - Also radius of turns is bigger (beware in the mountains)
- but  $V_{ne}$  is a TAS (because of flutter)
  - so be careful when going high and fast
    - be careful in wave

# ASI errors

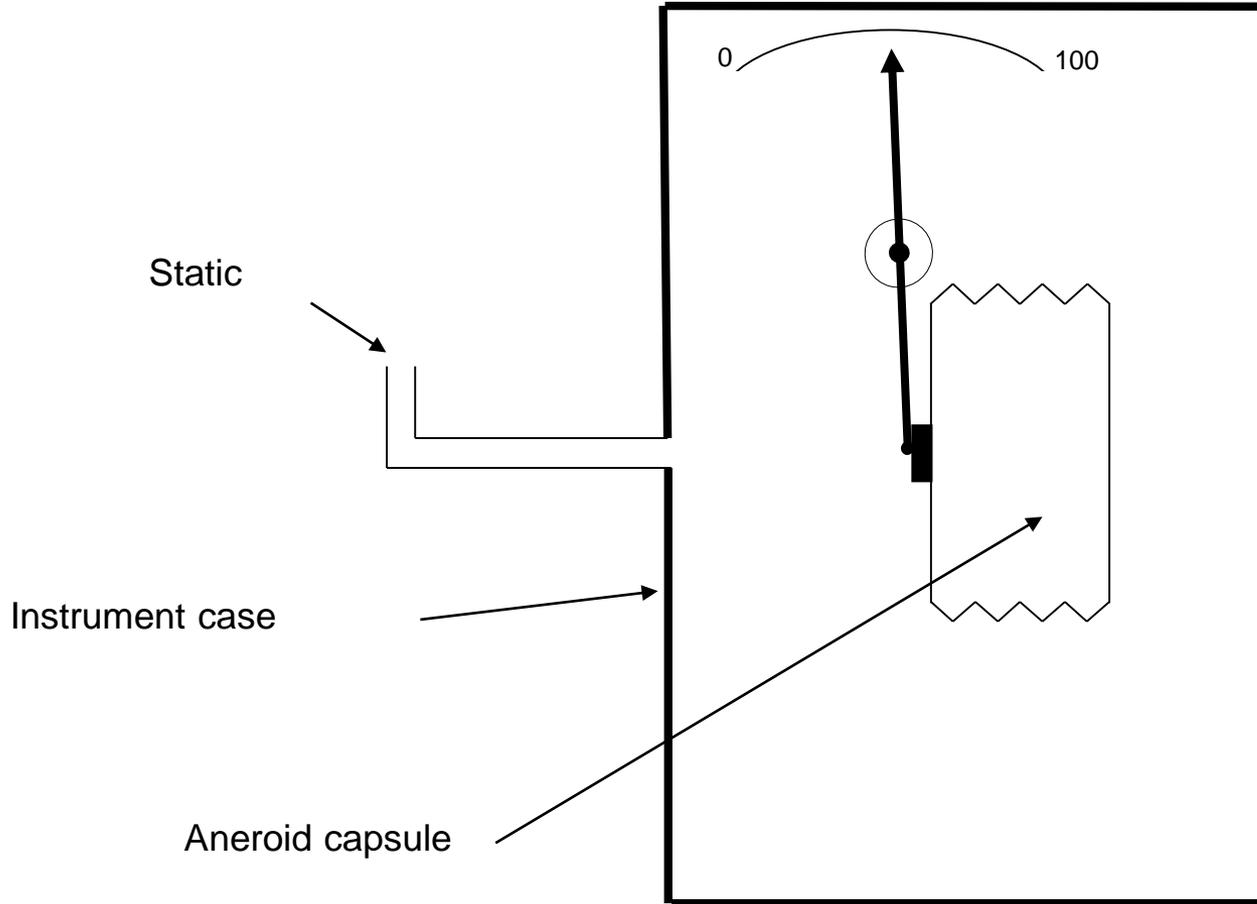
- Position errors
  - i.e. position of ports may lead to errors
    - » (CAS=calibrated airspeed lists these)
- Blocked static
  - » ASI will under-read if climbing and over-read if descending
- Blocked pitot
  - » ASI will read zero/stop moving much

**ALTIMETER**

# ALTIMETER – principle of operation



# ASI – principle of operation



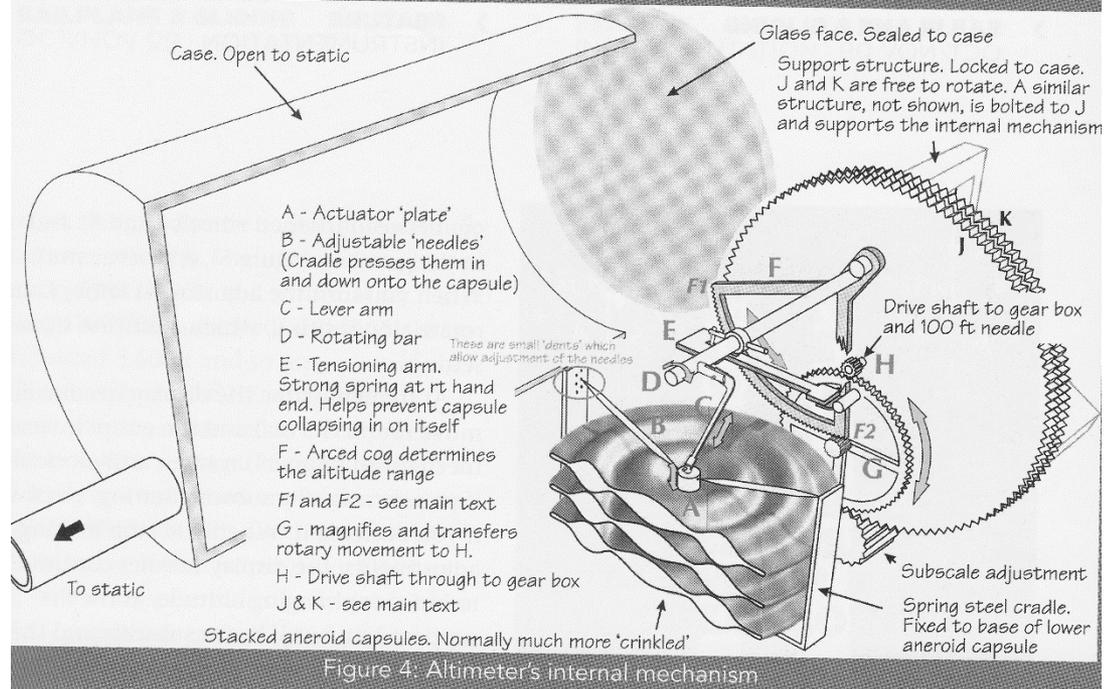
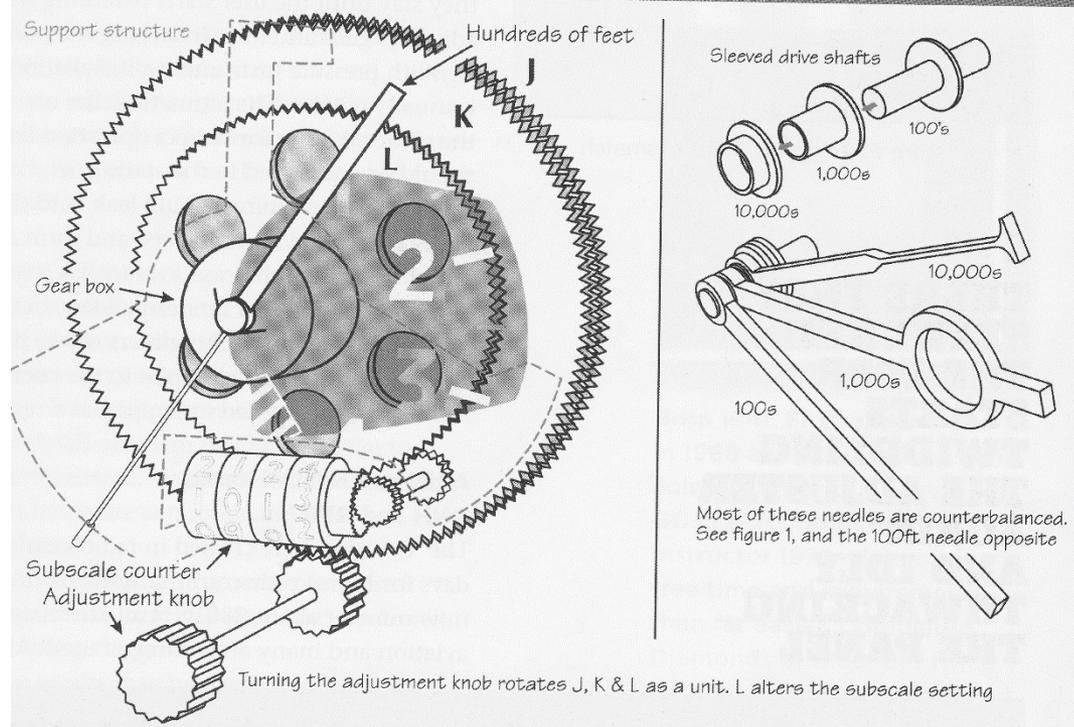


Figure 4: Altimeter's internal mechanism



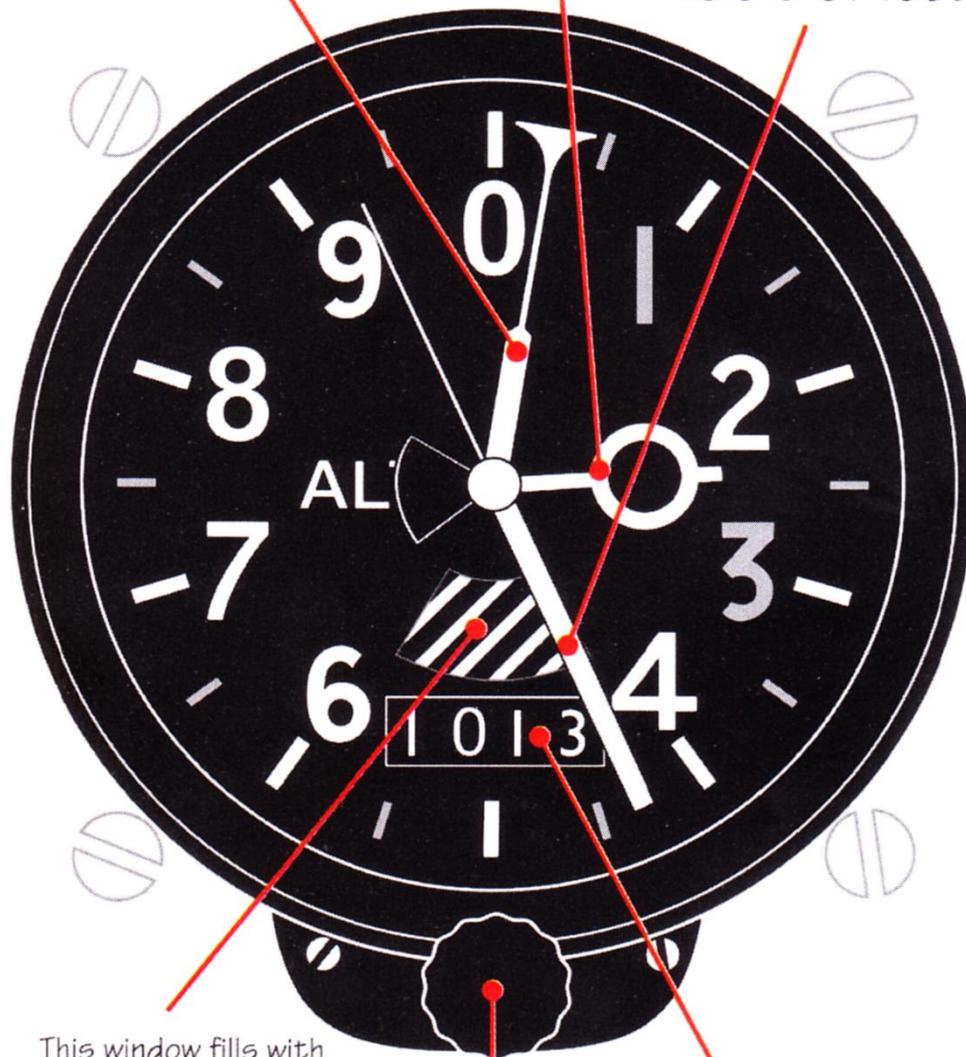
# Altimeter errors

- “No cracked or broken glasses” ?
- The glass may be part of the ‘case’ and if cracked or broken may, or may not, be a problem
  - Discuss!

10,000's of feet

1,000's of feet

100's of feet



This window fills with stripes when the altitude is 10,000ft or lower. Many altimeters don't have this.

Adjustment knob

millibar (mb) subscale

# Altimeter

- The Altimeter measures ambient air pressure, like a barometer, but it is interpreted on the dial as altitude
  - 3 mb = approx 100 ft, 30 mb = approx 1000 ft
- The design assumes the ISA
  - Pressure Altitude = equivalent alt in the ISA i.e. when set to 1013mb
- There is a knob used to adjust the indicated height whatever the ambient pressure
  - i.e to set the datum or 'where you start from'

# Altimeter errors

- Changes in pressure and/or temperature after initial setting will affect readings
  - since they affect air density
- In particular
  - Flying towards a LOW will make the altimeter over-read
    - » (because you are drifting to the right)\*
  - Flying towards a HIGH will make the altimeter under-read
    - » (because you are drifting to the left)\*
  - How do you know?

\* Northern hemisphere

# Altimeter errors

- Altimeter Lag
- There may be calibration (design/manufacturing) errors
  - A calibration chart should be provided
- If the static vent is blocked the altimeter reading will 'freeze'

# Altimeter errors

- Because of inherent errors **ALWAYS** have a margin of safety
  - above required level for dangers below
    - e.g. the ground
  - below required level for dangers above
    - e.g. airspace on top

# ALTIMETRY

- **HEIGHT** is defined as above the ground (take off or landing point)
  - **QFE** (? Query Field Elevation)
    - Set the altimeter to zero before takeoff
      - What you get on the millibar scale is ‘the QFE’
- 

- **ALTITUDE** is defined as above sea level
  - **QNH** (? Query Not Height) (?Query Nautical Height)
    - You can get this by setting the altimeter to the known airfield elevation amsl before takeoff
      - What you get on the millibar scale is ‘the QNH’
    - Regional QNH
- 

- **FL (Flight Level)** is defined with a setting of 1013mb
- **QNE** (??? Query Nautical Elevation)
  - Set 1013 on the millibar scale
    - And you are reading FLs

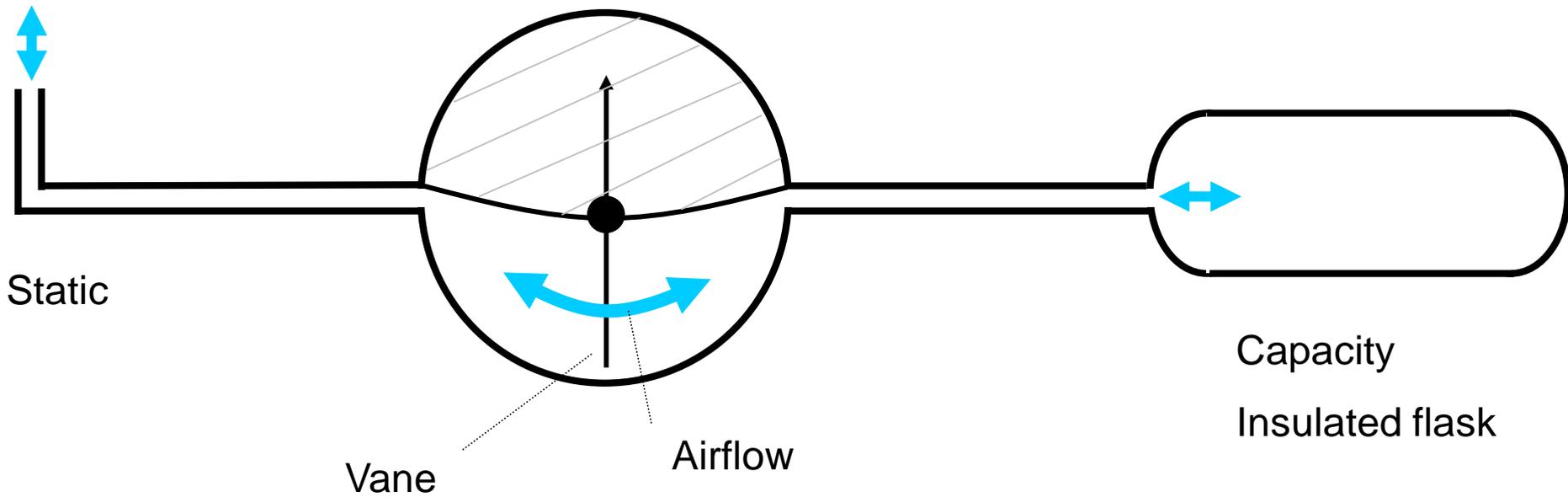
# VARIOMETERS

Mechanical

Electronic

- Powered aircraft have Vertical Speed Indicators (VSIs) but these are not sensitive enough for gliders - which use **Variometers**.
- Vertical speed is reflected by the rate of change of atmospheric pressure. Varios measure this, either directly, or by the consequent airflow into or out of a capacity

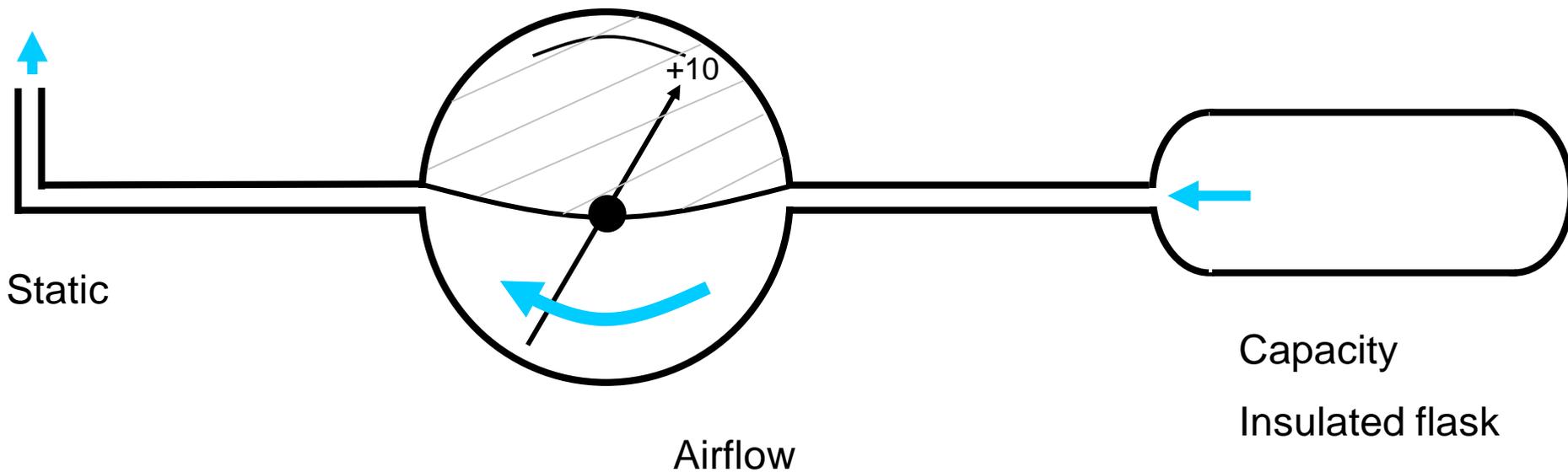
# MECHANICAL VARIOMETER – basic principle of operation (vane type)



# MECHANICAL VARIOMETER – basic principle of operation (vane type)

## ASCENT

Pressure  
decreasing



Capacity  
Insulated flask

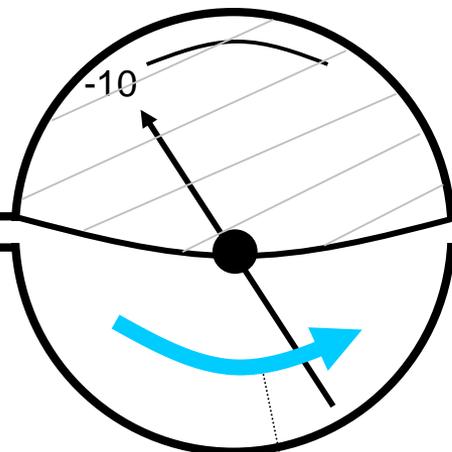
# MECHANICAL VARIOMETER – basic principle of operation (vane type)

## DESCENT

Pressure  
increasing



Static

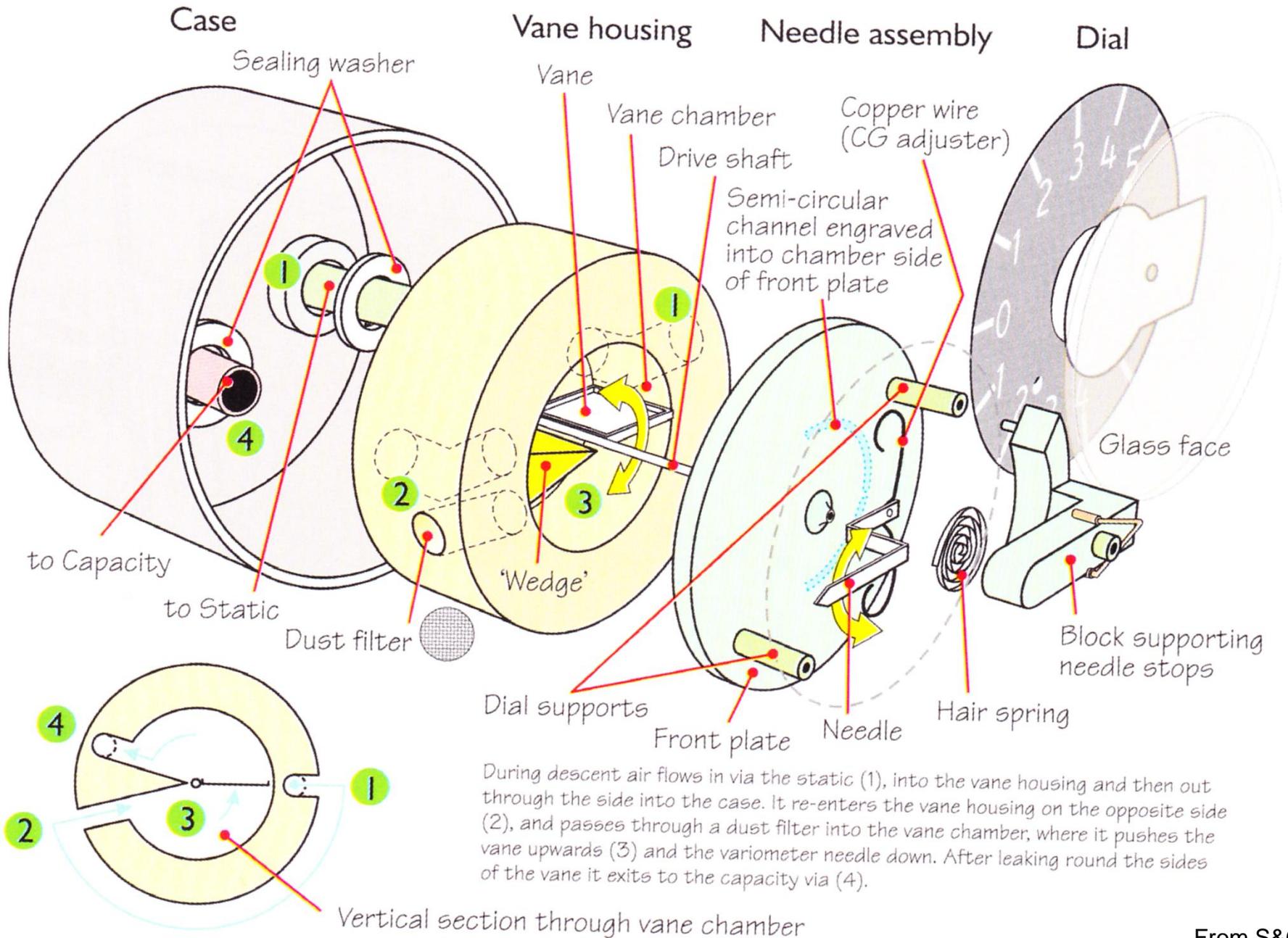


Airflow



Capacity

Insulated flask



# Variometers

- Vane type = Winter, PZL
- There are other types of mechanical variometers using different principles
  - e.g. aneroid/taut band etc
- Variometer Lag
  - Mechanical variometers inevitably suffer lag which depends on design/installation
  - They therefore need a certain technique to use
- Doesn't need battery power!
- Can have a McCready ring



# ELECTRONIC VARIOS:-

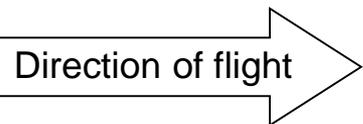
- use an electronic ‘transducer’ to measure pressure
- Everything else is done by computer (microprocessor) and associated firmware
- Electronically, minute changes can be measured and the computed results displayed virtually instantly. So no lag!
- Also an ‘audio’ output can be provided
- and an **AVERAGER**
- and an input to any other electronic function (‘flight director’, gps, navigation, McCready calculations using the glider’s polar etc)
- BUT if the battery supply fails – no electronic vario!



# TOTAL ENERGY etc

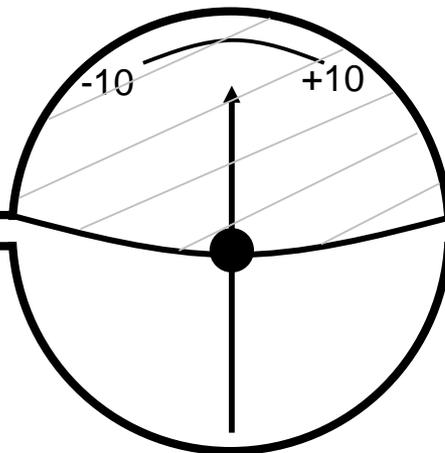
- If you pull-up in still air, you gain height and a basic vario will indicate lift which isn't actually there (stick lift).
- To avoid this, instead of connecting the vario to the static vent, it is connected to a total energy tube. This has a backward facing hole which provides 'suck'

# TOTAL ENERGY PROBE

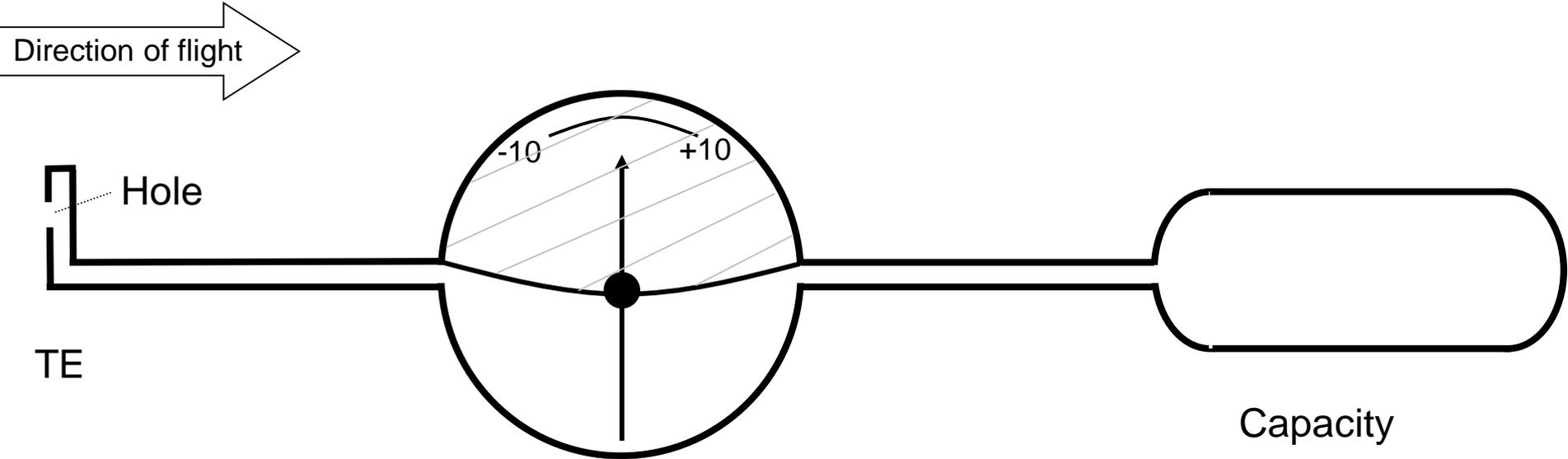


Hole

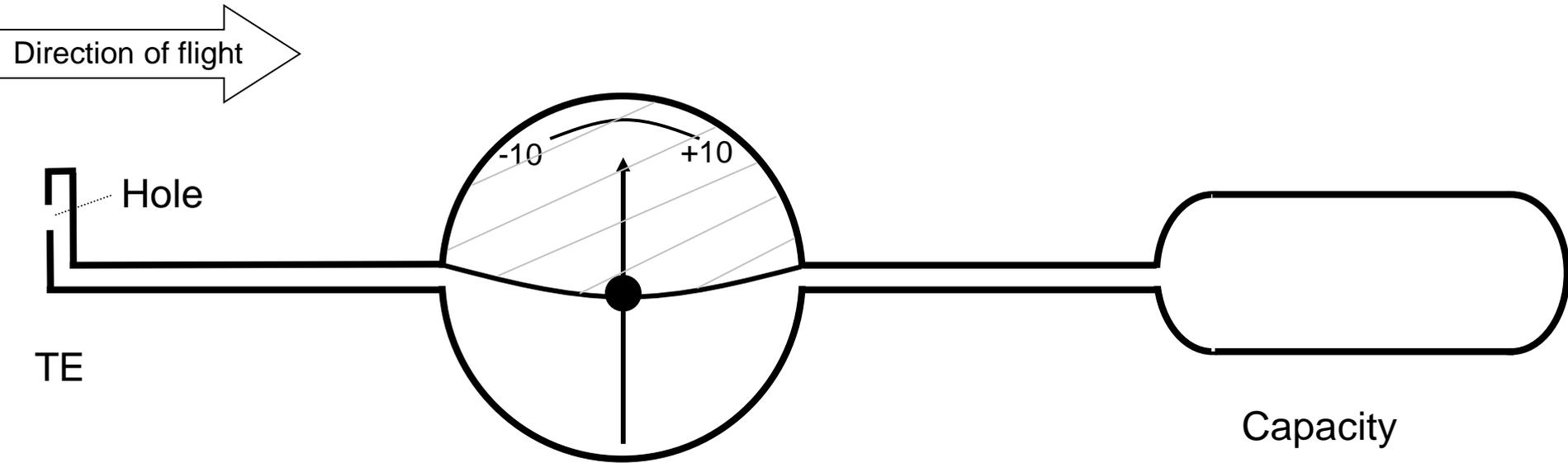
TE



Capacity



The 'suck' lowers the pressure in the system but system pressure will still remain constant for a constant speed and height when the vario will read zero because no air is flowing in or out



In a climb at constant speed the suck remains constant and the climb will still be registered by the out-flow of air into the lower atmospheric pressure

But if you pull up you will slow down and the 'suck' will be reduced. This will increase the pressure in the system and will balance the reduction in pressure due to the climb, so reading remains zero

# TOTAL ENERGY etc

- Or do it electronically !
  - Using knowledge of polar etc

# Netto Variometer

- Netto (or airmass) variometers show the lift/sink rate of the actual airmass by removing the sink rate of the glider.
- In mechanical variometers this is done with a calibrated leak from the pitot into the capacity.

Tap = cruise/climb switch  
open/close

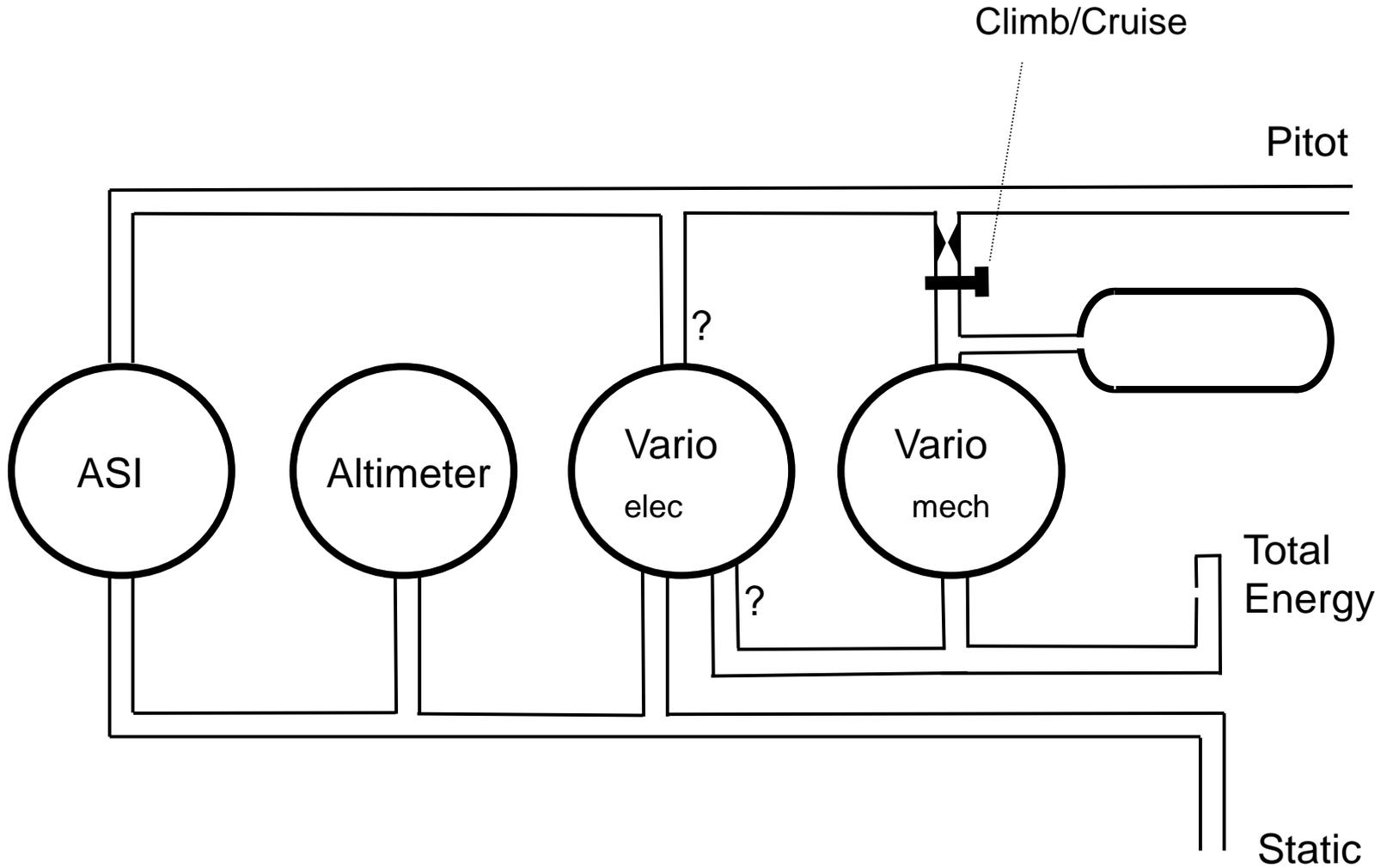
# Netto variometers

- The 'Cruise' setting is needed when using the McCready ring
  - The 'Climb' setting will require successive approximation
- Or it can be done electronically via the stored polar

# Super-Netto Variometer

- Only electronic (as far as I am aware)
  - Gives your climb rate in the thermal IF you were slow down to thermalling speed
  - Uses stored polar info

# PLUMBING



# STATIC/PITOT SYSTEM

- Tubes connecting vents to instruments must not leak
  - because pressure changes are small

# Dangers with ports

- Blocking with wax, bugs, rain, ice
- DO NOT blow down them!
  - If you do you will damage the instruments The innards of pressure instruments are very sensitive.



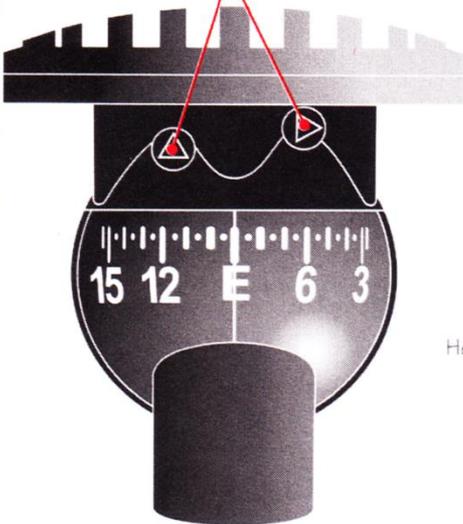
# COMPASS

- Legal requirement ??
  - apparently not unless you have an engine !?
- Types
  - Vertical card
  - PZL/Airpath
  - SIRS/Smiths
  - Cook
  - Boli

Vertical card compass

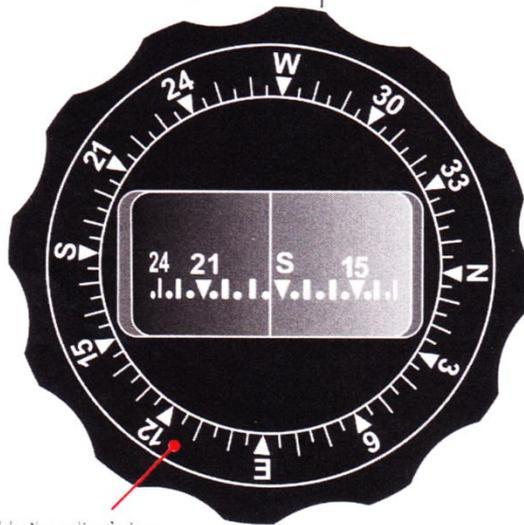


E/W and N/S adjustment screws



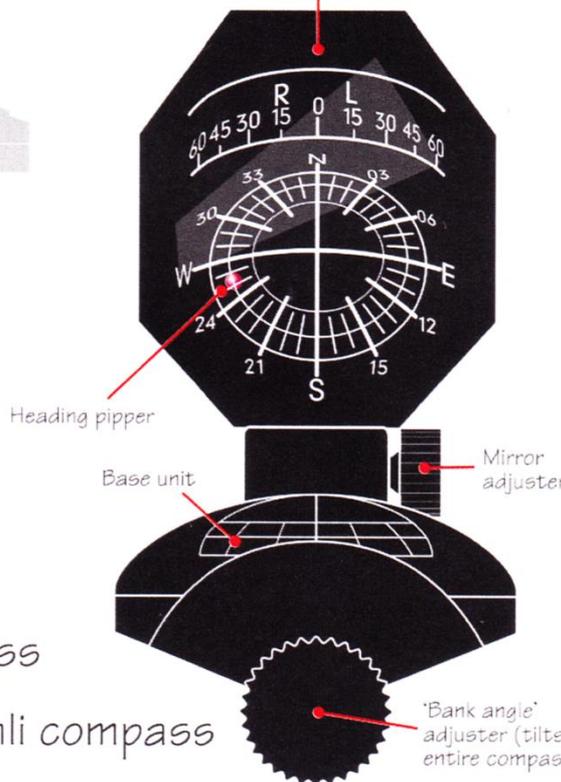
Standard 'wet' compass

PZL compass



Adjustable 'heading' ring

Display in mirror reflects main display in base unit



Heading pipper

Base unit

Mirror adjuster

'Bank angle' adjuster (tilts entire compass)

# Acceleration/Banking

## With a normal compass

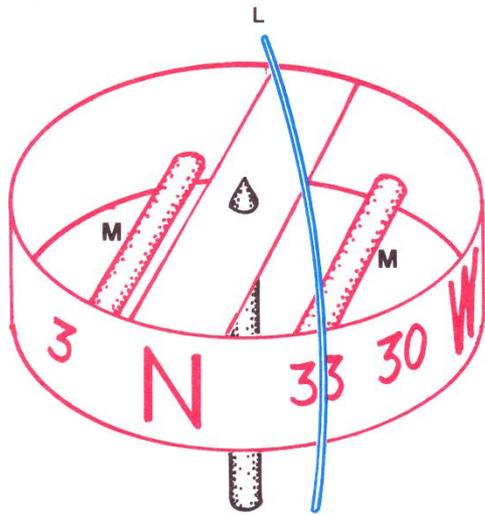
- Both turning and changing speed will cause the compass card to lag or lead
- This is related to rate of turn, g forces, the dip angle & the CofG of the compass needle
- Thus straightening up on a heading is difficult
  - A normal compass may swing wildly when turning or hitting a thermal
  - UN, OS

# Cook/Boli Compasses

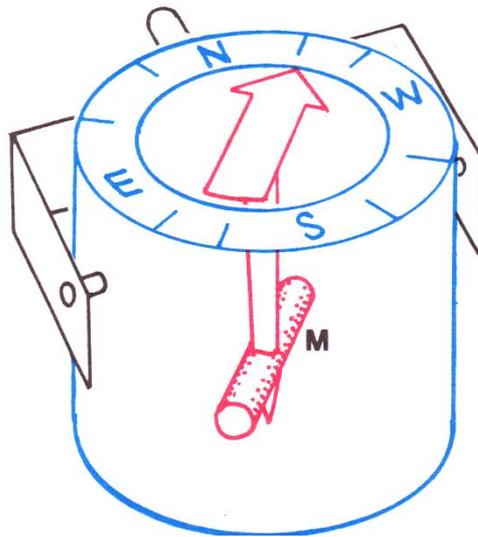
To avoid turning errors:-

- The Cook compass
  - pilot adjusts it to the vertical, it swings in pitch
- The Boli compass
  - Needle free to move in 3D and so stays in line with the dip. A red pip on the end indicates N on a graduated dome
    - » Pilot can rotate whole instrument
- Neither still manufactured ! GPS?

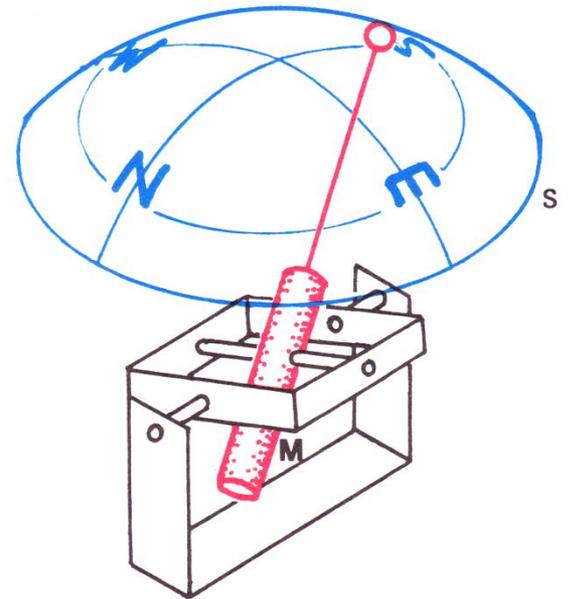
'Normal'



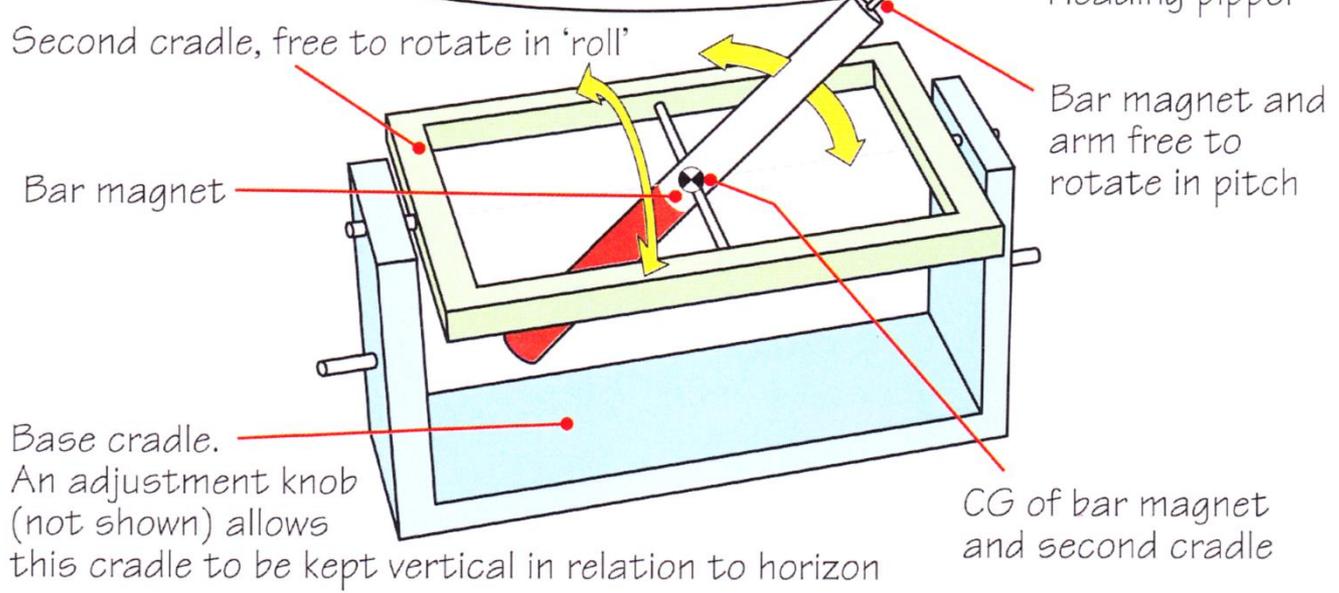
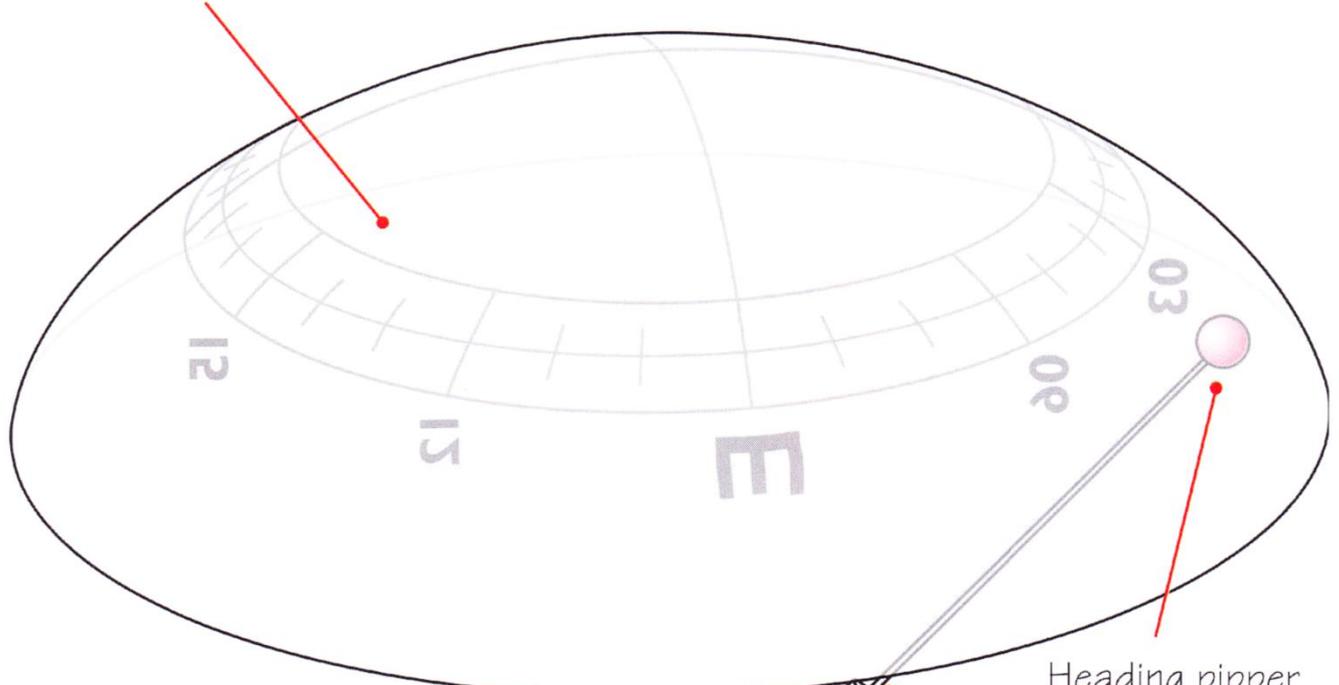
Cook



Boli



Heading 'cupola'. Headings are viewed reflected in the main mirror (see figure 2)



# COMPASS ERRORS

- Acceleration errors
- Banking errors
- Dip
  
- Variation
  - Difference between true north and magnetic north
- Deviation
  - Difference between magnetic north and compass north
    - » Deviation card

# Variation

- Varies from point to point.
- See  $\frac{1}{2}$  million chart
- Isognomic lines join places of equal variation
- Changes from year to year
- This is covered in Navigation

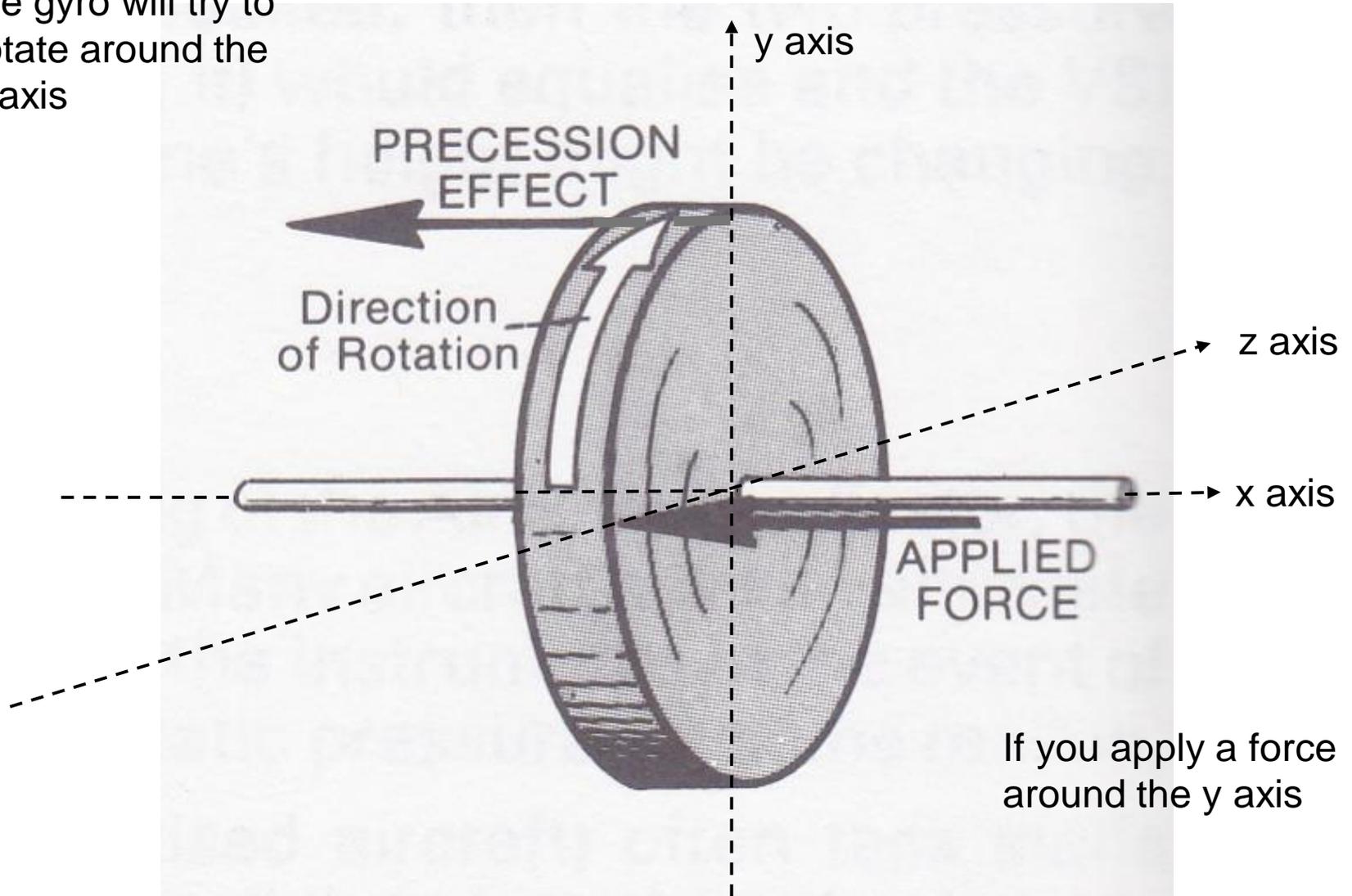
# Deviation

- Anything metal (ferrous) in the glider will affect the compass
- Anything electrical is likely to affect the compass
  - especially motors and speakers
- The compass must be 'swung' and these errors adjusted out as much as possible
  - All electrical equipment needs to be switched on at the time
  - Errors left are recorded in the 'Deviation Card'

# GYRO INSTRUMENTS

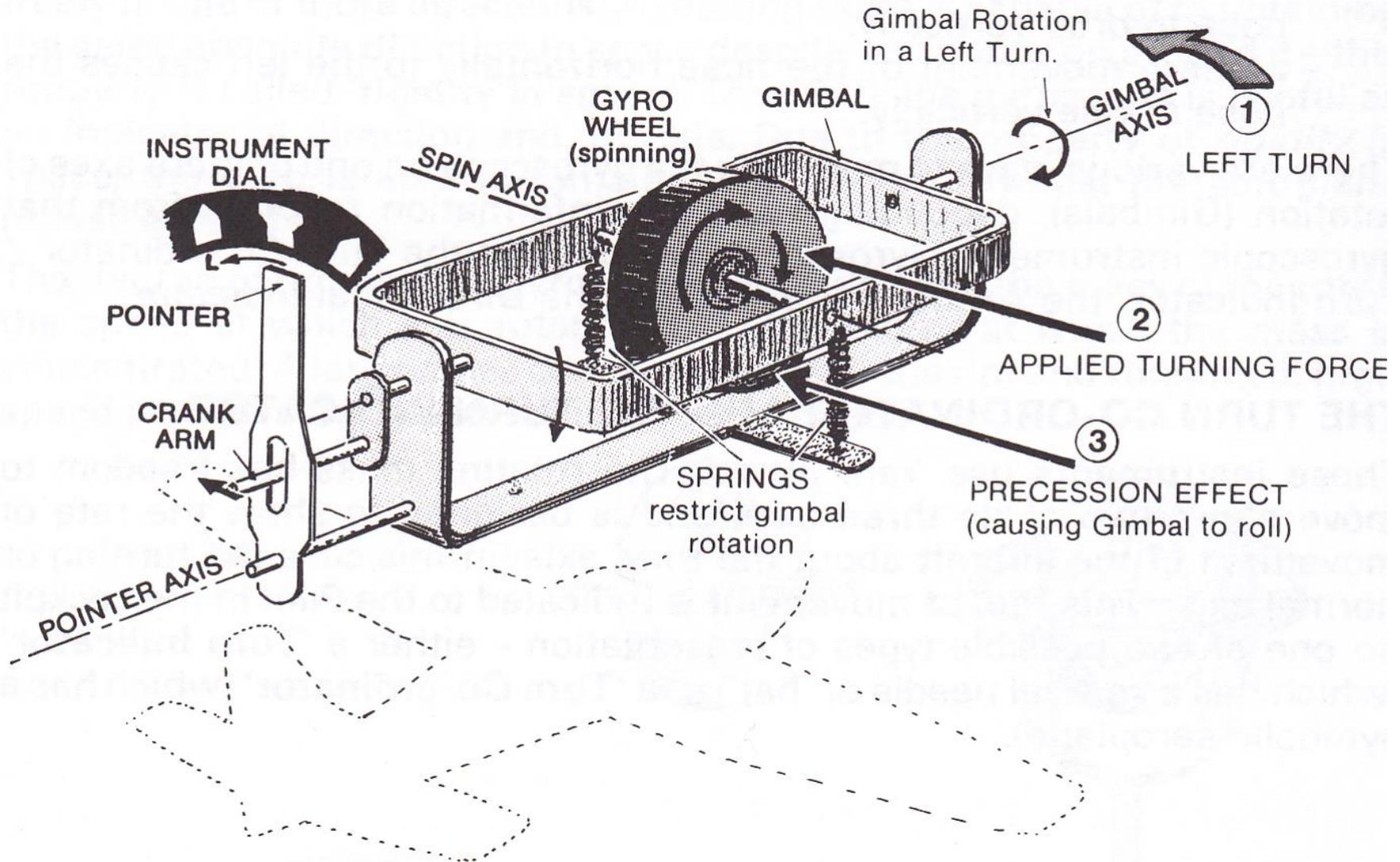
# THE GYRO

the gyroscope will try to rotate around the z axis

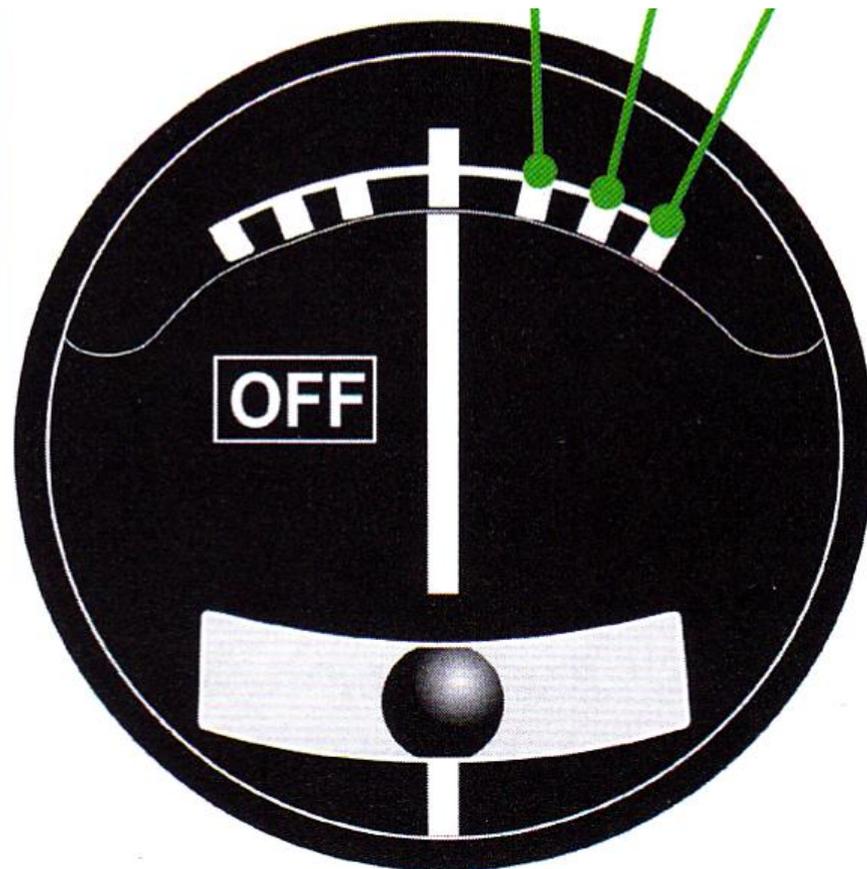


If you apply a force around the y axis

# Turn (and Slip)



# Turn & Slip



# Turn & Slip

- Shows rate of turn
  - NOT angle of bank

# ATTITUDE INDICATOR

- Gyro has freedom of motion in all axes and indicates the glider's pitch and bank angle
- Mechanical AIs consume a lot of battery power (around 2 amps)
- Electronic ones are coming into use
- Cloud flying
  - Legalities
  - Common sense

# ATTITUDE INDICATORS

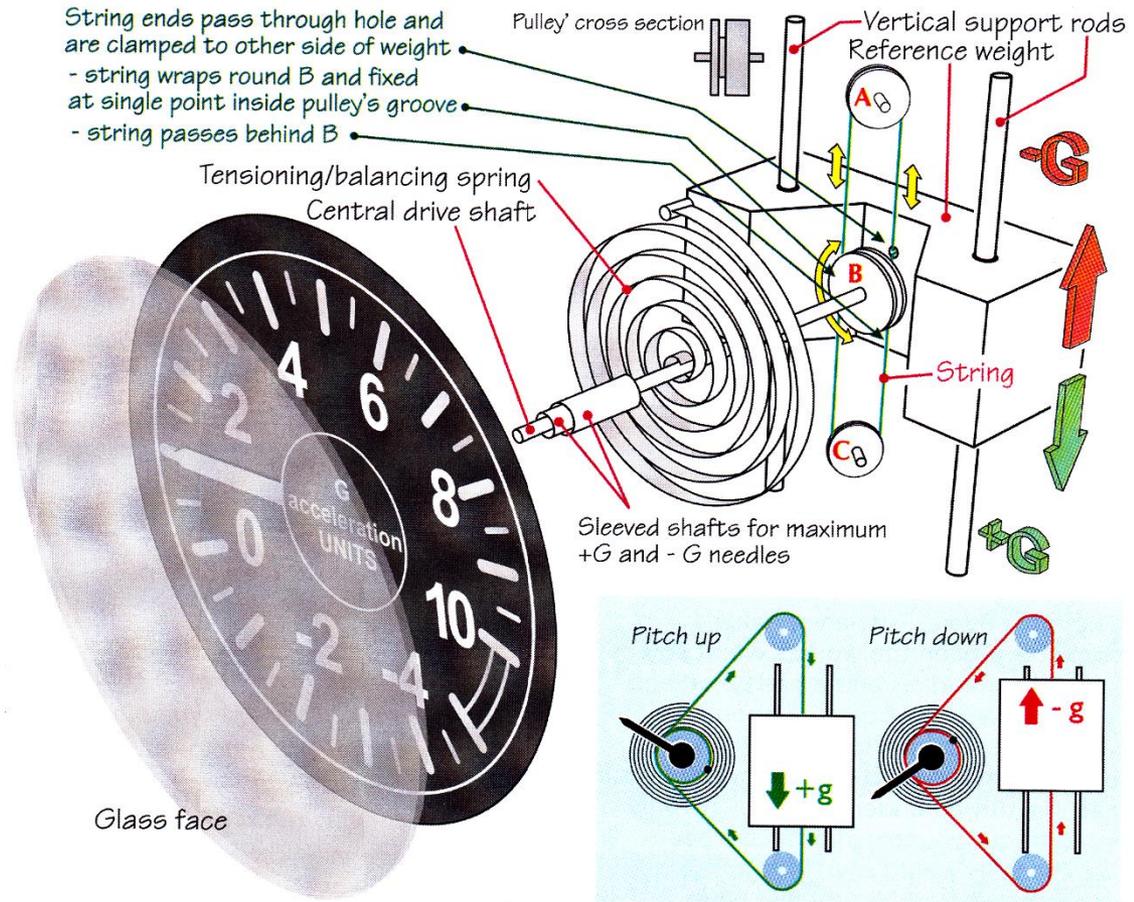
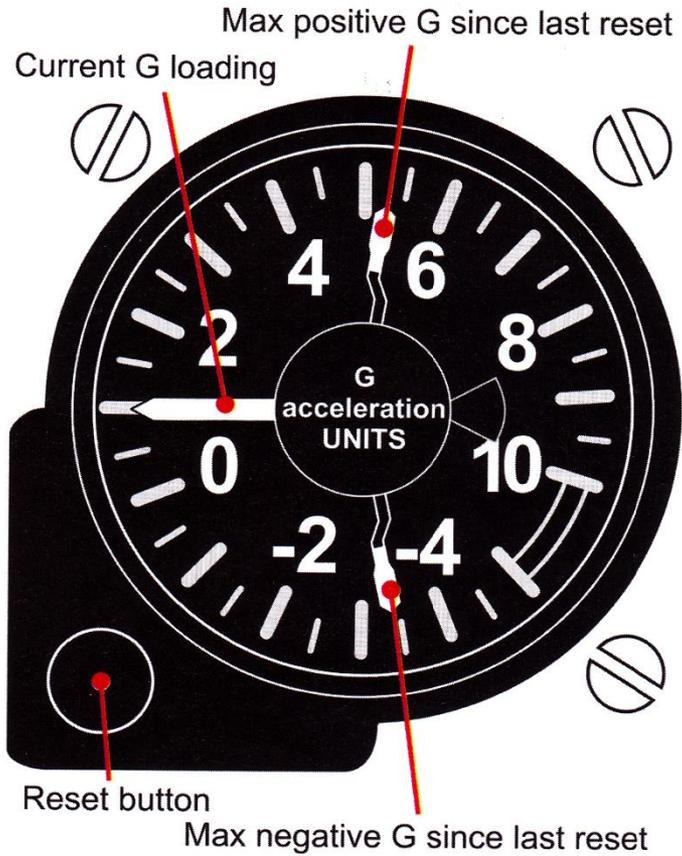


Mechanical



Electronic

# G-METER



# G-METER

- Required for aerobatics
- Report if max loads exceeded.

