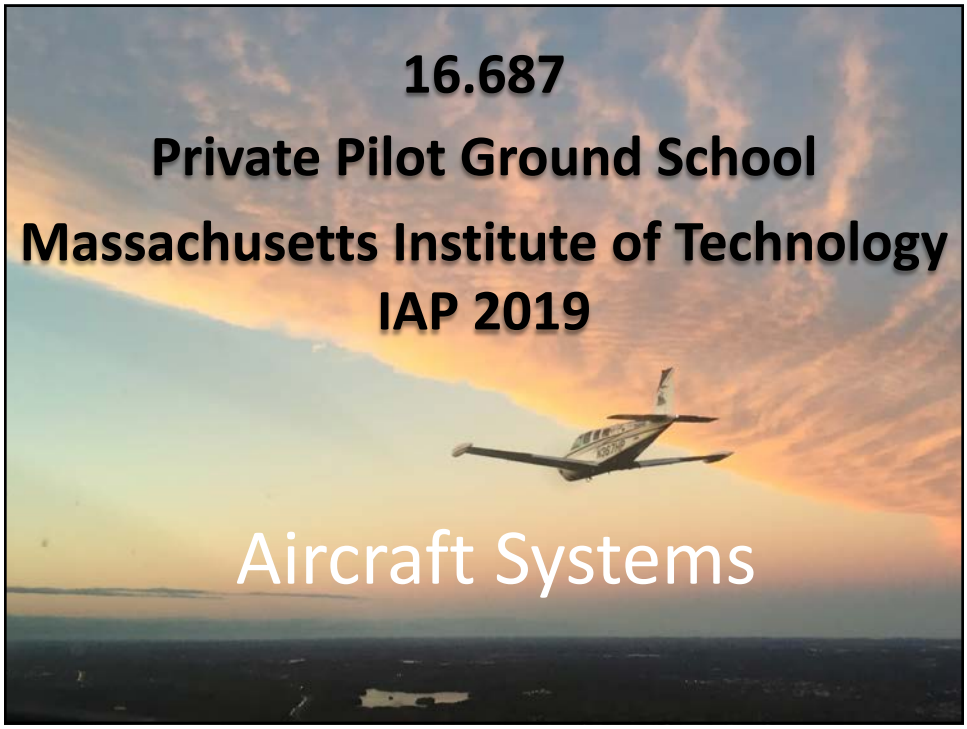


Canadair Regional Jet systems

16.687

- EICAS (engine-indicating and crew-alerting system)
- Electrical (AC and DC!)
- Fire Protection
- Fuel
- APU
- Engines
- Hydraulics
- Landing Gear
- Brakes

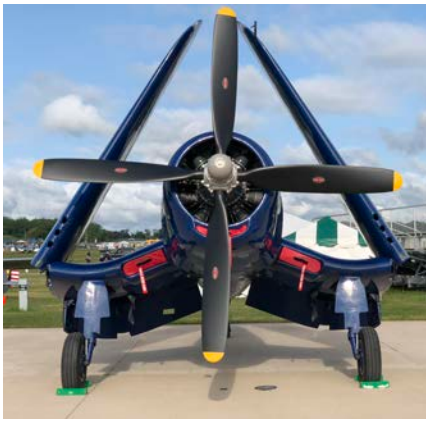
- Flight Controls
- Pneumatics
- Air Conditioning
- Pressurization
- Ice - Rain Protection
- Oxygen
- Flight Instruments
- Communications
- Navigation
- Autoflight

Red = we'll talk about it

Radial Engines

16.687

2,000 HP Corsair



3

Turboprop Engines

16.687

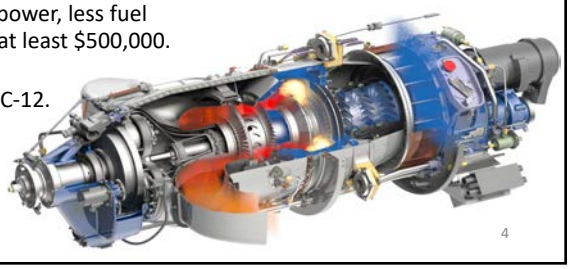
A turbine engine that spins a propeller: *turboprop*.

Popular examples: Pratt & Whitney PT6 (free turbine); Garrett/Honeywell TPE331 (direct drive through transmission). PT6 uses more fuel; the Garrett is more challenging to maintain. New contender: GE Advanced Turboprop (below), based on the Czech Walter design.

Advantages: Lightweight, reliable, and powerful.

Disadvantage: For moderate horsepower, less fuel efficient than piston engines. Cost at least $500,000.

Airframes: Beech King Air, Pilatus PC-12.



4

Turbofan ("jet") Engines

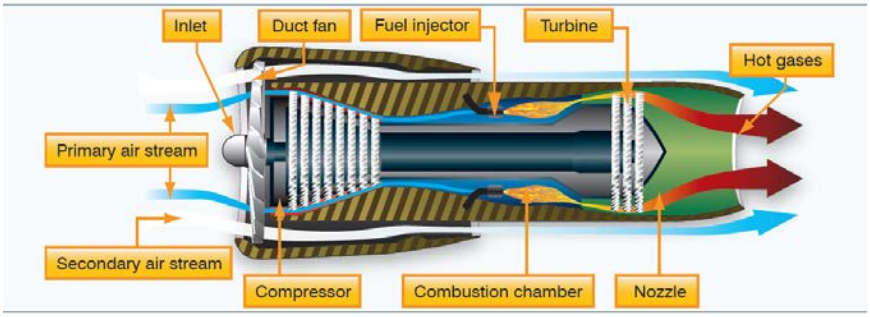
16.687

- Powerful, reliable, fuel-efficient (Boeing/Airbus size)
- Normally aspirated
- Low noise and vibration
- model planes to A380 with one gap: 4-seaters
- Cost $100,000+
- Birds, gravel? Parachute for single engine!

5

Compress and Burn Smoothly

16.687



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Reciprocating (Piston) Engine

16.687

- Lycoming and Continental produce designs unchanged since the 1950s (or earlier!)
- In your basic Cessna or Piper:
  - 4-Cylinder
  - Horizontally Opposed
  - Normally Aspirated
  - Direct Drive
  - Air/oil-cooled
  - Carburetor
  - 160-180 HP

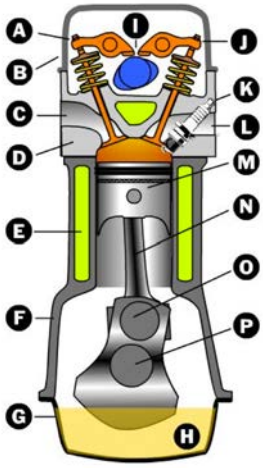
Reciprocating Engine Variations

16.687

- Fuel-injection: most new airplanes
- Turbocharger: high-altitude power (one oil system!)
- Horizontally opposed = less vibration; go to 6 cylinders for more/smoother power (310-350 HP common)
- Rotax: high RPM, water-cooled, transmission drives prop at a lower speed

One cylinder within a reciprocating internal combustion engine

16.687



A Intake Valve, Rocker Arm & Spring
B Valve Cover
C Intake port
D Head
E Coolant
F Engine Block
G Oil Pan
H Oil Sump
I Camshaft
J Exhaust Valve, Rocker Arm & Spring
K Spark Plug
L Exhaust Port
M Piston
N Connecting Rod
O Rod Bearing
P Crankshaft

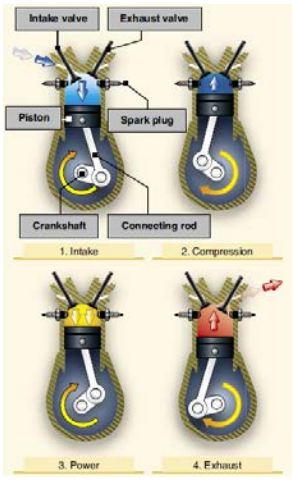
Source: public domain

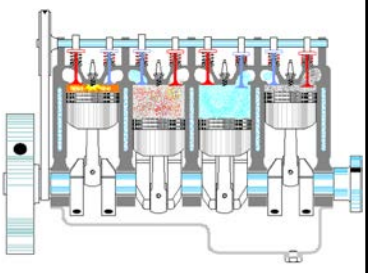
The Reciprocating Internal Combustion Engine: 4-stroke cycle

16.687

4-Stroke Cycle:

- Intake
- Compression
- Combustion
- Exhaust





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How are Engines Cooled?

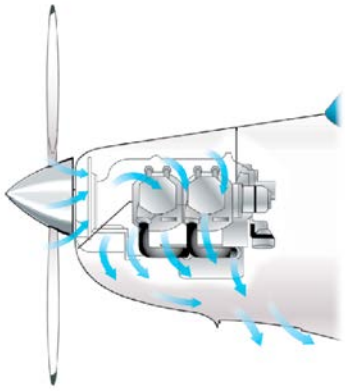
16.687

Air-cooled

Oil circulation also cools engine

To help cooling

- Lower nose in climb
- Increase airspeed



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The Mixture Control

16.687

- Adjust to compensate for density changes as aircraft flies at different altitudes and temperatures
- Decreased air density → lean mixture

Source: public domain

Fuel/Air Mixture

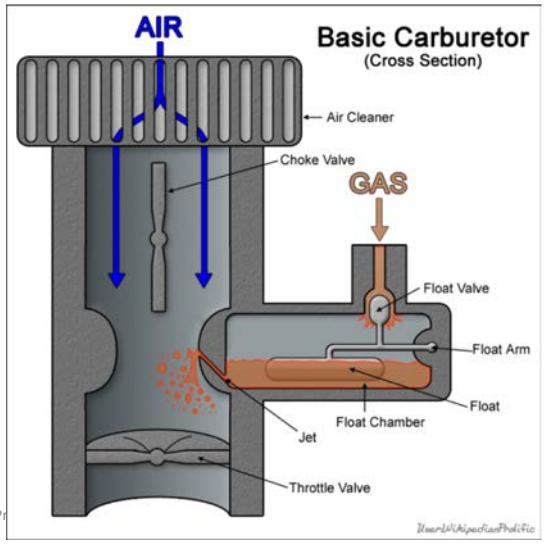
16.687

- Ratio of air to fuel based on weight
- Too Lean
  - Engine will run rough
  - Cylinder Head and Oil Temps too high
- Extra Rich
  - Provides added cooling to engine
  - In some cases can cause roughness also (fouled spark plugs)

The Carburetor

16.687

- Mixes fuel and air in something close to an appropriate ratio (nowhere near as precise as a 1980s automobile!)



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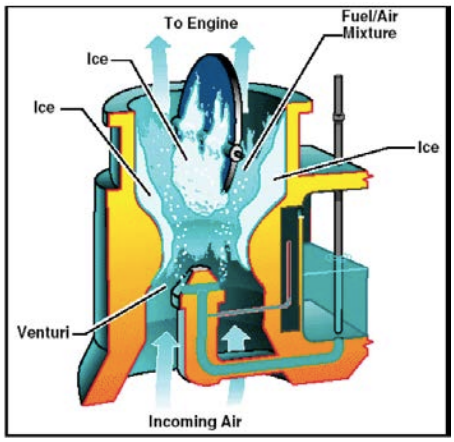
Carburetor Icing

16.687

- Conditions for carburetor ice formation
  - Outside air temp 20-70 degrees F
  - High humidity
- Carb. ice detected by loss of RPM
- Carb. Heat used to eliminate ice
- Carb. Heat enrichens mixture
- Carb. Heat *reduces* performance



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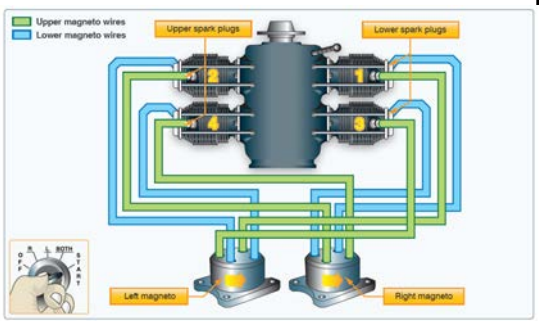
Ignition System

16.687

- Independent of electrical system
- Magnetos generate electricity for spark
- Each cylinder has two spark plugs
- Each plug within a cylinder is driven by a different mag
- Engine will run on single magneto, but not with as much power.
- No Battery? No Problem!



Source: public domain

Abnormal Combustion

16.687

- Pre-Ignition: slow burn before the spark
  - Hot spot inside cylinder
- Detonation–explosive burn before the spark
  - Can be caused by wrong fuel grade or too lean mixture
  - Indicated by
    - High Cylinder Head Temperatures
    - High Oil Temperatures
    - "Knocking" sound
  - Corrective actions
    - Lower nose in climb
    - Increase airspeed
    - Enrich mixture

Read: PHAK 7-18-19

Aviation Fuel

16.687

- 100LL (low lead) – blue
- Old days: 100/130 (green); 80/87 (red). (LEAN/RICH)
- Future: UL94, G100UL, 91/96UL
- Jet Fuel (tan/straw): hazardous to pistons
- Clear "fuel" in the sump?

Mixture of jet fuel and 100LL may still look blue/legit.

Propellers

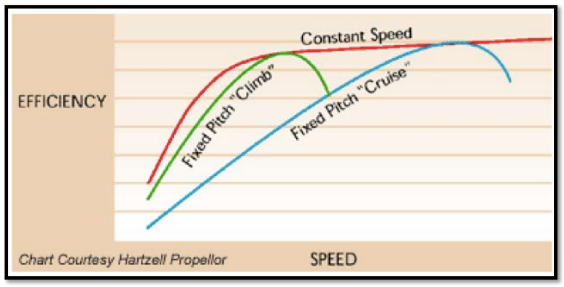
16.687

Fixed Pitch Propeller

- Non-adjustable

Constant Speed Propeller

- Blade angle changes to maintain selected RPM



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Constant Speed Propellers

16.687

Three control levers

- Throttle
- Propeller – engine RPM via blade angle
- Mixture

Avoid high power, low RPM

Source: public domain

See: PHAK 7-6, AFH 11-5

Source: public domain

FLIGHT INSTRUMENTS

"Steam-Gauge" Flight Instruments

16.687

Standard 1950s Six Pack:

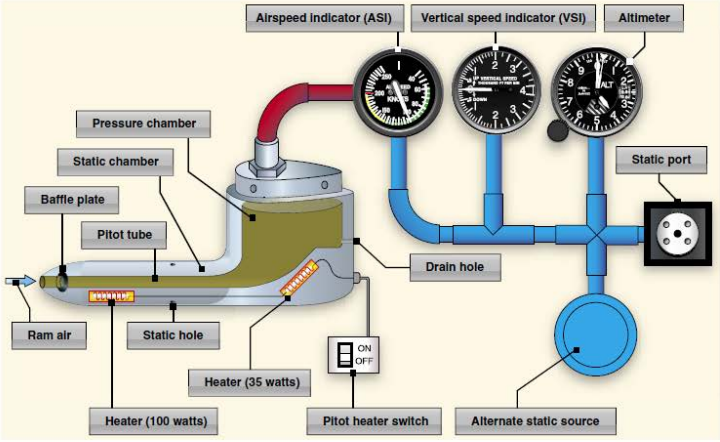
- Airspeed Indicator (ASI)
- Attitude Indicator (AI)
- Altimeter
- Turn Coordinator
- Directional Gyroscope (DG)
- Vertical Speed Indicator (VSI)

Source: public domain

Electric!

Pitot Static System

16.687



Source: public domain

Bug in pitot? Tape on static? See PHAK 8-10

23

Airspeed Indicator (ASI)

16.687

Standard color coded markings

- White arc – flaps
- Green arc – normal
- Yellow arc – smooth air
- Red line – never exceed speed

Source: public domain

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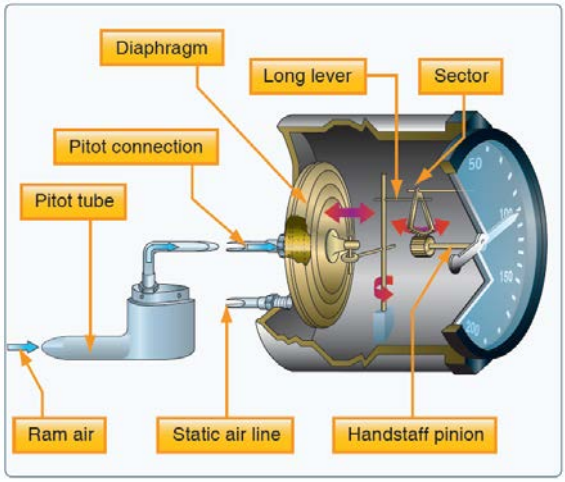
ASI: Under the hood

16.687



Source: public domain

ASI and V-speeds

16.687

- V_{S0} – Stall speed in landing configuration
  - Lower limit of white arc
- V_{S1} – Stall speed in specified configuration (clean)
  - Lower limit of green arc
- V_{FE} – Max flap extension speed
  - Upper limit of white arc
- V_{NO} – Max structural cruising speed
  - Boundary between yellow and green arc
- V_{NE} – Never exceed speed
  - Red radial line
- V_A – Manuevering speed
  - ***Not indicated on ASI***

Source: public domain

The SR20 needs this

16.687

Altimeter

16.687

- Pressure sensing from static port
- Hundreds, thousands, ten thousands hand
- Kollsman Window to adjust for nonstandard prevailing pressure
- (10,180')

Source: public domain

Our Previously Wonderful Standard Atmosphere

16.687

Altitude (ft)	Pressure ("Hg)	Temperature (°C)	Temperature (°F)
0	29.92	15.0	59.0
1,000	28.86	13.0	55.4
2,000	27.82	11.0	51.9
3,000	26.82	9.1	48.3
4,000	25.84	7.1	44.7
5,000	24.89	5.1	41.2
6,000	23.98	3.1	37.6
7,000	23.09	1.1	34.0
8,000	22.22	−0.9	30.5
9,000	21.38	−2.8	26.9
10,000	20.57	−4.8	23.3
11,000	19.79	−6.8	19.8
12,000	19.02	−8.8	16.2
13,000	18.29	−10.8	12.6
14,000	17.57	−12.7	9.1
15,000	16.88	−14.7	5.5
16,000	16.21	−16.7	1.9
17,000	15.56	−18.7	−1.6
18,000	14.94	−20.7	−5.2
19,000	14.33	−22.6	−8.8
20,000	13.74	−24.6	−12.3

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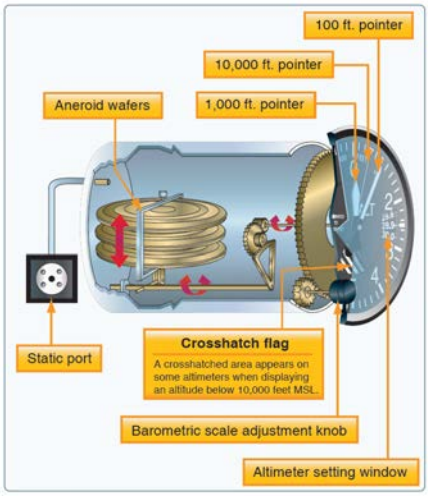
Altimeter: Under the hood

16.687



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Altitude Definitions

16.687

- True – actual height above sea level
- Indicated – what is shown on altimeter
- Absolute – height above the ground
- Pressure – height above standard datum plane (29.92" Hg), read from altimeter set to 29.92"
- Density – pressure alt. corrected for non standard temperature

Altitudes

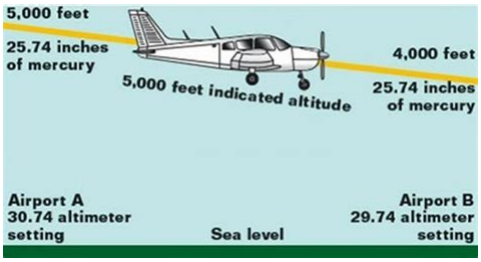
16.687

- Pressure Alt. = Density Alt.
  - At standard temperature
- Pressure Alt. = True Alt.
  - Standard atmospheric conditions
    - 15 deg C, 29.92 inches of Mercury

High to Low Look Out Below

16.687

- Turn knob 1” higher in Kollsman Window and the altimeter will read 1000’ higher
- Inadvertently do this flying from high pressure to low pressure weather.

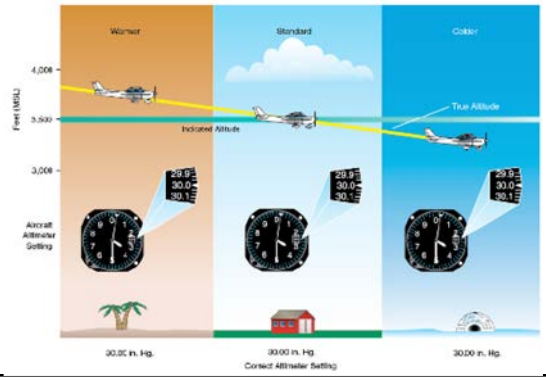


Source: public domain

High to Low (Temp) Look Out Below

16.687

- True altitude < indicated when pressure is lower than Kollsman Window setting
- Same situation if air is colder than standard



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Vertical Speed Indicator (VSI)

16.687

- Indicates rate of climb or descent in hundreds of feet per minute
- Slight lag unless it is an "IVSI," more common in helicopters

Source: public domain

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VSI: Under the hood

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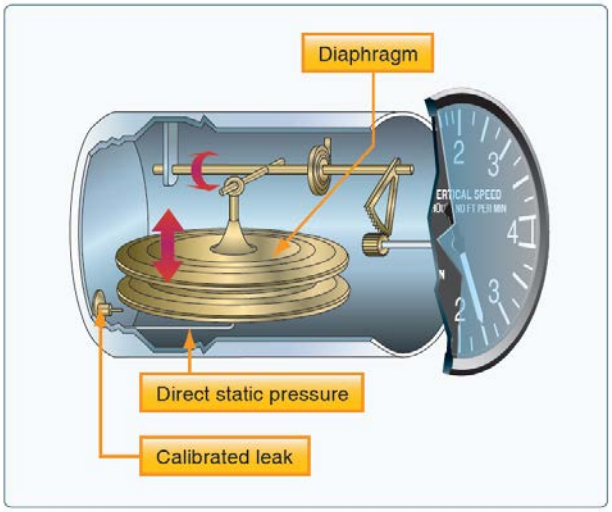

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Gyroscopes: Main Properties

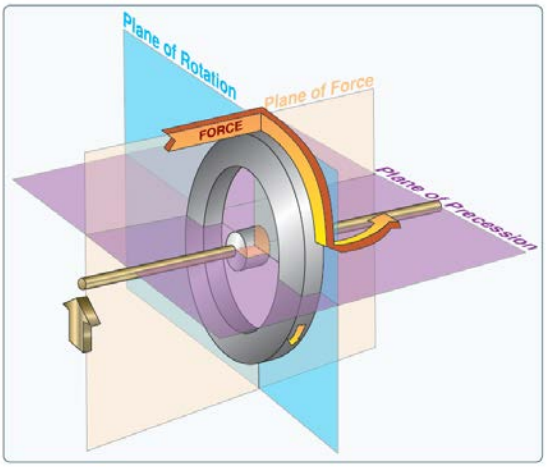
16.687

- Rigidity in space
  - Gyroscopes resist attempts to reorient themselves
- Gyroscopic precession
  - A deflective force applied to a spinning gyroscope acts as if applied 90 degrees in the direction of rotation

PHAK 8-15

Gyroscopes: Precession

16.687



Source: public domain

Figure 8-19. *Precession of a gyroscope resulting from an applied deflective force.*

Turn Coordinator

16.687

- Gyroscopic Instrument
- Angled to indicate both initial rate of roll and rate of yaw
- Ball indicates "quality" (coordination) of turn

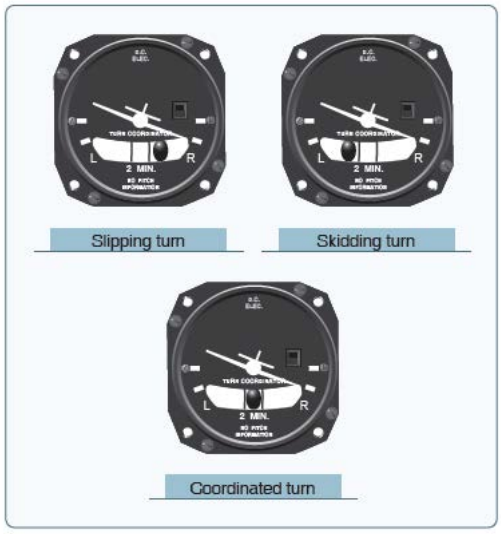
PHAK 8-16

FIGURE 5.—Turn Coordinator.

Source: public domain

Turn Coordinator Turning

16.687



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Attitude Indicator (AI)

16.687

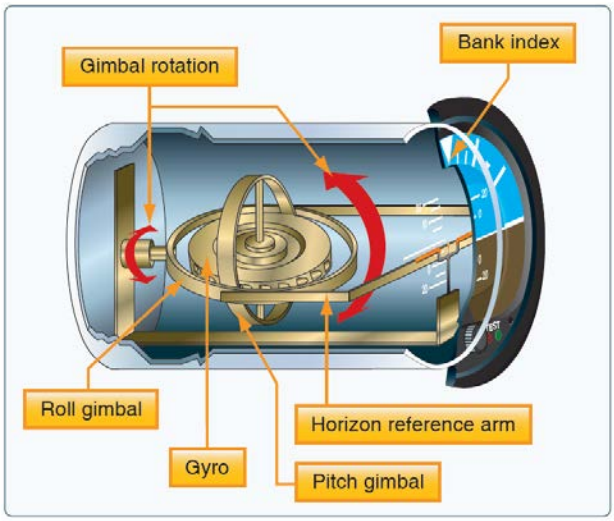
- Gyroscopic
- Indicates pitch and bank
- Set reference "airplane" in level flight only

Archaic: "Artificial Horizon"

Source: public domain

AI: Under the hood

16.687



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AI for the pilot

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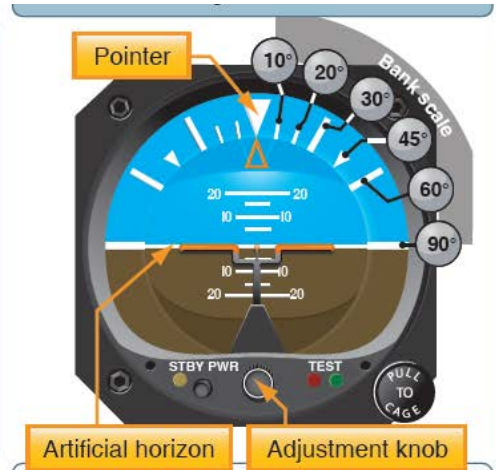

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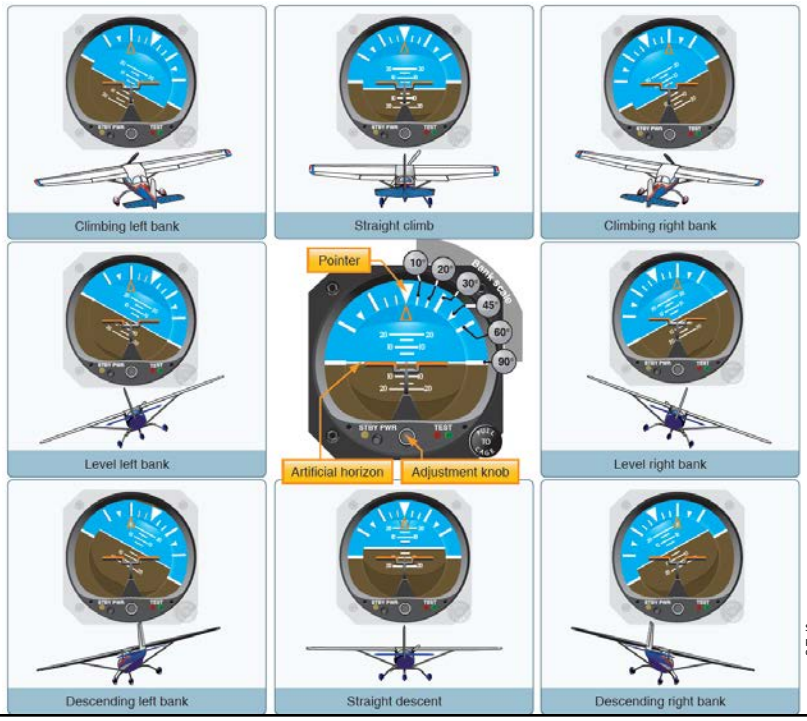

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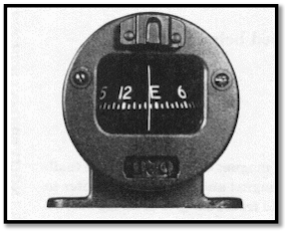
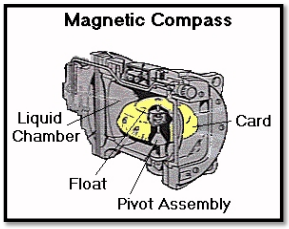
Magnetic Compass

16.687

- Aligns itself with magnetic north pole
- Accurate when straight and level
- Full of errors! (read PHAK 8-24)



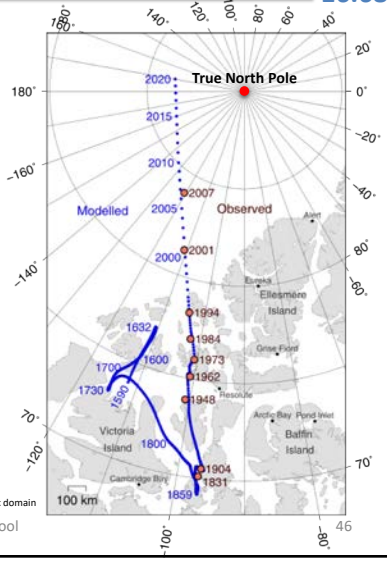


Source: public domain

Magnetic Variation

16.687

- True North Pole
  - Earth's rotation axis, where line of longitude meet
- Magnetic North Pole
  - compass points here
  - Moves over time



Source: public domain

Local Magnetic Variation

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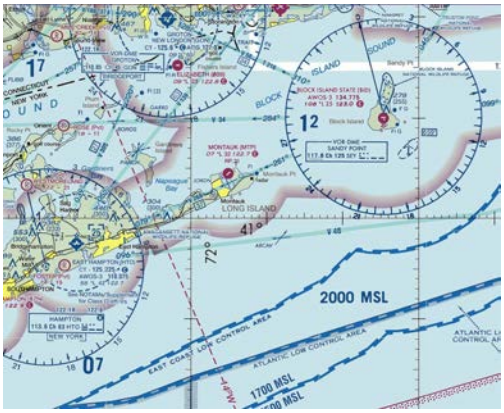
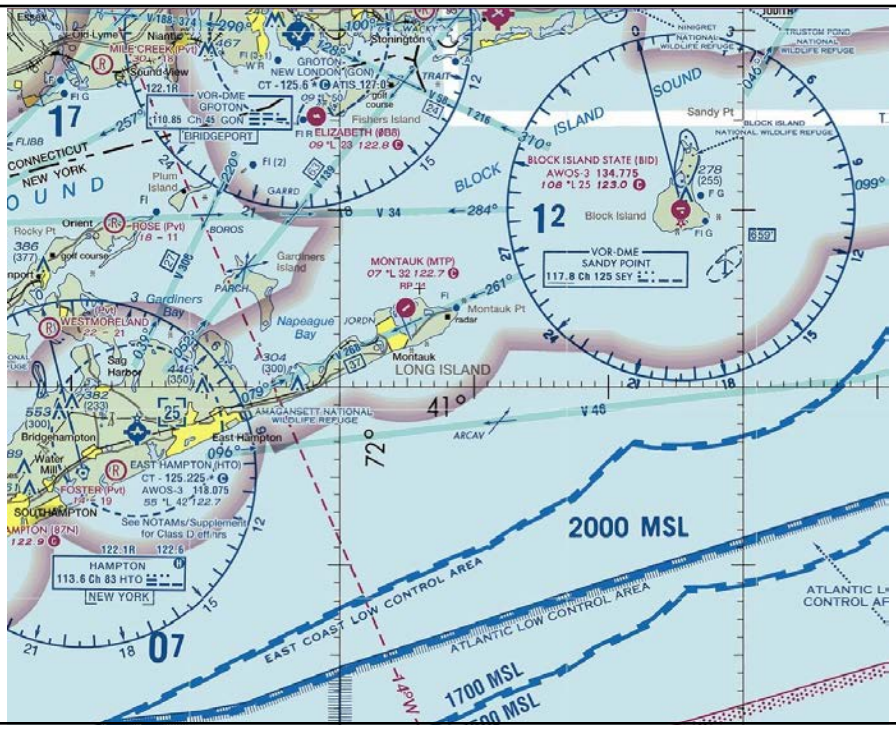
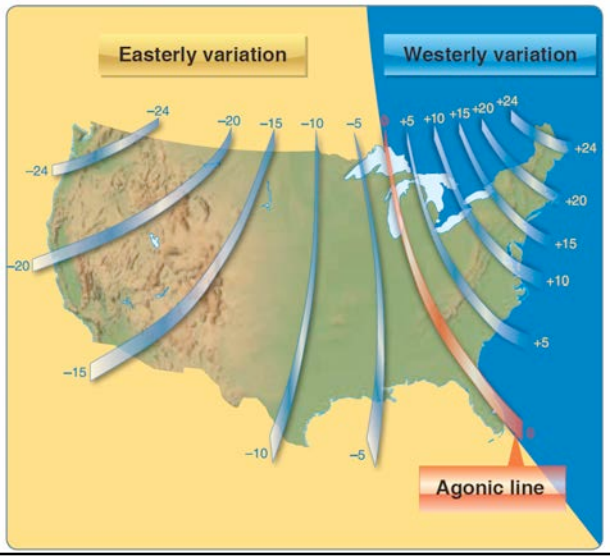
- True north != magnetic north
- VORs in magnetic
- Isogonic lines
- “east is least; west is best”: true + W variation = mag





National Magnetic Variation

16.687



Source: public domain

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Magnetic Deviation

16.687

Compass error due to stuff in the plane.

Read PHAK 8-24 for the rest:

- dip-related
- acceleration-related

Ask New Age passengers to leave the healing magnets at home.

Heading Indicator or "DG"

16.687

- Directional Gyroscope
- Does not seek north
- Pilot periodically aligns to Magnetic Compass

Source: public domain

HI/DG: Under the hood

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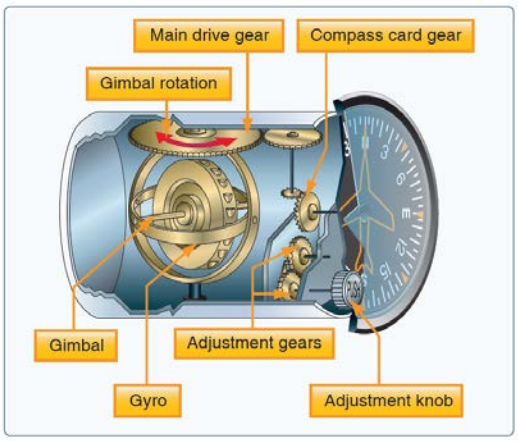

Source: public domain

HSI: Horizontal Situation Indicator

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- Looks similar to Heading Indicator
- Normally "slaved" to compass
- Combines navigation and heading information

Source: public domain

TAA: Technologically Advanced Aircraft

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"glass" (LCD) cockpit popular since 2003 in light aircraft

Pioneered by Cirrus with Avidyne (MIT spin-off). Adopted industry-wide by 2007, mostly with Garmin.

Aftermarket electronic flight instruments are widely available as retrofits for aircraft built 1930-2000.

Source: public domain

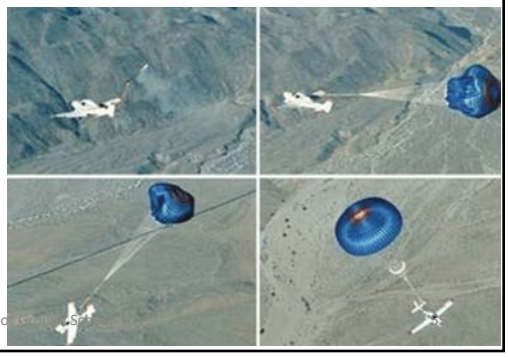
Ballistic Airframe Parachute

16.687

Pioneered on ultralights.

1999: Cirrus SR20 first certified airplane to include.

Today: most experimental and some certified aircraft, including Cirrus Jet(!)



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Summary

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- Piston engines can have quirks; turbines will just quit
- Six pack: Airspeed (pitot), Attitude (gyro), Altitude (static), Turn/Ball (gyro), DG/HSI (gyro), VSI (static)
- Altimeter measures percentage of atmosphere above/below
- Compass full of errors except when straight and level
- Aircraft manufacturers are really systems integrators.
- ***Study: pitot-static failures***
- ***Study: compass errors***

Source: public domain

MIT AEROASTRO

Questions?

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IAP 2019