Private Pilot Ground School

Winter 23/24 – Week 3
Chapter 4 – Electrical Systems
Chapter 5 – Flight Instruments

HOSSFLIGHT

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Review - Aerodynamics

- Stalls
- Load Factor
- How an airplane turns
- Drag
- Flaps
- Left Turning Tendencies
- Structural Limits - V-g Diagram
- Propellers

2

Review – Powerplants

- Types - Turbine and Piston
- Piston Engine Components
- Four Stroke Engines
- Induction System
- Carburetor
- Carburetor Icing
- Fuel/Air Mixture
- Fuel Injection
- Exhaust System
- Fuel System
- Oil System
- Cooling
- Transmitting Power - RPM vs Manifold Pressure
- Constant Speed Props

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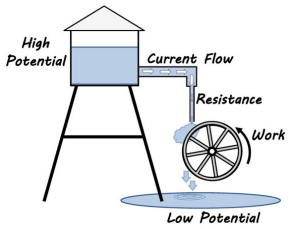
Electrical Systems

Chapter 4

4

Electricity as water

Electricity	Water
Wires	Pipes
Voltage	Pressure/Depth
Current	Flow
Battery	Water Tower
Alternator	Pump
Switch	Valve
Device	Water Wheel



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How Electricity Flows

- Electricity is the flow of electrons
- Voltage is like pressure
  - This is why transmission lines need to run on towers, power lines need to run on poles, but outlets can just use cords. 100KV/10KV/0.1KV
  - A measure of how many electrons are stacked on one side of the circuit
- Battery - storage for electricity
  - Charging pumps electrons from one side of the battery to the other, increasing potential
  - Connecting a device across the terminals allows the electrons to flow back, decreasing potential
- Alternator/Generator - converts physical movement into potential
  - Turning the alternator produces a voltage potential on its terminals
  - If connected to devices, they will run off the alternator
  - If connected to a battery and the battery has less potential, charges the battery by moving electrons from the positive terminal to the negative terminal

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Circuits

- Electrons do work by equalizing potential
- Wires and Devices provide a path for electrons to flow from high potential to low potential
  - Lights
  - Starter
  - Instruments
  - Radios
  - GPS
- Switches interrupt the flow of electrons to control devices
- Breakers and fuses interrupt the flow if it flows too fast (too much current)
  - Fuses melt a thin strip of metal that breaks connection
  - Breakers use properties of metal that deform under heating to trigger a switch to flip
- Ground
  - Cars, tractors, airplanes, etc. typically have substantial metal frames or bodies, which readily conduct electricity
  - One of the terminals of the battery is connected to the frame/body (usually negative terminal)
  - Now the entire vehicle has a return path for electrons to flow nearby and devices can be supplied with electricity using only one wire

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Measuring Electricity

- Voltage
  - Pressure or Potential
  - Unit: Volts
  - Measured with Volt Meter
- Current
  - Flow
  - Unit: Amperes (Amps)
  - Measured with Ammeter or Load Meter
- Power
  - Ability to perform work
  - Unit: Watts, equal to Volts times Amps
  - Measured with Wattmeter, or computed with ammeter measurement and known voltage
- Work
  - Amount of power exerted over time
  - Unit: watt hours, or amp hours
  - A battery's amp hours specification is the amount of work the battery can perform at its nominal voltage from a full charge.

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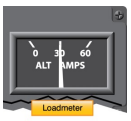
Ammeter/Loadmeter

- Load Meter - Measures the current produced by alternator
  - Positive indication shows alternator is working - if devices are on or battery is discharged
  - Zero indication means either nothing is drawing current or alternator isn't producing any
- Ammeter - Measures the current flowing in and out of the battery
  - Positive - battery is charging - good, unless very high, which would indicate a short circuit of some sort
  - Negative - battery is discharging - alternator is not producing sufficient power to run devices and/or charge battery
  - Zero - battery is full



Loadmeter

Ammeter

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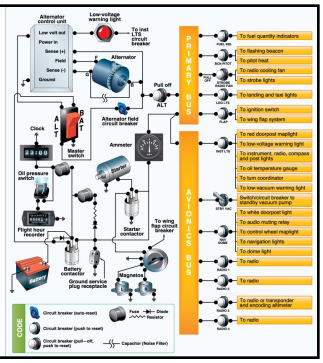
A Typical
Electrical System



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Flight Instruments

Chapter 5

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Magnetic Compass

- An essential instrument for navigation (and required equipment)
- One of the oldest and simplest instruments for indicating direction
- The card has a permanent magnet in it that aligns to the north pole
- The card in the magnetic compass has markings in 5° increments, with numbers printed every 30°
- Vertical line is called a lubber line
- The case is filled liquid filled to help stabilize the card
- The card turns backward from what you'd expect
- Magnetic compasses are prone to a number of errors…
- Variation, Deviation, and Dip Errors

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Variation Error

- The magnetic poles of Earth are not aligned with the axis of rotation of the planet
- Additionally, the constitution of the planet that the magnetic lines of flux pass through affect the direction and strength of the field.
- As a result, the difference between the compass reading and true north is different depending on where and when you are.
- This called magnetic variation, and the amount of variation can be found on sectional charts in the form of isogonic contour lines

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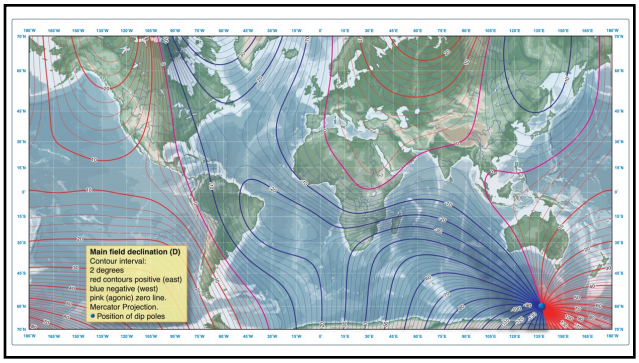

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Deviation Error

FOR STEER	000	030	060	090	120	150
RDO. ON	001	032	062	095	123	155
RDO. OFF	002	031	064	094	125	157

FOR STEER	180	210	240	270	300	330
RDO. ON	176	210	243	271	296	325
RDO. OFF	174	210	240	273	298	327

- Deviation is similar to variation, except it is concerned with the aircraft
- Magnets, magnetic metals such as steel, or electronics can bend magnetic fields
- As a result, the components or structure of an airplane will slightly change the the compass readings
- A compass correction card is created/updated by the aircraft maintenance technician as equipment is installed or removed
- The compass correction card shows the deviation for several headings

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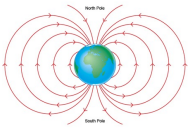
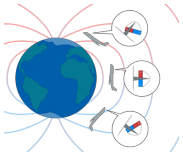
Dip Errors



- The magnetic field of Earth is parallel to the surface only near the equator.
- Further north or south, it begins to dip towards the planet, becoming vertical at the poles
- This dip causes the compass magnet to be pulled down slightly on the side closest to a pole
- This force causes the compass to read incorrectly in some cases, these are called dip errors
- Dip errors are pole-dependent and have opposite effects in the southern hemisphere
- Turning and Acceleration Errors



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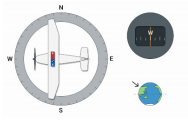
Turning Errors

When turning…	the magnetic compass will…
through NORTH	LAG the actual heading
through SOUTH	LEAD the actual heading
from a NORTHERLY heading	Initially turn OPPOSITE
from a SOUTHERLY heading	initially EXAGGERATE the turn
through EAST or WEST	indicate CORRECTLY
from EAST or WEST	initially indicate CORRECTLY



Remember: NOSE
North Opposite
South Exaggerated

Rule of thumb

- when rolling out on a northerly heading, stop the turn early by 15 degrees + half the lattitude
- southerly heading: roll out 15 deg + half the lattitude after desired heading

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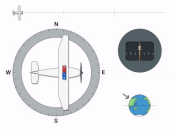
Acceleration Error

When…	on a(n)…	the magnetic compass will…
accelerating	EASTERLY or WESTERLY heading	pull to the NORTH
decelerating	EASTERLY or WESTERLY heading	pull to the SOUTH
accelerating	NORTHERLY or SOUTHERLY heading	indicate CORRECTLY
decelerating	NORTHERLY or SOUTHERLY heading	Indicate CORRECTLY



Remember: ANDS
Accelerate North
Decelerate South

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Introducing: The Six Pack

1. Airspeed Indicator
2. Attitude Indicator
3. Altimeter
4. Vertical Speed Indicator
5. Heading Indicator (DG)
6. Turn Coordinator

- Glass cockpits
  - These are essential instruments and are all displayed on the PFD
  - The first three are often installed as steam backup instruments

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Pitot Static System

- Provides air pressures sampled at the pitot tube and static
- Static air pressure is used for altitude, vertical speed, and airspeed
- Pitot tube pressure is called ram air pressure or impact air pressure and is used only for the airspeed
- Six Pack/Steam cockpits have plumbing connecting these air pressures directly to the instruments
- In glass cockpit systems, the ram air and static air are connected to a component called the Air Data Computer (ADC), which takes digital measurements and sends the information to the PFD electronically
- Alternate Static Source - inlet in the cockpit in case the static port is blocked

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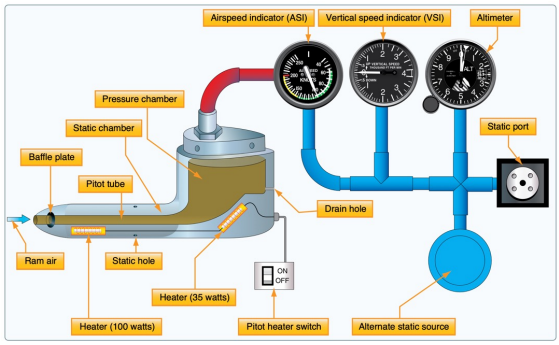

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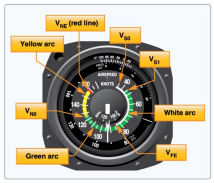
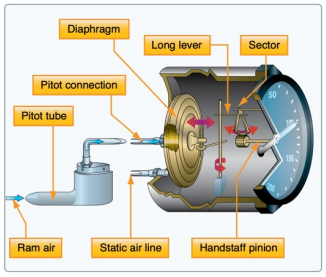
Airspeed Indicator

- Shows the speed of air moving over the wings*
- Works by measuring differential pressure between ram air and static air





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Types of Airspeed

- **IAS: Indicated** - Number read on the ASI
- **CAS: Calibrated** - Indicated airspeed corrected for installation error (correction chart in POH)
- **EAS: Equivalent** - Calibrated airspeed corrected for compressibility error - only a significant factor at high speeds
- **TAS: True** - Equivalent airspeed corrected for non-standard temperature and pressure
  - Air is less dense when warmer or at higher altitudes, and this affects the number displayed as you climb
  - Note that stall speed will stay the same indicated airspeed as you climb
    - The same factor that is causing the ram air pressure to drop is causing less air to flow over the wings.
    - So as you climb, stall indicated airspeed will stay the same, but stall true airspeed will increase.

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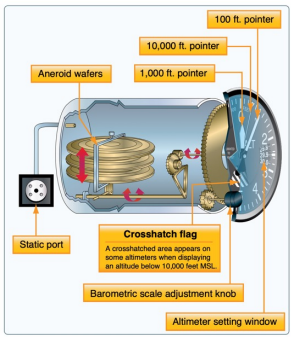
Altimeter

- Shows the number of feet above the selected reference pressure
- Works by measuring differential pressure between static air pressure and a calibrated reference



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Altitude Types

- AGL: Absolute Altitude - Height above the ground
- MSL: True altitude - Height above sea level
- Pressure altitude - Height above 29.92”Hg reference plane
  - Also what’s reported by Mode C transponder via altitude encoder

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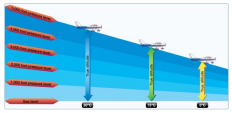
Measuring Altitude

- Pressure decreases by approximately 1”Hg/1000ft
- Pressure altitude = True altitude when local sea level pressure = 29.92”Hg
- ISA - International Standard Atmosphere - 29.92”Hg and 15 deg C/59 deg F
- Local temp and pressure affected by weather systems
- High/Low pressure areas offset the pressure
- Temperature expands or compresses the pressure levels



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Solving Altitude Questions

- Draw out the pressure levels, including slopes or compression/expansion due to temperature
- Figure out the surface elevation in relation to the pressure levels
- Remember 1”Hg/1000ft
- Remember that the hands move the same direction as the numbers in the Kollsman window
- *Hot to cold, look out below* - you will be lower than expected
- *High to low, look out below* - you will be lower than expected

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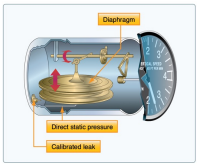
Vertical Speed Indicator

- Shows the rate of climb or descent in feet per minute
- Works by measuring differential pressure between static air pressure and a leaky reference.
- Similar design to altimeter, but with a calibrated leak
- As you climb, the pressure in the case drops, and the needle moves up just like an altimeter. But simultaneously, the higher air pressure in the bellows begins to equalize by passing through the calibrated leak.



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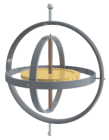
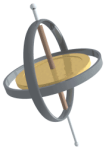
Gyroscopes

- The other three instruments of the six pack are gyroscopic instruments
- Each instrument contains a disc spinning at 10,000-20,000 RPM and hanging in gimbals
- Gyros have two key properties
  - Rigidity in space
    - Gyro will resist moving from the plane of rotation
  - Precession
    - a force applied to the disc will be experienced 90 degrees in the direction of the spin





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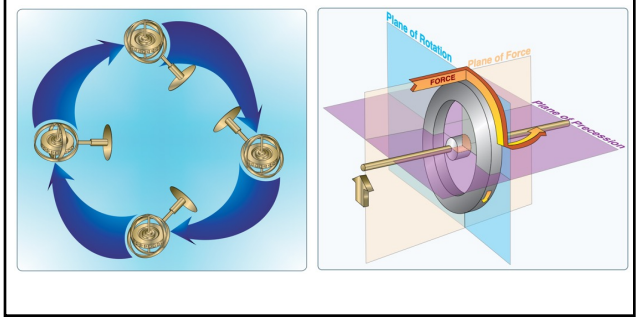

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Gimbals

- The spinning disc in a gyro is suspended in frames called gimbals
- Gimbals provide low friction joints and the ability to articulate in additional dimensions
- The number of axes the gimbals can move in is also called degrees of freedom
- One or more of the degrees of freedom will be connected to the instrument display

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Vacuum Driven/Electric/Solid State

- In steam panels, gyro instruments are powered either by electricity or by an engine-driven vacuum pump
- Aircraft with a vacuum system will have a vacuum gauge in the panel
- Glass cockpits and some newer electronic six pack instruments have solid state gyros with no moving parts
- In glass cockpit systems, the gyros are contained in the Attitude/Heading Reference System (AHRS)

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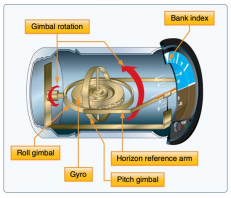
Attitude Indicator

- Shows the aircraft attitude using an artificial horizon displayThe disc is connected by gimbal linkage to a card at the front of the instrument
- In steam panels, the AI is typically vacuum powered, but all electric and solid state varieties are becoming popular
- Vacuum powered AIs take a minute or two to spin up and erect themselves after the engine is started.



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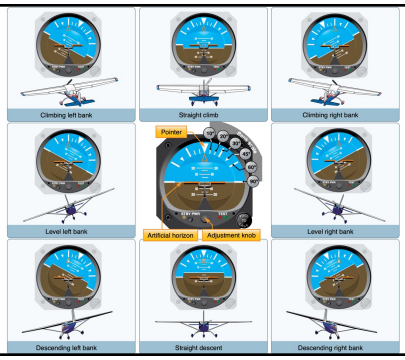

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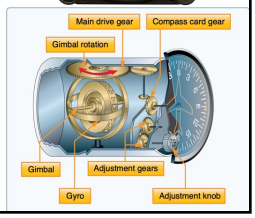
Heading Indicator

- Shows the current heading
- Far better instantaneous fidelity than magnetic compass
- The HI has a knob for aligning the compass card to the current heading.
- Some HIs have another knob to set a heading bug that can mark a desired heading on the the card for quick reference
- In steam panels, the HI is typically vacuum powered, but like the AI, electric and solid state varieties are becoming popular
- Solid state HIs often have a magnetometer inside them or somewhere on the plane that allow them to automatically align themselves.



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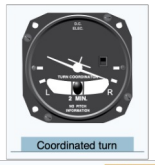
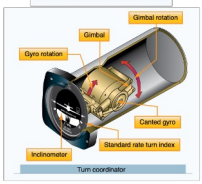
Turn Coordinator

- Shows rate of turn and turn quality
- The instrument card has lines that indicate level and below those, lines that indicate a standard-rate turn
- Standard rate is a 2-minute turn, 360 in 2 minutes (3 deg/min)
- The turn coordinator is typically electric to provide some redundancy for instrument flying. Instrument students will practice partial panel approaches, where the AI and HI are covered up and they must complete the approach with only the other four instruments in the six pack.





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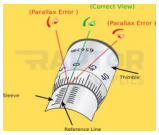
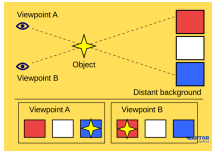
Parallax

- Effect where viewing angle changes perception of position
- Happens to all gauges and instruments with an indicator needle that is on a higher surface than the markings
- Most prominent when reading instruments on the opposite side of the panel
- Instruments are designed to read coaxially, so any deviation up, down, left, right, will introduce some error, though not necessarily big for instruments in front of you





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