Student Study Notes – Canadian PPL
Aviation Ground School: Flight Theory & Aircraft

This version of my "Flight Theory & Aircraft" study notes is from January 1st, 2017. I'll update this document any time I find the need to make any changes, and as I continue to progress through additional training.

I am sharing these study notes for anyone else who is taking their PPL in Canada. These aren't intended as a replacement for proper training. I'm only sharing these notes as a supplement covering many of the key points that I decided that I really needed to memorize while going through my own PPL studies. The info in these notes comes from a large number of different sources: The Transport Canada Flight Training Manual, Transport Canada's Aeronautical Information Manual (AIM), various flight schools and instructors (in multiple provinces), and numerous other books and online sources. These notes are not always in any particular order, although I tried to keep similar topics together in many cases.

Please note that while I have made every effort to ensure that all of the information in these notes is accurate, based on the sources from which I learned, you should verify everything here against what you've learned in your own study programs. I (Jonathan Clark) shall not assume any liability for errors or omissions in these notes, and your official pilot training should always supersede any information presented herein. As the Canadian PPL curriculum is updated occasionally, I recommend that if you want to be 100% certain that everything in this set of study notes is correct, you should print a copy and ask your instructor to review these notes with you.

If the aircraft type is not specified in the notes below, you should always assume that they refer specifically to characteristics of a Cessna 172M, which is a common training aircraft, and the type that I have used most frequently. Know the characteristics of your own specific training/examination aircraft by memory!

To download PDF or audio MP3 versions of these notes, visit: http://djbolivia.ca/aviation.html

Let's Get Started – Ground School: Flight Theory & Aircraft

GA – General Aviation

Standard Rate Turn – The aircraft moves through three degrees of turn per second. Therefore, a turn of 180° would take one minute, and a complete 360° circle would take two minutes. This is also known as a "rate one" turn.

Attitude (Pitch) plus Power (Throttle) = Performance. This formula is very important!

Fuselage – Houses passengers, pilot, cargo. Does not include the engine cowling, which houses the aircraft's engine.

The **Attitude Indicator** is sometimes called the Artificial Horizon.

The **Altimeter** must always be set to the proper barometric pressure in order to give accurate and useful readings. However, in some areas such as all high level airspace, and in Northern Domestic Airspace (which are SPR's or Standard Pressure Regions), all altimeters are set to 29.92, the international standard.

The **Heading Indicator** is sometimes called the Directional Gyro.

The **VHF Omnidirectional Range** (VOR) is the primary system used to define airways.

Instrument Landing System (ILS) – A very sensitive VOR that also includes vertical and glide slope info. Useful for precision approaches when landing in poor weather conditions.

Automatic Direction Finder (ADF) – Sometimes referred to as the Radio Compass.

Mode C Transponders can send back altitude info to ATC (not all transponders can).

Types of **Airframes**:
- Truss.
- Monocoque & Semi-Monocoque.
- Composite.

Bulkhead – A partition within an airframe used as a divider or barrier.

Truss – Steel tubes covered with metal, fabric, or composite materials for aerodynamic purposes. The primary tubes used are called **longerons**. Shorter cross-bracing tubes can be called **struts** and can be run horizontally, vertically, or diagonally. **Stringers** can run along the top.

Semi-Monocoque – A series of formers or bulkheads held together by stringers (360^o orientation). The frame is then wrapped with a stressed skin. This skin takes some of the load.

Monocoque – Similar to semi-monocoque but does not have stringers. Less rivets, less skin friction.

Composites – Make use of materials like fiberglass or kevlar. Stronger and lighter than metal and do not have fatiguing problems.

Advantages of **Tricycle Gear**:
- Does not nose over as easily.
- Better directional stability on the ground.
- Better visibility over nose while taxiing.
- Better ground handling.

Advantages of **Conventional Gear**:
- More propeller clearance.
- Less parasite drag from landing gear.
- Better on rough and unimproved runways.
- Less damage to the plane if the wheel gives out.

Retractable Landing Gear:
- Huge reduction in parasite drag and noise.
- More complicated, and risky that you could be distracted and land with it retracted.
- Operated by electrics, hydraulics, or manually (always has a manual backup).

Types of **Main Gear**:
- Split Axle: Bungie or oleo.
- Spring Steel Cantilever: Steel or composite, flexes.
- Single Strut: Oleo (almost vertical).

Differential Braking – Brakes can be operated independently (more control, tighter turns).

Heels on floor! Never land with brakes on!!

Flaps:

- Increase the lift and drag of the wing by increasing the camber.
- Can be electric, hydraulic, or manual.
- Types include: Plain, split, slotted, fowler, or combinations thereof.

Tires that are either low pressure and/or large are better on soft or rough airstrips.

Flaperon – Combination aileron and flaps. The pilot has separate controls and mechanical devices to make it work. Although slightly more complex, it can reduce the weight of an aircraft.

Cowling Flaps – Control the amount of air circulating around the engine for cooling. They are partially or fully closed during cruise/descent or when less air is needed.

Horizontally Opposed Engine – This is the most common type of reciprocating, air-cooled, four-stroke piston engine used in GA aircraft.

The **ring gear** is not what makes your propeller spin. It is only connected to the starter when cranking the engine. The prop is spun because it is connected to the pistons via the camshaft.

Each cylinder in an aviation piston engine has two spark plugs for redundancy.

Radial Piston Engine:

- Round shaped, air cooled with an odd number of cylinders (per bank).
- High power-to-weight ratio.
- Economical to buy, but maintenance intensive.
- Guzzles oil, using a dry sump.

Most aviation (and automotive) engines are **four-stroke**, as opposed to something like a chain saw or lawnmower, which are only two-stroke.

Four Stroke Cycle:

1. Intake: The intake valve is open and the exhaust valve is closed, which creates a vacuum. Vacuum pulls the fuel/air mixture into the cylinder thru the open intake valve. At this point, the piston is only moving due to inertia. The camshaft is what opens the intake valve.
2. Compression: Both valves are closed. Compression of the fuel & air allows the mixture to reach its maximum potency.
3. Power: Both valves are still closed. Prior to the piston reaching top dead center, the spark plug fires. As the mixture burns (not explodes) it forces the piston back down.
4. Exhaust: The piston is coming back up. The exhaust valve is open to allow exhaust to leave the cylinder.

Most piston engines are air cooled, although a few are liquid cooled. But liquid cooling is heavier and more complex, although there is less drag in liquid-cooled.

Magneto – Provides electrical current to the spark plugs (not supplied by the battery). Magnetos are always live and are designed to continue operating even after a magneto ground wire failure. Modern aviation piston engines have two magnetos, cross-wired to each cylinder, as a redundant fail-safe.

A shroud is often placed around the muffler to provide cabin heat. However, leaks are possible, which can lead to carbon monoxide poisoning. If you smell exhaust in the cabin, turn off the cabin heat.

Mixture Control:
- Rich means that it is heavy to fuel.
- The proper ratio of fuel to air is 1:14 or 1:15 by weight, not by volume.
- A lean mix increases engine efficiency and saves fuel. Also runs cleaner (avoids spark plug fouling and pre-ignition).

The Throttle and Mixture can have varying settings, from all the way "in" to all the way "out," like a light on a dimmer switch. Although carb heat has a similar type of "plunger" control, you should only ever do "all the way in" or "all the way out" for carb heat. Carb heat is either On or Off.

Be aware that when the carb heat is on, your aircraft is ingesting unfiltered air.

Turbochargers and Superchargers compress and increase the density of air. As we climb, the air becomes less dense, so compressing it makes the engine perform the same way as if it was at a lower altitude.

Turbocharger:
- Powered by the engine exhaust turning the turbine.
- Lightweight, does not rob power from the engine.
- Hot, expensive, maintenance intensive.
- Compresses air prior to entering carb.
- Engine is not turbocharged when the waste-gate is open.

Supercharger:
- Powered directly by the engine (gear driven off crankshaft).
- Reliable, not expensive.
- Compresses fuel/air downstream of the carb.

Density altitude is the altitude that the aircraft thinks it is operating at.

A "chop and drop" where you have a large power reduction and descend quickly, is hard on the engine due to shock cooling.

Engines with temperature gauges should generally not be allowed to cool more than 30^{o}C per minute. Do a partial block of the engine intake in sub-zero temperatures.

Optional Gauges that you might see on some aircraft include:
- Cylinder head temperature.
- Exhaust gas temperature (EGT).
- Carb temperature.
- Fuel flow/pressure.

Brake Horsepower – The power available after friction and other losses have been accounted for.

A landing is nothing more than a controlled crash. And if you're worried about landing with the engines out, remember that glider pilots do it every single time.

The camshaft only rotates once for every two rotations of the crankshaft.

Know the difference between a piston and a turbine engine. The piston engine is also known as a reciprocating engine because the mechanism (piston) moves back and forth. A turbine is based upon a rotary or circular design. A piston engine can move a large amount of air fairly quickly. A turbine can move a smaller amount of air extremely quickly.

A **turbo prop** is what results when you put a prop onto a turbine engine instead of onto a piston. It is a hybrid design which gives some advantages of each type of engine.

Turbochargers are not associated with turbine engines, despite the similarity in the names.

The **carburetor** (carb) has two purposes. It mixes the fuel and air in the proper ratio, and it regulates the amount of that fuel/air mix that enters the engine.

Updraft Float Carburetor:
- Mounted under engine.
- Outside air routed through ducts in the carb.
- Fuel/air mix sucked up into engine.
- Has a small chamber with fuel and a float valve to regulate fuel demands.
- As fuel leaves the carb, it is vaporized going into the piston intake.

Accelerator Pump – Provides additional fuel for sudden engine acceleration.

Economizer Valve (Idle Jet) – Allows engine to idle when the throttle is closed.

A rich mixture will lower the engine temperature somewhat.

As an aircraft climbs, the mixture automatically gets richer due to the decreasing density of the intake air.

The **EGT gauge**, on aircraft that have them, is great for adjusting the fuel/air mixture very accurately. The gauge focuses on relative temperatures rather than absolute.

Peak EGT Temperature = Maximum Economy

Best Power = Maximum Tach = Maximum Airspeed
(This is usually about a 1:12.5 fuel/air ratio, and about 100^{o}F cooler on the rich side).

It is definitely not good for the engine to be running "lean of peak." You really need a fuel injected engine, and should have an engine analyzer gauge, if you're going to do this.

Induction Icing – Impact ice can form on the air induction port when the air temperature is below 0^{o}C. This is most prevalent around -4^{o}C in air with lots of precipitation or moisture.

Carb Icing – Occurs inside the carb itself. Carb heat comes from air inside the cowling, which passes thru a heat box. In the event of impact ice on the induction port or air filter, carb heat can be used as an alternate air source.

Any time you see a decrease in RPM's (or a drop in the manifold pressure gauge in a constant speed prop) and you don't know why, *always* apply carb heat immediately. The engine performance may become even more rough, but don't take the carb heat off! That's the carb ice melting.

MOGAS is more susceptible to carb icing than AVGAS.

Throttle Valve Ice occurs most often with partially closed throttle, and at low power.

Most fixed pitch aircraft should almost always use carb heat below 2100 rpm.

Understand the differences between carb icing, throttle icing and fuel vaporization icing. Throttle icing is one type/component of carb icing, and fuel icing is the other component. Carb icing, overall, is caused by a temperature drop inside the carburetor, which can happen even in conditions where other forms of icing cannot occur on the exterior of the aircraft. The causes of this temperature drop are two-fold. Fuel vaporization icing is due to the evaporation of fuel inside the carb, and this fuel icing is generally responsible for about 70% of the temperature drop inside the carburetor. This icing forms on the walls inside the carb. Throttle icing relates to the temperature loss caused by the acceleration of air and consequent temperature drop specifically around the throttle valve, with ice forming from water vapor condensing onto the throttle valve. Fuel vaporization icing and throttle icing generally occur at the same time, and they are known collectively as carb icing.

Variable Pitch Propeller Aircraft:

- Throttle controls manifold pressure and therefore engine power.
- Propeller control regulates both the engine RPM and the propeller RPM.
- Setting the power of the engine requires adjustment of both of the above controls.

When taking off from an airport at a high elevation, make sure you lean out to the best power for takeoff!

Fuel Injection Systems:

- Only subject to throttle icing.
- No risk of carb icing (fuel vaporization icing) since fuel is not introduced into the venturi section of the regulator unit.
- Fuel is vaporized by nozzles, as it is discharged into the air stream entering the intake manifold.
- Throttle is connected to a fuel metering valve.
- More uniform distribution of fuel to each cylinder. Each cylinder gets its own supply.
- More power since it doesn't need to heat carb air.
- Carb icing is not possible.
- Better fuel economy.
- Easier starting in cold weather (but harder in hot).

Vapor Lock – Bubbles of vaporized fuel in the fuel line of a fuel injected engine.

Unlike a carb, you'll probably want to start a fuel injected engine as rich-lean-rich.

Aircraft can have either 12v or 24v batteries.

Alternators can create current with a fairly low RPM, but **generators** require a high RPM. Piston engines usually use alternators, while turbine based engines use generators.

The **master switch** is a linked switch:

- Battery can be on or off, the position of the alternator doesn't matter.
- Alternator can only be on if the battery is also on. If the battery is off, the alternator also turns off, regardless of the position of the switch.

Piston aircraft **battery types**:

1. Lead Acid Flooded Cell.
2. Acid/Absorbed Glass Mat (AGM). This is a sealed battery. Try not to ever let an AGM get below a 50% charge.

A negative charge/deflection on the ammeter may indicate that the alternator is not charging the system, and the battery is carrying the load.

The alternator often puts out 28v (at 60 amps) even though the battery is only 24v, and this output is regulated appropriately.

A **loadmeter** shows the number of amps being drawn.

A very high positive reading on an ammeter possibly indicates that the battery was heavily discharged, and will go away after a few minutes as the battery takes up a charge. A positive deflection means that the alternator is providing power, a negative deflection means that the battery is providing power, and zero means no flow.

Voltage Regulator:
- Prevents the alternator from overloading the electrical system.
- Prevents the battery from being overcharged.

Transports (large commercial aircraft) usually use NiCd nickel cadmium batteries.

Reasons for having oil in the engine:
1. Lubricating.
2. Cooling.
3. Sealing.
4. Cleaning.

Viscosity – The thickness or resistance to flow of a fluid.

Detergent Oil – Normal motor oil, which has additives to keep the engine clean and to keep sludge from forming.

Mineral Oil – A non-detergent oil, normally used to break in a new engine. Often only used during the first fifty hours of operation.

Oil distribution systems in an engine can either be forced-feed or splash (gravity). If using forced-feed, there are two types:
- Dry Sump: Uses a separate tank of oil that is forced into and through the crankcase and back by a pump.
- Wet Sump: Oil is contained in the bottom of the crankcase where it is fed through the engine by a pump.

Blow By – A vent for excess oil to be expelled from the engine if it is overfilled or expands too much on heating.

Oil Filters – Only fitted to forced-feed systems. Usually located on the outside of the engine, downstream of the oil pump.

Pressure Relief – A force fed dry sump has a valve used to help regulate oil pressure in the engine.

A non-congealing oil cooler will prevent overheating by a by-pass that allows the viscous oil to flow and warm up, then warm up the remaining oil.

Octane Rating Fuel Colors:
Blue: 100LL – low lead. A type of AVGAS.
Green: 100/130 – high lead, rare. A type of AVGAS.
Clear: Jet A. Jet Fuel.
Yellow: Automobile gasoline. MOGAS.

Octane Ratings – When you see two numbers, the first is the octane rating at lean mixture, and the second is at rich.

Using a lower grade fuel gives you more heptane and less octane, and may lead to detonation.

Octane doesn't tend to explode, it burns slowly. **Heptane**, however, is extremely explosive.

AVGAS at 15ºC is 6 pounds/US gallon. Jet fuel at that temperature is 7 pounds/US gallon. Fuel gets denser and heavier as temperature decreases.

Possible **additives**:

1. Ethylene Dibromide: A cleaning agent, minimizes oxidation on spark plugs.
2. Anti-Icing: Delays the formation of ice crystals.
3. Lead Tetra-Ethylene: Slows combustion.

Baffles in the fuel tanks keep it from sloshing around too much.

Fuel tank vents allow air to come in slowly to prevent a vacuum situation, but also can act as an overflow.

Drain Valves – Allow checking for water, ice, or other contaminants in fuel, and also to drain such contaminants.

Detonation can be caused by leaning too much, or by low octane fuel.

Primer – Vaporizes fuel and sprays it directly into the entrance of the cylinder. Minimizes wear and tear on the starter, and less battery drain.

Never trust fuel gauges. Do a visual check before every flight.

MOGAS can only be used if the engine has been specifically modified to use it.

You should usually fly with fuel tanks set to "both" unless you're trying to balance the weight in the aircraft.

In the event of an engine failure, one of the first things you should reach for and change is the position of the fuel selector.

Fuel pumps can be engine driven to provide fuel pressure during the start. Electric pumps may be used as a backup on low winged aircraft.

Supplemental oxygen is used in non-pressurized aircraft that go above 10,000 feet.

Re-breather masks are simple but not very efficient. Used in drop-down systems.

Demand O_2 Systems:

- O_2 flows into the mask only when inhaled.
- Efficient, no re-breather bag.
- Mask must be firmly seated on face.

In a pressurized piston airplane, the pressurization is provided by the turbocharger.

In a turbine aircraft, bleed air from the compressor is used to pressurize the cabin.

There is usually an outflow valve and also an emergency dump valve in a plane with a pressurization system.

The differential from sea level to 10,000 feet is 4.6 PSI. From sea level to 35,000 feet is 11.2 PSI. Most planes will have a maximum pressure differential level, ie. King Air is 4.0 PSI, Airbus is 8.0 PSI. The aircraft has an "internal altimeter" that you set to the desired cabin pressure.

Differential Pressure – Difference in PSI from the inside to the outside of the airplane.

Cabin Altitude – The equivalent altitude that the cabin is pressurized to. Most transport aircraft set the cabin to 8,000 feet.

Vacuum System – Powers the gyros. Usually engine driven, although classic/heritage aircraft may have a venturi. Often only has a shelf life of 500 hours. Be prepared, because you'll lose some of your instruments when this happens (ie. attitude and heading indicators).

De-Icing Systems – These systems remove ice from critical surfaces during flight. Reactive.

Anti-Icing Systems – Prevent ice from forming in the first place. Proactive. Systems can be fluid, electrical, heating devices, etc.

Control Riggings – Cable (in most small GA aircraft), pushrods, or "fly by wire."

Manifold Pressure Gauge – Found on aircraft with a variable pitch propeller (and therefore a fixed RPM). Measures how much air is allowed to enter the engine for the purpose of combustion. This indicates how much power the engine might produce, not what it is producing. And it is actually measuring suction, not pressure, because higher manifold is lower suction.

To check the Manifold Pressure Gauge:

1. Set altimeter.
2. Subtract 1 inch Hg (mercury) per 1000 feet AGL.
3. The Manifold Pressure gauge should show close to this value (ie. manifold pressure is lower than altimeter).

Static Manifold Pressure – The pressure before startup. On takeoff, you should see about one inch less of manifold pressure than static manifold pressure, due to the resistance of the air filter and various bends in the ductwork.

An engine at full throttle can now draw as much air as it is capable of mixing with fuel and burning, but it will usually not reach the static manifold pressure value due to intake filter, throttle plate, and ducting bends, etc. However, it is possible to exceed ambient manifold pressure due to ram air effect.

As long as the engine is running/windmilling, it is sucking air, which is measured as manifold pressure. Manifold pressure on a dead engine will not drop.

Manifold pressure depends on:

1. Ambient pressure.
2. Position of the throttle plate.
3. Speed of the pistons.

How to detect an induction system leak:

- Engine roughness during ground idle.
- Whistling noise during idle.
- Abnormally high manifold pressure for throttle position.

Bernoulli was concerned with conserving the overall energy of the system (fluid).
Newton was concerned with conserving the overall momentum of the system.

Newton's law as applied to flight would suggest that since the wing is at an angle to the airflow, the airflow pushes the wing up by reflecting and bouncing off the bottom, thus the wing is reacting by moving in the opposite direction.

A plane rises because it has excess thrust, not lift (technically speaking).

Lift – The component of aerodynamic force that is perpendicular to the relative airflow.

Aerofoil – The shape of a wing. The bottom is usually flat and the top is usually curved.

Camber – The bend/curve of the top of the wing.

Lift Equation: $L = (C_L \times p \times V^2 \times S) / 2$
C_L – determined experimentally based on airfoil and angle of attack
p – air density
V – velocity
S – surface area

The **drag equation** is exactly the same, substituting C_D for C_L and Drag (D) for Lift (L).

An increase in lift *always* results in an increase in drag.

Parasitic Drag:
- Caused by parts of the aircraft that do not contribute to lift (antenna, fuselage, struts, landing gear).
- Unwanted resistance.
- Broken down into form drag, skin friction, and interference drag.

Induced Drag – Generated by lift.

Form Drag – Created by the shape of a body.

Skin Friction – Air flowing over a body, which tends to cling to its surface.

Interference Drag – Resistance caused by the effect of one part on another.

To control power in an aircraft with a variable pitch propeller, this means adjusting both the throttle and the propeller pitch control.

Lift is approximately equal to the angle of attack multiplied by the velocity.

Minimum drag is L/D_{MAX} = **Best Glide Speed** or Maximum Range. In the event of a power failure to the engines, you need to set the aircraft up for this configuration immediately.

Parasite drag increases with speed.
Induced drag decreases with speed.

Equilibrium is when lift balances weight and thrust balances drag, and the aircraft is not at rest. A plane is never at equilibrium in a turn, when accelerating or decelerating, or ascending/descending at a varying speed.

Load Factor – The total load supported by the wings, divided by the total weight of the airplane. In a turn, the weight of an airplane increases due to centrifugal force.

Resultant Load – The load on the wings when the downward weight of the aircraft is mathematically resolved with the centrifugal force.

Load factor chart:
15^{o} turn = 1.04 G's
45^{o} turn = 1.41 G's
60^{o} turn = 2.00 G's
75^{o} turn = 4.00 G's

An aircraft will descend in a turn unless you pull up and increase the angle of attack.

Relative airflow – Always the direction opposite that of the wing's movement (or aircraft's movement).

Angle of Attack – Angle between relative airflow and chord line.

Angle of Incidence – Angle at which the wing is mounted to the fuselage.

The Center of Gravity (CoG) is typically located *ahead* of the Center of Pressure (CoP). The horizontal difference between where these two forces act through the aircraft is important.

As your angle of attack increases, the center of pressure moves forward. When you stall, the center of pressure moves back behind the center of gravity, and the plane pitches forward.

Downwash – When the air passes over an airfoil, the air is directed downward. It is an upwash going up in front of the wing.

Stagnation Points – Calm areas for air at the front of the wing and back of the wing. The stagnation point is what allows a straight or symmetrical wing/airfoil to generate lift, because it pushes airflow in a way that creates camber.

Airflow below the wings is generally diverted out from the center of the aircraft, and airflow above the wings is generally diverted inward.

The worst wake turbulence is encountered behind a slow, clean, and heavy aircraft.

Size of **wake vortices**:
- Two wing spans wide and one wing span deep.
- Settle below and behind at 300-500 feet/minute.
- Level off about a thousand feet down.
- Can often trail by 10-16 nautical miles (NM).

A stalled wing is still generating *some* lift.

Ground effect:
- Downwash deflected more parallel to the surface.
- Wingtip vortices reduced.
- Induced drag is reduced, therefore more thrust.
- Smaller angle of attack required to generate lift.
- Within a half wingspan of ground.
- A heavily loaded airplane may be unable to "push through" ground effect.

- Higher density altitude makes the danger greater of not getting out of ground effect.

Laminar wings are more susceptible to the effects of icing.

When flying at glide speed:

- Increase speed slightly when flying into a headwind to increase glide range.
- Decrease speed slightly when flying into a tailwind to increase glide range.

If you are flying at best glide speed and feel that you're coming in short on landing, pulling up will increase the chance of crashing short. You *must* fly at best L/D_{MAX} speed and/or add throttle.

Force Couples – Equal in magnitude but opposite in direction, ie. thrust and drag in equal amounts, or lift and weight in equal amounts.

Points of Action:

- Lift – through the center of pressure.
- Weight – through the center of gravity.
- Thrust – through the propulsion system.
- Drag – through the center of pressure and parallel to the relative airflow.

A coarse angle in a fixed pitch propeller is one that has the prop blades almost horizontal to the ground.

The number of propeller blades is typically between two and six (two on a Cessna). Twin engine aircraft usually have three or more blades, which are generally shorter.

Multi-Blade Propellers:

- Higher and less objectionable sound frequency.
- Reduced vibration.
- Greater flywheel effect.
- Improved aircraft performance.

Propeller Twist – Change in blade angle from hub to tip, produces even thrust, because prop speed varies across diameter. There is a direct relationship, in that twice as far out the prop is twice the rotational velocity of that point.

Propeller Slip – Difference between geometric and effective pitch.

Geometric Pitch – The theoretical distance that a propeller should advance in one rotation.

Effective Pitch – The actual distance that a propeller will advance in one rotation.

Prop Efficiency – Ratio of thrust horsepower to brake horsepower.

Fixed Pitch Propellers:

- One piece props with two blades at an unchangeable angle.
- Pitch must be high enough for good cruising performance, but low enough for acceptable takeoff and climb.
- Props are economical and lightweight.
- Designed to produce maximum thrust near maximum torque from engine.

Fine Pitch – Good for takeoff/landing.

Coarse Pitch – Good for cruise.

Variable Pitch Propellers are less common than fixed pitch. They have a hub to allow the blades to change angles.

Effects of a prop:

1. Torque: The prop in a Cessna spins clockwise from the pilot's perspective. This causes left yaw during the takeoff roll. In flight, helical prop-wash strikes the left side of the tail, which again causes left yaw.
2. Asymmetric Thrust: In level flight, both blades have the same initial angle of attack. If you pitch the nose up, the right descending blade pitch angle increases, and the left ascending blade pitch angle decreases. Increase the angle of attack and you increase thrust.
3. Slipstream: The vertical fin and rudder have been installed at a slight angle to align with the airflow, not with the axis of the aircraft.
4. Gyroscopic Precession: Prop acts like a gyro. Pitching of the nose causes yaw, and yawing of the nose causes pitching.

A power-off descent will need left rudder, and the initial takeoff roll or slow flight will need right rudder. These are especially applicable in tail-draggers.

Always try to minimize high RPM's when on the ground, for the sake of the propeller.

Do not push or pull on propellers (90^{o} to the disc of rotation) because it can hurt actuating components.

Try to clean props by wiping with oil if operating near salt water.

Blades should be non-reflective flat black on the side facing the pilot, and colorful-visible on the front.

Variable Pitch Propeller – The pitch is changed hydraulically with engine oil.

1. Constant Speed: Pitch increases with oil pressure. Usually on single engine.
2. Constant Speed Full Feathering: Pitch decreases with oil pressure.
3. Manifold Pressure plus RPM setting gives power. A coarse pitch is called a low RPM setting, used for cruise, and has a big bite. A fine pitch is called a high RPM setting, used for takeoff, and has a small bite.

Feather – A pitch used for eliminating propeller drag during an engine failure (essentially horizontally/flat).

Beta – Neutral thrust.

Reversing – Reverse blade angle. Pushes you backwards, good for landing.

Constant Speed (Non Feathered) permits the pilot to select the propeller pitch and engine speed for any situation, to automatically maintain the RPM. For economy cruising, the pilot can throttle back to the desired manifold pressure for cruise conditions, which decreases the pitch of the propeller while maintaining the pilot selected RPM.

The pilot's prop valve position directs oil flow to govern the propeller pitch.

On Speed – The RPM automatically stays constant because of oil flow in changing flight conditions.

An **overspeed** condition results as airspeed increases when the aircraft begins a descent, or when engine power is increased. If the aircraft begins to climb or engine power is decreased, an **underspeed** condition results.

Feathering – Achieved through a mechanical linkage that overrides the flyweights and speeder spring.

Unfeathering Accumulator – Permits a feathered propeller to be unfeathered in flight, for air-starting the engine. Uses compressed nitrogen to keep oil under high pressure during normal flight.

Types of fixed pitch props include cruise, climb, and power (takeoff). With a fixed pitch prop, the RPM will change in a climb or dive with the initial given power setting:

- Large blade angles will impose a greater load on the engine, slowing it down.
- Small blade angles will unload the engine, allowing it to speed up.

Technically, constant speed and variable pitch are not exactly the same because there are non constant speed props that can be adjusted in pitch on the ground by hand. But we normally talk about fixed pitch vs. constant speed.

The constant speed prop is now the most common and most efficient prop used in aviation. The pilot will choose a manifold pressure and prop speed or RPM, the combination of which will give a known power setting. They will then set it, and let the automation keep it for them.

Flat pitch = Fine pitch = High RPM
Coarse pitch = High pitch = Lower RPM

Governor Failures:

- Single Engine: Moves toward fine pitch.
- Multi Engine: A governor failure or loss of oil pressure causes props to move to feather due to spring and centrifugal counterweight forces.

When a full feathering prop shuts down, centrifugal latch pins lock the blades in a medium pitch position when RPM's drop off, otherwise, it would be hard to start.

Prop Positions when Sitting On Ramp:

1. Single Engine: Full flat pitch, driven by the spring.
2. Twin Engine: Full coarse, but pinned to keep from completely feathering.
3. Free Turbine: Full feather.

Startup:

1. Single Engine: Oil pressure comes up but prop remains in the flat position (prop level fully forward).
2. Twin Engine: Oil pressure comes up and prop blades will be moved to the low pitch mechanical stops. RPM is controlled by power.

Run-up:

- Prop lever fully forward.
- RPM 1700-2000.
- Blades will be in full fine (on low pitch stops).
- Prop angle remains constant until prop control is moved back enough to request less than run-up RPM.
- This allows us to check magnetos (mags) without governor keeping RPM constant.
- RPM will fall when prop lever is pulled back, due to greater load on engine.
- Cycling the props allows the governor to be tested, and to circulate fresh oil.

Takeoff:

- Power to full.
- RPM, manifold pressure, and fuel flow checked on roll.
- Initially, RPM near redline and blades fully flat (fine pitch).
- Airflow will eventually take load off engine and RPM will increase.

- Blades will come off low pitch stops and maintain selected RPM for takeoff.

Engine Failure in a Twin Engine:

- RPM on failed engine stays the same as the running engine.
- Most gauges (manifold pressure, RPM, oil pressure, oil temp) except for the EGT will show few changes.
- The windmilling prop is enough to power the governor.

Wing Planform – The shape of the wing when viewed from above.

Chord – Imaginary line from the leading edge to the trailing edge.

Aspect Ratio = Span divided by chord.

- High ratio: Low induced drag, high parasite drag.
- Low Ratio: High induced drag, low parasite drag.

Camber – The curve of an airfoil. If the lower surface of the airfoil is curved downward, then we would refer to it as negative camber.

Laminar Flow – Smooth air flow over the wing.

Laminar Flow Wing – A design that moves the transition point further aft, which reduces the drag of the wing (and lift). Maximum camber is located further back. During a stall, a laminar flow wing won't pitch forward as well as a regular wing.

Sweepback Wing – Designed for high speed operations to delay the onset of supersonic shock waves. Performs poorly at low speeds. Swept wings may get slats, slots, and extra flaps.

Dihedral – The "V" look of wings when viewed from the back of the aircraft, ie. the upward angle from the wing root to the wing tip. Higher dihedral increases lateral stability by helping prevent roll.

Anhedral – Opposite of dihedral, wings are droopy.

Washout – A twisted wing. The angle of incidence at the wingtip is less than it is at the wing root.

Slats – Small airfoils that open in the front of the wing, to smooth airflow over the wing.

Slots – Openings built into the leading edge of the wing that allow the high pressure air to pass through it at a high angle of attack and increase the lift.

Spoiler – Destroys lift by causing the airflow to separate from the top of the wing. Can assist with braking.

Spoilerons – Spoilers that assist with aileron control.

Reasons for Flaps:

- Increase lift and drag by increasing camber.
- Steeper approach angle without increasing airspeed.
- Reduces stall speed.
- Increase in forward visibility.

Vortex Generators – Placed along the span approximately ten percent aft of the leading edge of the wing to create a tiny vortex in the air stream over the airfoil. This vortex energizes the normally stagnant boundary layer of air on the wing's upper surface. Surprisingly, an energized boundary layer is more resistant to flow separation than a stagnant boundary layer, so airflow sticks to the wing longer, permitting flight at lower airspeeds and a higher angle of attack, and improving control authority.

Winglets – Vertical tabs at wingtips that increase the effective wing span of an airplane by reducing induced drag.

Canard – An aerofoil mounted in front of the wing that produces lift upwards, whereas stabilizers produce a negative lift. Can be fixed or controllable. An airplane with a canard will not enter a full stall.

Load Factor – What our aircraft thinks it weighs.

Some manoeuvres increase a plane's stalling speed, especially those that somehow accelerate the aircraft.

The best (most efficient) way to increase lift in a turn (to prevent losing altitude) is to pitch up, rather than to add throttle. Be careful though, because it increases your angle of attack. So add a tiny bit of power in a steeper turn.

Considering and accounting for turns is a critical skill for a pilot. The most important time to do this is in the circuit.

A late turn to final, coupled with increased rudder and aileron, can lead to a spin. This is one of the biggest dangers for private/recreational and other pilots! These accidents occur with a greater frequency with a crosswind that pushes you past the runway on a turn from base to final.

If you're slow, especially in slow flight with flaps on, the wind will probably be coming up at you with a high angle of attack.

Stall speed in turns: $V_{S(turn)} = V_S$ x square root of Load Factor (V_{ST})

Negative Load Factor – Caused by upward centrifugal force that decreases the G load to less than one.

Manoeuvring Speed (V_A) – The maximum speed at which the aircraft can be safely stalled. It will be greater for increased weights. This is a simple multiplier formula. $V_A = V_S \times 1.7$
Make sure you memorize this for maximum weight and also for a couple of lower weights.

A combination of flight controls or gust loads created by turbulence should not create an excessive load factor if the airplane is operated below V_A. The aircraft will stall before the acceleration can produce a damaging load.

Load Limit – The load factor that the pilot must keep the aircraft within. Above this load, the aircraft will sustain damage or failure.

Ultimate Load – The aircraft is designed and certified to withstand 1.5x the load limit.

Load Limit Chart:
Normal, + load limit = 3.8G
Normal, - load limit = 1.52G
Utility, + load limit = 4.4G
Utility, - load limit = 1.76G
Aerobatic, + load limit = 6.0G
Aerobatic, - load limit = 3.0G

Types of Operations:

- Standard: Few restrictions, but cannot be used for airline or commuter operations.
- Restricted: One purpose only, no passengers, need a “restricted” and “no passenger” sign, an example would be an aerial application aircraft.
- Experimental: Used for testing, or homebuilt. Passengers allowed. Need a placard to state that the aircraft has not gone through a certifying process.

Stability – The ability of an aircraft to remain in a position or attitude during flight and then return to a given position or attitude following a disturbance.

Types of Stability:
- Positive Stability: Like a ball in a bowl. Always returns to its original position following a displacement or disturbance.
- Neutral Stability: When displaced, it remains in its new position.
- Negative Stability: Like a ball on an upside down bowl. The slightest displacement will cause it to continue to move in that direction, sometimes at an accelerating rate.

Static Stability – Initial tendency of an aircraft to return to its original position directly.

Dynamic Stability – The overall tendency of the aircraft to return to its original position following a series of oscillations.

Stability Around an Axis:
- This is a bit confusing, so memorize it.
- Longitudinal stability is around the lateral axis.
- Lateral stability is around the longitudinal axis.
- Directional stability is around the normal axis.

Longitudinal Stability:
- Affected by the size and position of the horizontal stabilizer and the position of the center of gravity.
- An aircraft that is nose-heavy is more stable.
- This is also known as pitch stability (because it is around the lateral axis).

Lateral Stability:
- Trainers are positive, aerobatic planes are neutral or negative.
- Best lateral stability is achieved by dihedral, sweepback, keel effect, and proper distribution of weight.
- Also known as roll stability (because it is around the longitudinal axis).

Directional Stability:
- Stability around the vertical axis.
- Achieved by tail surfaces, fin and rudder, keel effect, and sweepback.
- Also known as yaw stability (because it is around the normal axis).

Stabilitor – When the entire stabilizer moves in response to elevator control pressure.

Aileron Drag – Created because the greater drag of the down-going aileron causing yaw in the direction opposite of roll. This is one type of adverse yaw.

Frise Aileron – Has an offset hinge, is used to reduce aileron drag. The leading edge of the up-going aileron moves into the oncoming airflow below the wing. The lower lip catches the airflow. It also forms a slot, making it effective at slow airspeeds.

Differential Ailerons – The up-going aileron is moved higher than the down-going aileron. It is used to reduce aileron drag.

Dynamic Balance Controls – Allow the pilot to move the controls more easily.

Mass Balance – Used to counteract flutter by positioning a weight ahead of the hinge. Mounted either internally or externally on the airplane's control surface.

Static Balance – When, in a situation with no airflow, the control surface's center of gravity is in the manufacturer's specified location.

When flaps go down, the nose goes up!

The more a pilot uses trim, the better the pilot. All airplanes have elevator trim, but some also have rudder and aileron trim.

Balancing Tab – Similar to a trim tab, coupled to the control surface. When the control surface is moved, the balancing tab is automatically moved in the opposite direction.

Servo Tab – Used on large airplanes. The tab is moved directly by the pilot, then the force of the airflow on the servo tab moves the control surface.

The Pilot-In-Command (PIC) is basically responsible for everything, including:

- Airworthiness of the aircraft.
- Knowing the forecast weather.
- Up-to-date charts and safety equipment.
- Briefing of passengers.
- Avoiding restricted airspace, following all CARS.

Clean Aircraft Concept – Takeoff is prohibited when frost, ice, or snow is adhering to any critical surface of the aircraft.

Cold Soaking – Occurs when an aircraft travels from warm to cold to warm, which might cause condensation and ice to build up on the aircraft's skin.

In-Flight **Airframe Contamination**:

- Occurs when you have visible moisture and a sub-zero temperature.
- Ice on Wing: Loss of lift.
- Ice on Prop: Vibration.
- Ice on Windshield: Loss of vision.

A high reliance must be placed on flight instruments during whiteout conditions. You are essentially IFR.

Severe turbulence can extend 20NM from a storm. Also, getting hit by lightning is not great. Avoid thunderstorms.

Mountain Flying:

- Rapidly changing and unpredictable weather.
- Downdrafts are most common on the shaded side, and updrafts are most common on the sunny side.
- Be able to complete a "maximum rate with minimum radius" turn at all times.
- Remember that ceilings and performance figures are all based on density altitudes.

Don't use strobe lights while taxiing or during flight in clouds.

Canadian Runway Friction Index (CRFI):

- CRFI of 1.0 is the maximum runway coefficient, ie. bare and dry. Perfect braking.
- A low CRFI of 0.1 to 0.3 would probably indicate an ice-covered, slippery runway.
- Obtained from ATIS, NOTAM's, FSS.
- The "increase in landing distance" chart can be very useful.

VASIS – Visual Approach Slope Indicator System.
PAPI – Precision Approach Path Indicator.

A good approach slope is three degrees.

There are three main types of **runway lighting**:

- Two bar VASI: Good when you have red over white.
- Three bar VASI: "White over white, fly all night … red over red, you're dead."
- PAPI: The better modern system.

If you're looking at a three-bar VASI system and you're in a small GA aircraft, ignore the top row of lights and pretend that the bottom two rows are a standard two-bar VASI system. Only large jets use all three (or use just the top two rows).

PAPI System – Uses four bars, horizontally. The same rhyme works as for 3-bar VASI. A perfect approach is two white and two red bars, side by side. This system is currently replacing VASI systems.

Minimum runway requirements at night:

- White X's on a runway mean that it is closed (white for visibility, instead of red).
- Yellow chevrons on a runway indicate that it is non load-bearing, do not use.
- White arrows mean displaced threshold, land further up past the threshold.

Towers (not ATC Control) affecting cross-country navigation:

- Under 1000 feet have steady red lights.
- Above 1000 feet have white strobes.
- Check NOTAM's and flight planning section in the CFS.

Memorize your **marshalling signals**. Can probably be found in "From The Ground Up."

Wheelbarrowing – Landing on the nose wheel because you're coming in too fast.

Porpoising – Aircraft bounces alternatively off main wheels then nose/tailwheel. Use back pressure to get proper landing attitude.

Rotating tires hydroplane at up to 9x the square root of the tire pressure in PSI.
Non-rotating tires hydroplane at up to 7.7x the square root of the tire pressure in PSI.

To recover from wind shear, prompt action is required. Use full power, and pitch up to maximum angle of attack.

High density altitude probably means low pressure.

Four factors affecting the **density of air** include:

- Barometric pressure.
- Altitude.

- Temperature.
- Humidity.

Humidity is not good for air density (lighter) because the molecular weight of vaporized H_2O is less than that of O_2 or N_2.

Air density decreases with barometric pressure decrease, but also with increases in air temperature, altitude, or humidity.

Service ceilings, absolute ceilings, and leaning settings for aircraft are all given in terms of density altitudes.

Lower air density causes:
- Less engine power.
- Less propeller thrust.
- Less lift produced by wings.

Ground effect reduces the amount of induced drag.

V_X is the **Best Angle of Climb**:
- Best used for takeoffs over obstacles.
- This speed changes with altitude, and increases as the altitude increases.
- Equal to L/D at the aircraft's ceiling.

V_Y is the **Best Rate of Climb**:
- Changes with altitude, becoming smaller (IAS) as we climb.
- At the aircraft's ceiling, it is the same as the L/D speed.

When an aircraft is at its absolute ceiling, then:

Best L/D = $V_X = V_Y = V_G$

V_A is the **Manoeuvring speed**. This is the maximum speed at which it is safe to use full deflection of the controls. The aircraft will sustain structural damage if operated at speeds above V_A, due to increased load factor. This speed varies with weight; it is higher when the aircraft is heavier. Always operate *below* V_A during turbulence.

V_{NE} – Never exceed this speed. If you do, your aircraft automatically becomes non-airworthy until inspected by an AME.

V_{FE} – Maximum flaps extended speed. Indicated by the top of the white arc on the airspeed indicator.

V_{SO} – Stalling speed with flaps fully extended. This is the bottom of the white arc on the airspeed indicator.

Indicated vs. True stalling speed:
- Indicated stalling speed always stays the same.
- True stalling speed increases with altitude.
- Indicated and true stalling speeds are equivalent at sea level.

Although you don't have to do a spin dive recovery on your flight test, you may have to verbalize how to recover.

The faster the speed of the aircraft, the steeper the bank angle required to maintain a standard rate turn.

Nose-heavy center of gravity:

- Needs more trim.
- Is more stable.
- Flies slightly slower.
- More drag, due to more tail pressure on the stabilizer.
- An aft-heavy center of gravity would be the opposite of all of the above.

A few millimeters of ice can increase the stalling speed by as much as 20%.

Ice accumulation with the thickness/coarseness of medium/coarse sandpaper will:

1. Decrease lift by up to 30%.
2. Decrease drag by up to 40%.

The Coefficient of Lift (C_L) is based upon the angle of attack and the shape of the airfoil.

Performance charts are obtained by pilots in brand new aircraft.

Types of charts:

1. Takeoff distance.
2. Cruise.
3. Fuel burn.
4. Climb.
5. Wind component and CRFI.

Always remember to read conditions/notes and to apply corrections in order.

Takeoff distances are longer than landing distances. Getting in safely is fine, but getting back out is what is ultimately most important.

Short Field Technique – Use full throttle prior to releasing your brakes.

Almost all performance charts require using pressure altitude equivalents.

Pressure altitude is extremely important. It is used to determine density altitude, true altitude, and true airspeed. One method of calculating the pressure altitude is to physically set the altimeter to 29.92 and then read the pressure altitude right off the dial. The second method, which would be useful during an exam when you don't have access to an altimeter, is:

1. Subtract the current altimeter setting from 29.92.
2. Multiply by 1000.
3. If positive, add the number to the actual elevation. If negative, subtract the absolute value from the elevation.

Problems with an **overloaded aircraft** include:

- Higher takeoff speed, longer takeoff run.
- Reduced rate of climb.
- Decreased range.
- Reduced cruising speed.
- Reduced manoeuvrability.
- Higher stalling speed.
- Higher approach/landing speed.
- Longer landing roll/stopping.

Standard Empty Weight – The weight of the airplane plus oil and unusable fuel, without equipment.

Basic Empty Weight – The standard empty weight plus equipment.

Maximum Takeoff Weight – The heaviest that a fully loaded plane can weigh, including fuel, cargo, pilot and passengers, and equipment.

Useful Load – Maximum takeoff weight less basic empty weight.

Maximum Ramp Weight – This might be a few pounds heavier than the maximum takeoff weight, to allow for an extra gallon or so of fuel that will be burned off by taxiing before takeoff.

Important **Fuel Weights**:

- AVGAS is 6 pounds per US gallon.
- OIL(65) is 7.5 pounds per US gallon.

A US gallon is 3.785 liters.

Zero Fuel Weight – Basic empty weight, crew, passengers, cargo, oil, and unusable fuel. But no usable fuel.

Maximum Zero Fuel Weight – Max weight before the rest must be fuel.

Datum Line – An arbitrarily selected point (set by the manufacturer) from which all horizontal distances are measured for weight and balance reports. This point is not the same as the fulcrum.

Moment = Weight x Arm (inch-pounds).

The moment is often listed in 1000's on charts, including on Cessna charts.

Mean Aerodynamic Chord (MAC) – The center of gravity is often expressed as a percentage of the average chord of the wing. Usually used for large commercial aircraft.

Methods of Determining **Weight & Balance**:

- Center of Gravity calculations.
- Center of Gravity graphs.
- Center of Gravity charts.
- Loading Schedules (placards).

For center of gravity calculations, add up all the weights and moments, then divide moments by weights.

Arms that are "aft" of (behind) the datum point are considered positive, and if they are "fore" (ahead) of the datum point they are negative.

Moment Loading Envelope – A graphical depiction to see if the moment arm falls within acceptable limits.

Center of Gravity Envelope – A graphical representation which shows the center of gravity in terms of inches aft of the datum line. Anything outside of the limits on the left side of the graph means that the center of gravity is too far forward, and outside on the right is too far aft. Do not fly with your center of gravity outside of the envelope. It is very risky and potentially fatal.

If the aircraft is **tail heavy**:

- You'll need to nose-down trim.
- It will be less stable.
- More susceptible to gusts.
- It will cruise faster.

Always calculate two weight and balance reports for each flight, one for takeoff and one for landing. You'll burn fuel during the flight, which will slowly shift the location of the center of gravity. As a pilot, you should know whether the center of gravity moves fore or aft as the fuel is burned.

LEMAC – Leading Edge MAC
TEMAC – Trailing Edge MAC

A percentage MAC position is the distance that the center of gravity is located behind the LEMAC in comparison to the TEMAC. Usually between about 10% to 30%, and 25% is a common measurement.

The **fulcrum** is located at the center of lift.

Weight Turbulence Categories:
- Light is less than 15,500 pounds.
- Medium is 15,500 to 300,000 pounds.
- Heavy is more than 300,000 pounds.

Search and Rescue Coordination Centers (REC) are located in Victoria, Trenton (Ontario), and Halifax.

SAR puts an airplane in the air at one hour past the end of the ETA in your flight plan. However, the investigation starts only a few minutes after your ETA has been exceeded. Always remember to amend your flight plan in-air if you think you're going to be delayed, even if you're only going to be a few minutes late.

Aiding **Persons in Distress**:
- Keep the distressed craft in sight as long as possible.
- Report the following to ATC: Time of observation, position of craft, general description of the scene, possible medical/triage info.

Radar Alerting:
- Squawk 7700 on the transponder.
- Monitor emergency frequencies.
- If you don't have two-way radio communication, and can only communicate through transponder location, signal by flying two triangles, resume course, repeat at five minute intervals.
- If your radio only has receive (R_X) functions but ATC cannot hear you, fly to the right on your two triangles.
- If your radio has neither transmit (T_X) not receive, fly to the left on your two triangles.
- Fly two minute legs for the sides of your triangles when your airspeed is less than 300 KTS, or one minute legs for speeds exceeding 300 KTS.

Although SAR is launched very quickly, the average SAR response time (for successful arrival at distressed aircraft) is twenty-four hours. Be prepared!

Three fires arranged in a triangle is the standard distress signal.

Three instruments are connected to the **Pitot-Static System**:
- Altimeter (ALT)
- Vertical Speed Indicator (VSI)
- Airspeed Indicator (ASI)

Pitot Tube – Uses ram air, is usually heated. This is to prevent icing, not specifically to heat the air. The ASI is the only instrument directly linked to this tube. The pitot tube must be heated for IFR flight.

Static Port – Needs normal (not forced) air. Attached to ALT, VSI, ASI. If the static port becomes blocked, the ALT and VSI will freeze. The ASI will read incorrectly. Airspeed will under-read in a climb and over-read in a descent.

If the pitot tube becomes blocked, the effect depends on whether the blockage is partial or complete.

Complete pitot blockage:

- Airspeed reads high in a climb.
- Airspeed reads low in a descent.
- ASI acts like an altimeter.

Partial pitot blockage:

- ASI will decrease to zero.

Indicated Airspeed (IAS) – Speed through the air. The airplane knows this, not how fast the ground is going by underneath. Variations include MIAS for mph, and KIAS for knots/hour.

Ground Speed – Indicated airspeed plus a wind component.

Airspeed Indicator – Measures the difference between the dynamic (pitot) and static pressure. This is read as indicated airspeed on the instrument. Contains a diaphragm which is connected to the IAS needle through a system of pulleys and levers.

Possible airspeed indicator errors:

- Positional error.
- Compressibility error.
- Density error.
- Ice or water blocking the pitot tube.

Calibrated Airspeed (CAS) – Accounts for positional error.

Equivalent Airspeed (EAS) – Takes into account compressibility. Only encountered in aircraft that travel at very high airspeeds, over 250 knots.

True Airspeed (TAS) – Accounts for density errors, which are caused by changes in air density (affected by altitude and temperature). A rule of thumb is to add 2% to IAS for every thousand feet of pressure altitude. Involves using a flight computer, rule of thumb, or true airspeed indicator.

Positional Error:

- Caused by the position of the pitot.
- Pitot needs to be placed as far as possible ahead of the wing's leading edge.
- Angle of air hitting the pitot leads to additional pitot error.
- When the IAS is corrected for positional error, we get the CAS.

Cruise Standard – Having the aircraft at "cruise" attitude, plus the throttle set at 2200 RPM's, probably gives you about 90 knots in a Cessna 172.

Approach Standard – Having the aircraft at the "approach" attitude plus 1500 RPM is probably going to give you about 65 knots in a Cessna 172 descending at 500 feet/minute.

Airspeed Indicator Markings:

- The "top" of any arc means the fastest recommended or permitted airspeed, and the "bottom" of an arc means the slowest.

- The white arc is associated with flaps usage.
- V_{SO} is the stall speed with flaps fully extended.
- V_{S1} is the stall speed with no flaps.
- V_{FE} is the maximum speed with flaps extended.
- The green arc is the recommended safe airspeed range.
- The yellow arc is the caution range for velocity, which you should only use if absolutely necessary, and only in calm, non-turbulent conditions.
- V_{NO} is the maximum recommended IAS for normal operations.
- V_{NE} is the "never exceed" speed (the red line).
- Blue lines are found on multi-engine aircraft. Associated with the best single-engine rate of climb speed (V_{YSE}) which should be maintained in the event of an engine failure.

Airspeed can be in MPH, km/hr, or Knots. Probably MPH in a Cessna. Metric (km/hr) is very uncommon.

Think of "**iced tea**" when moving between airspeed conversions: I-C-E-T
Indicated Airspeed → Calibrated (POH) → Equivalent (if >250KT) → True Airspeed

Our true airspeed at the stall is always higher at high altitudes or high temperatures. It only matches the IAS at sea level and at standard temperature.

Tape Type Airspeed Indicator (TAA) – Found on more advanced Garmin or Avidine flight panels. On a TAA, "G" stands for general cruising speed and "R" stands for rotation speed. If you see a pink vector bar on the side, it shows what your speed will be in six seconds.

MFD – Multi Function Display.

Other **important velocities**:
- V_R – Rotation speed.
- V_A – Manoeuvring speed. Changes with weight! Increases as weight increases. This is the maximum speed at which we can exert full controls without damaging the airplane. You do not want to exceed your maximum load factor.
- V_{DIVE} – Speed at which things start to shake, and maybe fall apart. $V_{NE} = V_{DIVE} \times 0.9$, V_{NE} makes an aircraft non-airworthy.
- V_{LE} – Maximum speed with retractable flaps extended.
- V_{LO} – Maximum speed at which you can extend or retract the gear. It is always slower than V_{LE} by necessity.
- V_S – This changes with changes in the center of gravity.

The "**dirty**" configuration means flaps are down/extended. **Clean** means flaps are up/retracted.

Vertical Speed Indicator (VSI) – Connected to the static port. Similar to the altimeter. Contains a small calibrated hole in the instrument case that allows the pressure to slowly leak out.

Possible errors in the VSI:
- Lag Error: Largest error. The VSI is a trend instrument, not an instantaneous one. It usually lags by about six to eight seconds.
- Reversal Error: A sharp and sudden pitch change will temporarily show the opposite of what the airplane is doing.

The ideal descent rate for approach on landing is 500 feet/minute in a small GA aircraft.

In an altimeter, the pressure in the sealed aneroid is at 29.92" Hg. This is "inches of mercury" and is known as Standard Pressure. An altimeter is an aneroid barometer. It is connected only to the static port. The common type in a small GA aircraft has three hands, similar to the concept of hands on a clock, and is called a Three Point Altimeter.

Drum Altimeter – Has an analogue dial rather than sweep hands, so it looks like an odometer.

Kollsman Window – The altimeter setting window on a pressure altimeter.

The altimeter only works correctly under these conditions:

- Must be at sea level.
- Air must be dry (no humidity).
- Barometric Pressure must be 29.92".
- Temperature must be 15°C.
- Temperature decreases at 1.98°C per 1000 feet.
- We lose 1" of pressure per 1000 feet.

If you don't have an outside pressure reading, you can set the altimeter to whatever reading gives you the proper elevation of the field.

ISA – Standard Atmosphere

If flying into a high or low pressure system, remember the following: "From high to low, look out below."

If you're doing a cross-country, you need to keep getting local pressure setting and making adjustments to the altimeter. An altimeter setting that is too high will give a reading that is too high.

Low systems have counter-clockwise flows.

The highest setting on most altimeters is 31.00" Hg. However, actual pressure can certainly be higher. Just set it to 31.00" Hg. You'll be Ok because this error is in the "safe" direction, and you won't fly into the ground accidentally.

For the same change in pressure, warm air will have a greater vertical depth (spread) than cold air.

Cold Correction Chart – Shows us how incorrect our indicated altitude can be in very cold conditions.

Mountain Effect – Due to Bernoulli's Principle, air that is deflected around mountains will increase in speed and decrease in local pressure. It will give an altitude reading that is too high! This is dangerous.

Mountain wave winds can extend for as much as 700 miles downwind of mountains. They can feature low pressure and severe downdrafts! They are most severe nearest the summit of the mountain. Downdrafts can run at more than 5000 feet/minute vertically.

Any time you fly in the mountains, you should fly much higher than you think you need to be.

Indicated Altitude – What we see on the instrument. It depends on the accuracy of the Kollsman value.

Pressure Altitude – What is indicated when the Kollsman is set to 29.92, or Standard Atmosphere. This is extremely important, and is used to determine things like density altitude and true airspeed.

True Altitude – The exact height above mean sea level. True altitude corrections need to include a correction for non-standard temperatures, and true altitude is important when we are trying to figure out if we have enough obstacle clearance. To calculate true altitude, use the left side of the E6B, then line up the outside air temperature and pressure altitude.

Absolute Altitude – The actual height above ground surface (AGL) with the altimeter correctly set and non-standard variations in temperature taken into consideration. To calculate the absolute altitude, find the true altitude, then subtract the height of the terrain below.

Density Altitude – Pressure altitude corrected for non-standard temperature. Our aircraft performs as if it is at this level. Density altitude gives us the density of the air. Therefore, it tells us how the aircraft will perform. All service ceilings and absolute ceilings are given in terms of density altitudes.

A lot of people get confused by Density Altitude, and think that a higher density altitude means that the air has a higher density. However, when you think of the phrase "high density altitude," don't be tricked by the fact that "high" and "density" are together. In a "high density altitude," the "high" refers to the "altitude," and of course at higher altitudes, the air is thinner.

Encoding Altimeter:
- Linked to transponder.
- Allows ATC to know pressure altitude as well as position.
- Known as Mode C.
- Controller sees a pressure altitude.

The magnetic compass is the only basic instrument (ignoring GPS) that helps determine the direction of flight.

Cardinal Points – North, South, East, West.

The **Magnetic Compass** case is filled with white kerosene. This dampens vibrations or oscillations. The center of buoyancy is above the center of gravity to minimize dip at higher latitudes. This dip occurs because magnetic lines of force are fairly horizontal at the equator and fairly vertical at the poles.

Lubber Line – Direction marker line (vertical) on the magnetic compass.

Isogonic Lines – Lines of equal magnetic variation.

Agonic Line – The isogonic line of 0^o variation. This currently passes in a north/south orientation just west of Thunder Bay.

Deviation – Error for a compass installed in an aircraft versus what it would read if outside the aircraft, caused by metal and RF instruments in the aircraft. Deviation errors are usually only a couple degrees, but you should still take them into account for navigation.

Variation – The difference between magnetic north and true north. This is also sometimes called Magnetic Declination, but be careful that you don't confuse declination with deviation. It's better for aviators to use variance instead of declination.

The west side of Canada has an easterly variation, and the east side has a westerly variation. We need to correct for variation on our navigation logs.

Converting from **True to Magnetic** – Subtract easterly from true to get magnetic, or add if westerly. Remember this phrase, "East is least, west is best."

To convert from **True to Magnetic to Compass**:
1. Start at True, and adjust for winds if necessary.
2. Come up with Magnetic by accounting for variation.

3. Come up with Compass by accounting for deviation.

Remember that a magnetic compass reads “backwards,” ie. higher numbers on the left.

Northerly Turning Error – On turns *from* the north, the compass will lag, and on turns *from* the south, the compass will lead. Also, from the north, the compass will *initially* turn in the wrong direction before correcting. This of it this way: A compass normally “wants” to point north. That is also its tendency during the turn. This northerly turning error is caused by magnetic dip.

Acceleration/Deceleration Errors – If flying east or west, accelerating the aircraft will cause the compass to register a turn to the north. Deceleration registers a false turn to the south. Again, you can remember this by thinking about the compass being “excited” by acceleration and wanting to turn north.

The magnetic compass only gives you a correct reading when in a wings-level attitude at a constant airspeed. Note that it can be accurate in a constant speed wings-level climb or descent. The altitude does not have to remain constant, as long as there is no acceleration or deceleration in the climb/descent.

Gyroscope – Any rotor, disc, or wheel spinning at high speed. Even automobile wheels are an example.

Gimbal – A universal mounting device for a gyro that allows its axis to be pointed in any direction.

When a gyro is rotating, it resists changes in direction. It has two predominant characteristics: rigidity in space, and precession.

Rigidity in Space – Once set into motion and spinning, gyroscopes resist turning. When gimbaled (in one, two, or three dimensions) any surface such as an instrument dial attached to that gyro assembly will also remain “rigid” in space.

Precession – The deflection of a spinning wheel 90^{o} to the plane of rotation, when a deflective force is applied at the rim.

Gyro instruments can be vacuum or electrically driven. They include:

- Turn coordinator: usually electric.
- Attitude indicator: usually vacuum.
- Heading indicator: usually vacuum.

Vacuum driven systems generally need 4-6 inches of mercury to operate. They can be engine or venturi driven.

There is probably a little red flag in the turn coordinator (and other instruments) that is visible only when there is no power, so this acts as a warning if the electrical fails.

The attitude indicator is the primary instrument in instrument flying.

Heading Indicator (HDI):

- Sometimes known as the Directional Gyro.
- Only valid when set by magnetic compass.
- Needs to be set at the start of each flight, and approximately every fifteen minutes thereafter in regular, non-accelerated flight.
- Vacuum powered gyroscope.
- Unaffected by acceleration, deceleration, or turns.
- Need to adjust for both apparent precession and frictional precession.
- Check the HDI again the runway number as you line up.

- Frictional precession relates to friction in the gimbal bearings.
- Apparent precession occurs because even though you might feel that you're flying in a straight line, you're actually travelling in an arc over the earth's surface. You may see an error of up to fifteen degrees per hour of flight.

Tumbling – When the HDI loses its gyroscopic characteristics after being subjected to severe manoeuvres. Can often happen after exceeding 55° of either pitch or bank.

Glass Panel HDI – Can show a 360° circle or a 140° arc. Options to show GPS, VOR, ADF, and ILS info are possible. Relies on an AHRS system.

Attitude and Heading Reference System (AHRS) – Gyroscope is replaced by lasers, accelerometers, and magnetometers.

Attitude Indicator (ATT):
- Vacuum driven gyroscope.
- Can be electrically driven.
- Gimbal mounted on a vertical axis.

V_Y in a Cessna 152/172 is typically very close to eight degrees pitch.

Most descents in light GA aircraft are between 3° and 5° pitch down.

Pull To Cage – A setting that locks a gyro into place and prevents tumbling during aerobatics, etc.

Attitude Indicator errors:
- Acceleration will indicate a climb.
- Deceleration will indicate a descent.

Turn & Bank Indicator:
- Older style of instrument, usually replaced nowadays with a Turn Coordinator.
- Uses an indicator needle with a left/right deflection instead of the visual representation of a small airplane that you'd see in a turn coordinator.
- Can only identify yaw, but not rolling.
- Lags slightly (by about one second).
- Two components: turn needle and doghouse.
- Doghouse has a mark on either side of the center that represents a standard rate turn.

Turn Coordinator:
- Two parts, the visual silhouette of the aircraft, and the "ball" (inclinometer).
- The purpose is to indicate the rate of turn and the quality of the turn.
- Can identify both yawing and rolling motions.
- Usually electrically powered.
- No lag.
- Red flag appears if it loses electrical power.

Inclinometer:
- Glass level containing a black ball.
- Provides the pilot with a measure of the turn quality.
- The ball should stay centered during both straight & level flight, and during turns! Otherwise, you are slipping or skidding.

Skid:

- Too much rudder for a given bank angle.
- The tail end of the plane swings to the outside.
- The ball is on the opposite side to the lowered wing.
- "Step on the ball" is the catchphrase, although you might need to release opposite rudder.

Slip:
- A turn where insufficient rudder is being applied.
- The ball is on the same side as the lowered wing (or needle).
- Also too much bank/aileron for the current amount of rudder.
- You can fix this by applying additional rudder OR reducing the bank angle.

In a turn coordinator, the gyro spins up and away from you. The gyro spin axis is angled or canted 30° to the horizontal. This makes it capable of responding to both yaw and roll.

Standard Rate Turn:
- If your airspeed is faster, your bank angle need to be higher in order to complete the turn in time.
- The rule of thumb for bank angle is (KIAS/10) + 7, ie. 120 KTS = 19° bank.
- For MPH, use (MIAS/10) + 5, ie. 140 MPH = 19° bank.

While learning to fly, learn to fly by looking outside, and by knowing your attitudes. Pay some attention to the instrument panel, but not too much!

Instrument Flying – Flying with sole reference to instruments. As a PPL candidate, you will only need to know this during an emergency.

Control Instruments:
- Attitude Indicator (ATT).
- Tachometer (or Manifold Pressure).
- This is because Attitude plus Power equals Performance.

Performance Instruments:
- Airspeed Indicator (ASI).
- Turn Coordinator (TC).
- Heading Indicator (HDI).
- Altimeter (ALT).
- Vertical Speed Indicator (VSI).

Pitch Instruments:
- Attitude Indicator (ATT).
- Altimeter (ALT).
- Vertical Speed Indicator (VSI).

Bank Instruments:
- Attitude Indicator (ATT).
- Turn Coordinator (TC).
- Heading Indicator (HDI).

Power Instruments:
- Tachometer (or Manifold Pressure).
- Airspeed Indicator (ASI).

The three fundamental skills are Scan, Interpret, and Control.

Scanning Instruments – Do continuous cross-checking. Common errors include fixation, omission, or over-emphasizing one instrument's indication.

Partial Panel – When you're flying without all six of your instruments. Usually, your vacuum system is the most likely system to fail, so you're probably flying without your attitude indicator and heading indicator when flying partial panel.

Unusual Attitudes – Any unexpected rate or instrument indication contrary to what you would have expected.

Nose Up AND Nose Down Recovery Considerations:

- Use ASI and TC as your primary instruments.
- Pay attention to the *trend* of the ASI.
- The ATT and HDI may have toppled, so they may be unreliable.
- The ALT and VSI may be unreliable due to lag.

To effect a **Nose Up recovery**:

1. Go to full power.
2. Put the nose down until the ASI stops decreasing.
3. Level wings based on TC.
4. Reduce power to cruise.
5. Cross check the instruments.

To effect a **Nose Down recovery**:

1. Power off.
2. Level wings based on TC.
3. Nose up until the ASI stops increasing.
4. Add throttle to return to cruise power.
5. Cross check the instruments.

Conclusion

The topics included in a study of flight theory & aircraft topics for aviation have a greater scope than I've covered here. It would also be wise to spend quite a bit of time studying the various publications that I've linked to on this page: http://www.djbolivia.ca/aviation.html

I have links there to several additional aviation-related publications.

Thanks for reading, I hope this was helpful to pilots in training. If you find any errors in the above information, feel free to contact me at jonathan.scooter.clark@gmail.com

- Jonathan Clark