PROFICIENCY LEVEL 4

TRAINING HANDBOOK

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INTRODUCTION

This handbook was created to assist Level 4 cadets to study for the Aviation related courses. It is expected that the cadets bring this handbook with them to all regular training nights and take notes where required.

Any issues with the handbook should be directed to your Senior Level Instructor.

PO 431 – EXPLAIN PRINCIPLES OF FLIGHT
EO M431.01 – EXPLAIN FEATURES OF WING DESIGN

AIRFOILS

Chord

The chord is an imaginary straight line joining the leading and trailing edges of the wing (See Figure 1). The mean aerodynamic chord (MAC) is the average chord of the wing.

The shape and design of the wing is directly influenced by the intended purpose of the aircraft. Aircraft designed to fly slowly typically have tick airfoils, while aircraft designed to fly fast have thin airfoils.

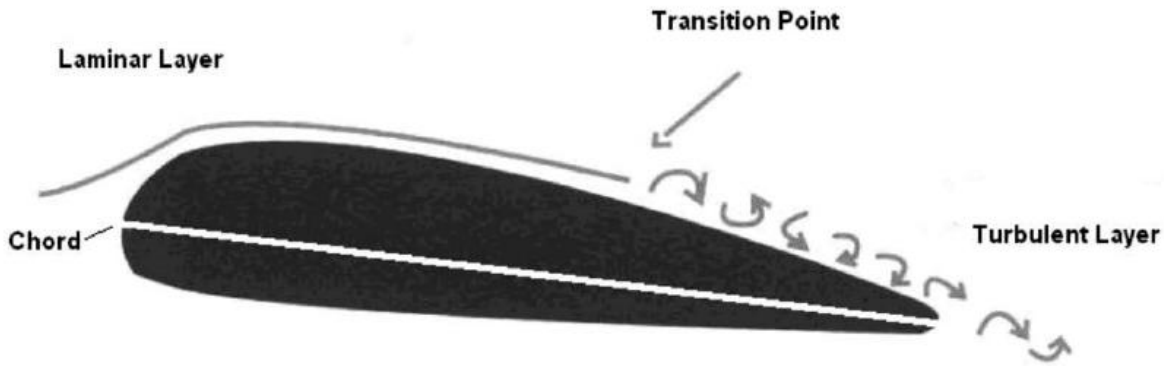

Figure 1 – Laminar and Turbulent Layers

The very thin layer of air lying over the surface of the wing is called the boundary layer. At the front of the wing, the boundary layer flows smoothly over the surface and this area is called the laminar layer. As the air flows further along the wing, it slows down due to skin friction, the layer becomes thicker and it becomes turbulent. The turbulent area is called the turbulent layer.

The transition point between the laminar and turbulent areas tends to move forward as airspeed and the angle of attack increase.

Conventional Airfoils

Conventional airfoils generally are the thickest at 25 percent of the chord and can be found in a variety of shapes and designs.

Figure 2 shows different conventional airfoil shapes. The column immediately to the right of the airfoil section describes the airfoil properties. The farthest right column identifies types of aircraft that would typically use that airfoil.

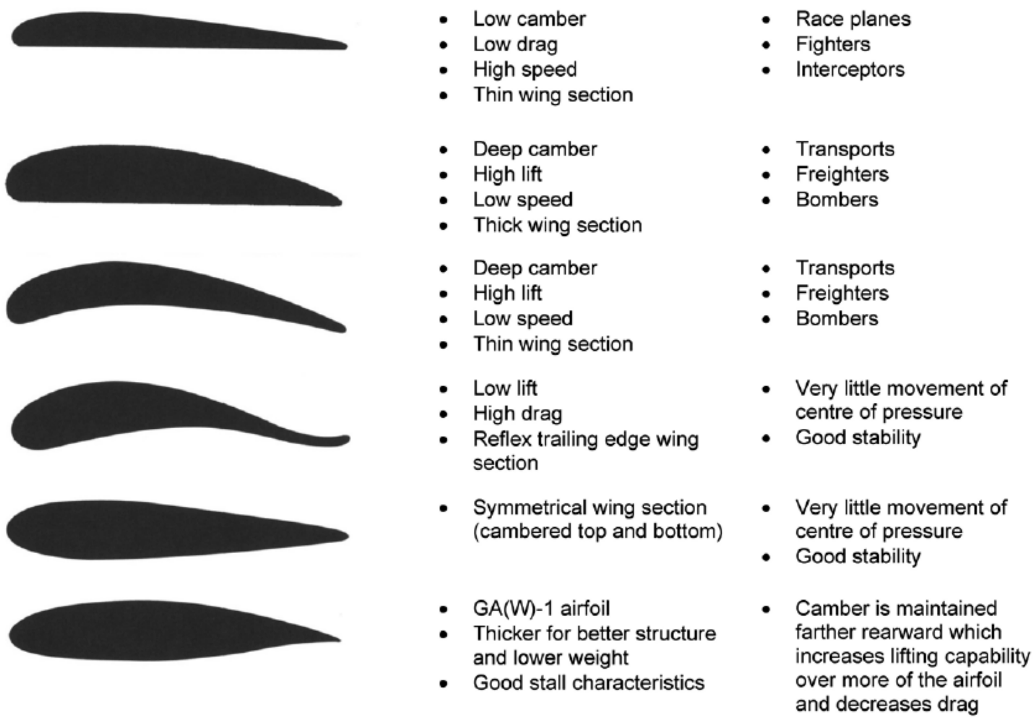

Figure 2 - Conventional Airfoils

Laminar Flow Airfoils

Laminar flow airfoils have their thickest point at 50 percent of the chord, a leading edge that is more pointed and upper and lower surfaces that are nearly symmetrical. Originally developed to make aircraft fly faster, they can be found on many different aircraft types. Figure 3 shows the difference between a conventional airfoil and a laminar airfoil.

The design of the laminar flow airfoil reduces drag by maintaining the laminar flow of the air throughout a greater percentage of the chord. The pressure distribution is more even, but the transition point moves forward more rapidly near the point of stall.

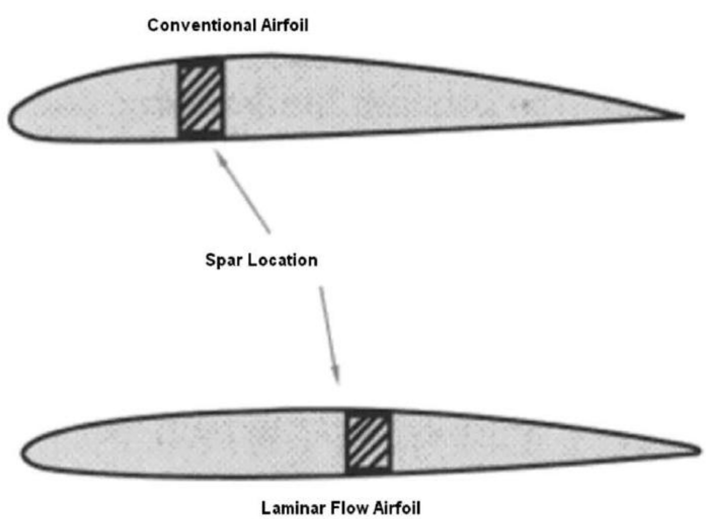

Figure 3 - Conventional and Laminar Flow Airfoils

Planform

The shape of the wing as seen from directly above is called the planform, see Figure 4. The three general wing shapes are:

- Rectangular;
- Elliptical (rounded); and
- Delta (swept).

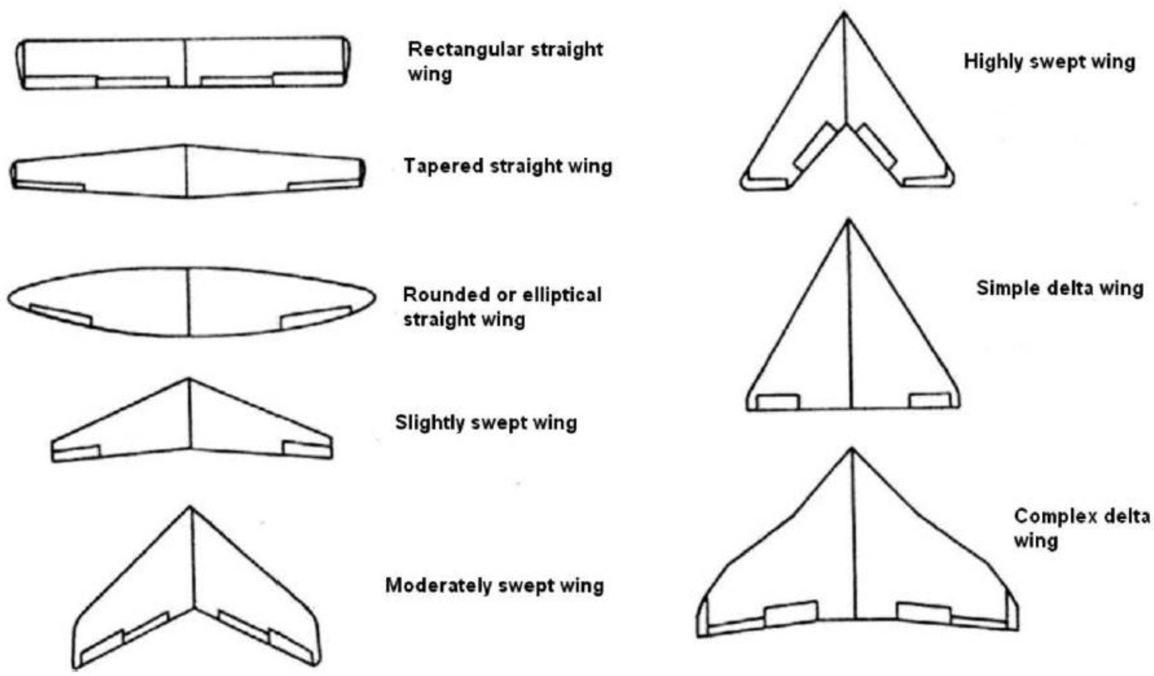

Figure 4 - Examples of Wing Planforms

Aspect Ratio

The aspect ratio of a wing is the relationship between the length of the wing and its width (chord). It is calculated by dividing the span by the average chord.
A wing with a high aspect ratio generates more lift with less induced drag than a wing with the same wing area and a low aspect ratio. High aspect ratio wings are commonly found on gliders.

Angle of Incidence

The angle of incidence is the angle at which the wing is permanently inclined to the longitudinal axis of the aircraft, see Figure 5.
The angle of incidence affects the following items:

- Flight visibility;
- Takeoff and landing characteristics; and
- The amount of drag in level flight.

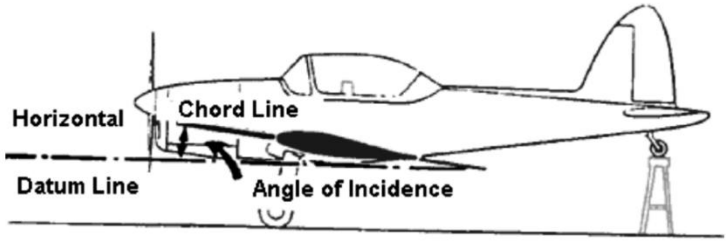

Figure 5 - Angle of Incidence

Wash-Out and Wash-In

To reduce the tendency of the wing to stall suddenly, the wing can be designed so that the angle of incidence at the wing tip is different than the angle of incidence at the wing root, see Figure 6. The twist in the wing causes the tip and root to stall a slightly different angles of attack and improves the stall characteristics. If the wing root stalls before the wing tip, the ailerons, located closer to the wing tip, and can still be effective during the early part of a stall. Decreasing the angle of incidence at the wingtip is call wash-out, and increasing the angle is called wash-in. Wash-in causes the wingtips to stall first, allowing the pilot to identify the onset of a stall with loss of aileron control.

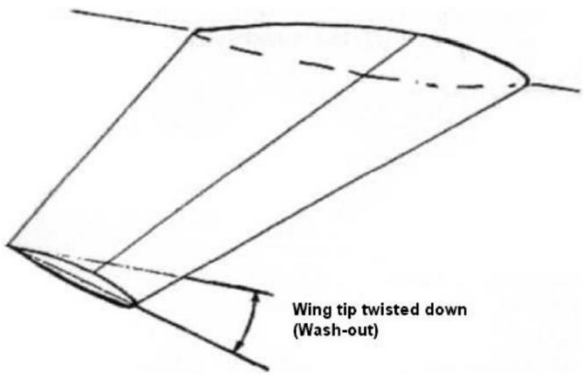

Figure 6 - Wash-out

What Happens to the transition point as airspeed and angle of attack increase?

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What is the aspect ratio of a wing?

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What is it called when the angle of incidence at the wing tip is decreased?

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HIGH-LIFT DEVICES

The efficiency of a wing can be improved by either increasing the amount of lift generated, or by decreasing the amount of induced drag created. High-lift devices can be used individually or in various combinations to create a very efficient wing.

Although great gains in efficiency can be realized by adding these devices to a wing, there are penalties to pay, such as increased weight and increased mechanical complexity.

Wing Tip Design

Induced drag can be reduced by limiting the formation of wing tip vortices. This is done by preventing air from spilling over the wing tip by modifying the wing tips in one of the following ways:

- Installing wing tip fuel tanks, see Figure 7;
- Using wing tip plates or winglets, see Figure 7; and
- Dropping the wing tips, see Figure 8.

Figure 7 - Wing Tip Fuel Tanks and Winglets

Figure 8 - Drooped Wing Tips

Wing Fences

Wing fences are vertical surfaces attached to the upper surface of the wing, see Figure 9. They act as guides and control the direction of airflow over the wing, especially at high angles of attack. This improves low-speed handling and stall characteristics.

Figure 9 - Wing Fences

Slats

Slats are auxiliary airfoils that automatically move out in front of the leading edge at high angles of attack, see Figure 10. The resulting opening changes the airflow over the leading edge, smoothing out eddies that form on the top of the wing.

Slots

Slots affect the airflow in the same way as slats, except they are passages built into the leading edge of the wing. Slots can either full or partial-span.

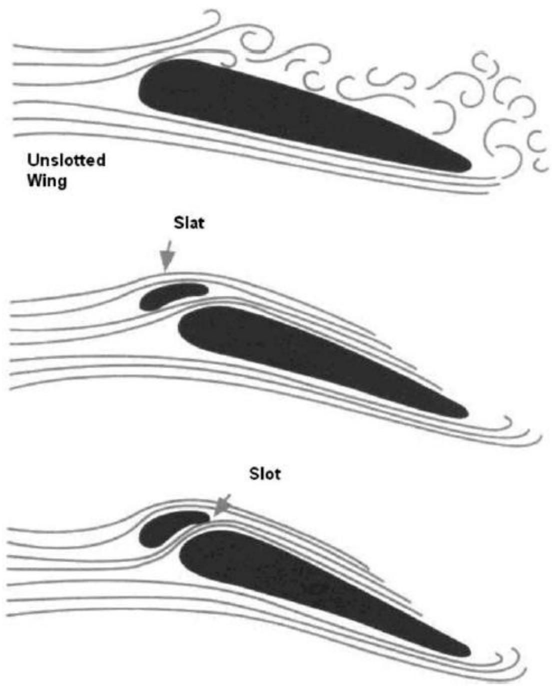

Figure 10 - Slats and Slots

** Slats are moving devices. Slots are built into the wing and do not move.

Flaps

The most common high-lift device found on a wing is the flap. Located at the trailing edge, their primary purpose is to increase lift by changing the camber of the wing. Some styles of flaps also increase the effective wing area. The increase lift causes a lower stall speed and allows the aircraft to approach at a slower airspeed.

With a small amount of flap deflection, the amount of extra lift produced is greater than the amount of extra drag. As the amount of deflection increases, the amount of extra drag catches up to and passes the amount of extra lift being generated, see Figure 11. The extra drag produced can be used to improve landing capabilities by slowing the aircraft down and creating a steeper approach angle (useful in approaching a runway with obstacles near the threshold).

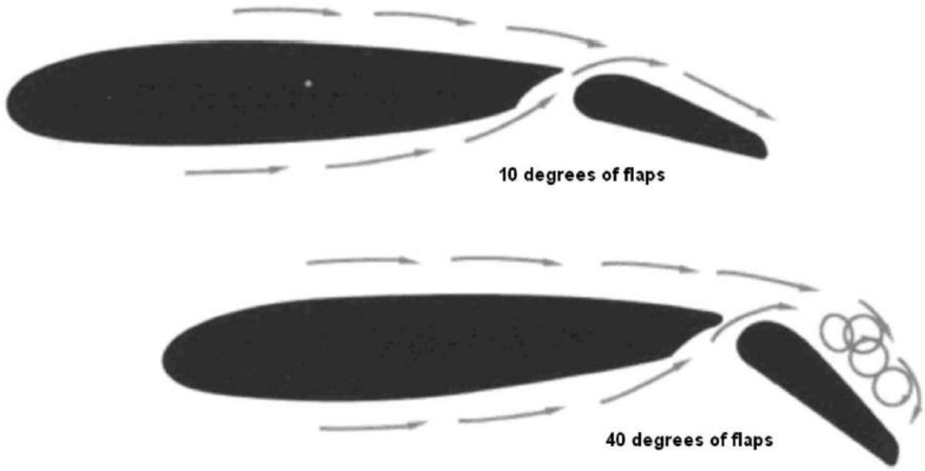

Figure 11 - Flaps

Generally the amount of drag produced by flaps reduces acceleration to the point where flaps should not be deployed during takeoff (as is the case with plain and split flaps). Slotted, Zap, and Fowler flaps produce more lift than drag at small amounts of deflection (5-15^{o}) and are usually recommended for takeoff. See Figure 12 for various flaps found on aircraft.

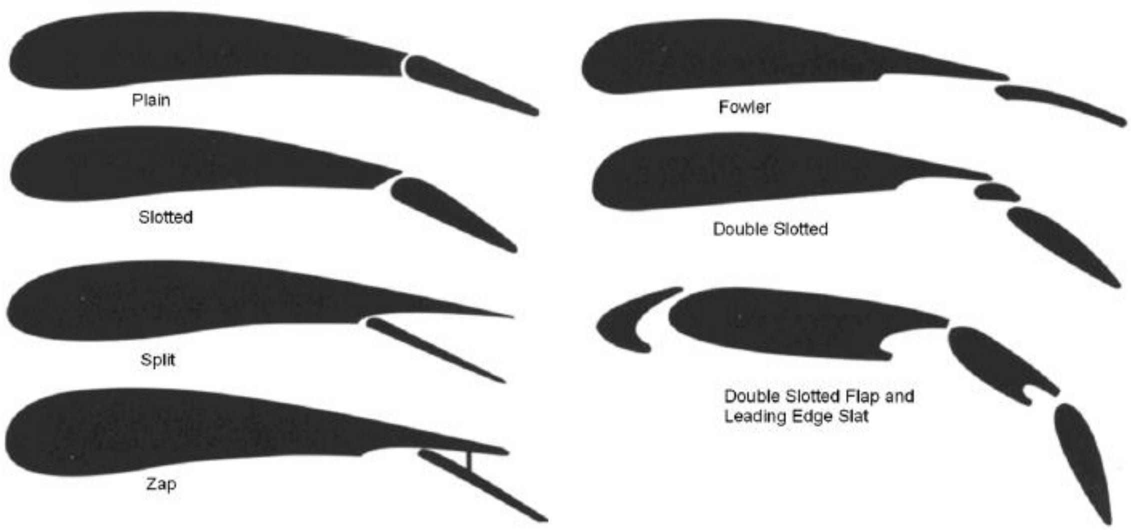

Figure 12 - Types of Flaps

SPOILERS

Spoilers are devices on a wing that are used to decrease lift and increase the drag being produced. They work by being extended up from the top surface of the wing and disrupting the airflow. Spoilers are found on almost all types of gliders and are used to increase the rate of descent during the landing approach.

Spoilers can also be used to supplement aileron control or replace ailerons completely. A deployed spoiler has the same effect as an up-going aileron, causing the aircraft to bank to that side.

SPEED BRAKES

Speed (dive) brakes are devices that are extended into the airflow, creating drag, with minimal effect on the lift being produced. Speed brakes allow aircraft to slow down without reducing thrust, and to control approach angles. Speed brakes may be plates that extend out of a wing or hinged doors that open out from the fuselage.

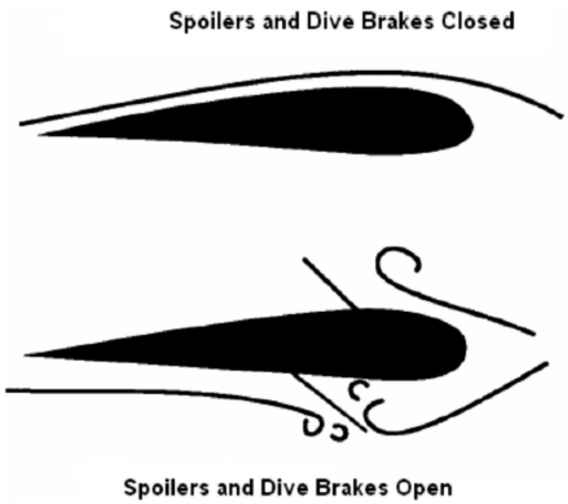

Figure 13 - Spoilers and Dive Brakes

Where are spoilers located?

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What control surface can spoilers supplement or replace?

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What do speed brakes create?

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How can adding devices negatively affect a wing?

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What do spoilers increase during the landing approach of most gliders?

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End of EO

EO M431.02 – DESCRIBE FLIGHT INSTRUMENTS

PITOT STATIC SYSTEM

Instruments connected to the pitot static system work on air pressure. There are two types of air pressure in the pitot static system:

- Pitot pressure; and
- Static pressure.

Pitot Pressure is the increase in air pressure caused by the forward motion of the aircraft through the air.

Static Pressure is the atmospheric pressure outside the aircraft, not affected by turbulence or motion.

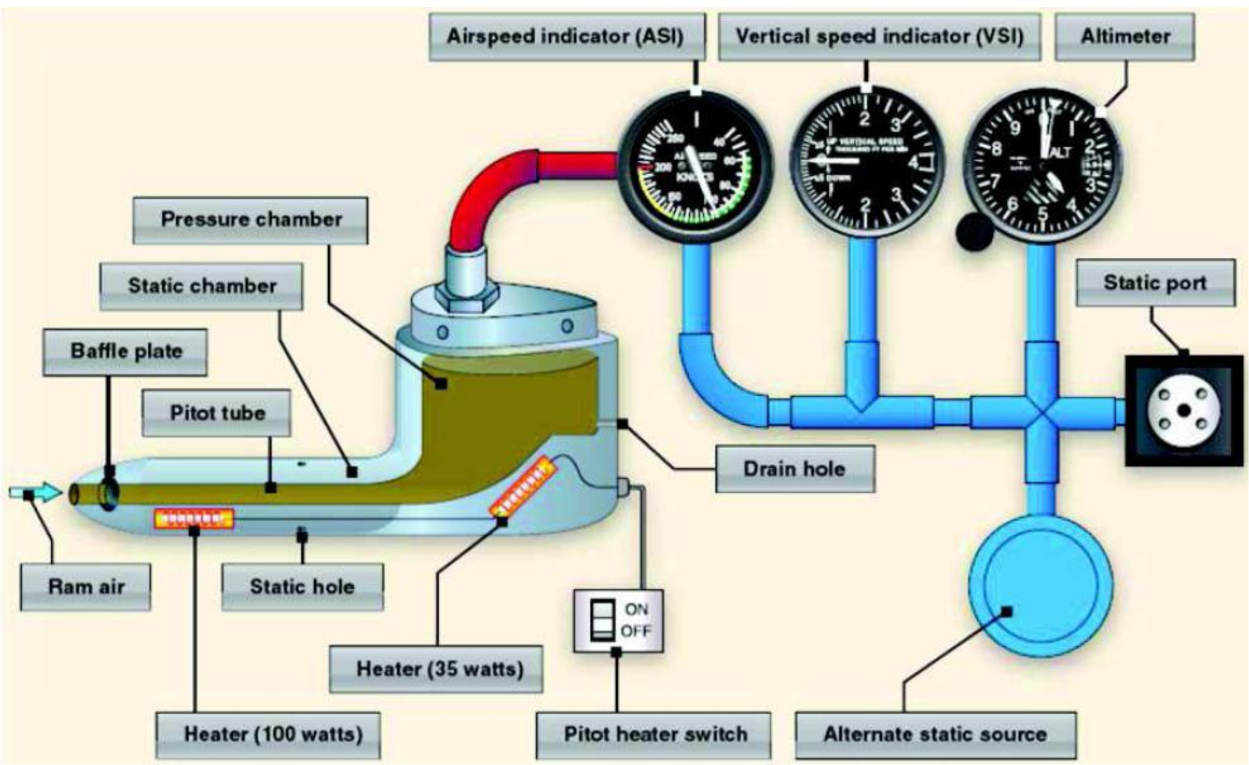

Figure 14 - Typical Pilot Static System

The airspeed indicator (ASI) is connected to both the pitot pressure source (usually a tube attached to the nose or wing) and the static pressure port(s) (usually a small vent on the side of the aircraft). The altimeter and the vertical speed indicator (VSI) are connected only to the static pressure port.

Both the pitot tube and static pressure ports should be carefully checked during the walk-around inspection prior to flight to ensure they are not blocked. A blockage will cause an instrument to provide an incorrect reading. During flight, it is possible for the pitot tube to become blocked by ice. Aircraft that are designed to be flown under instrument flight rules (IFR) will have a pitot heater to prevent ice build-up in the pitot tube.

AIRSPEED INDICATOR (ASI)

The ASI is connected to both the pitot pressure source and static pressure port(s) and displays the difference between the two pressures as the speed of the aircraft moving through the air (not over the ground).

ASI Marings

The ASI has colour-coded markings to indicate operating ranges and speeds, see Figure 15.

Figure 15 - Airspeed Indicator

Red – A red line indicates the never exceed speed (V_{NE}). In Figure 15, its 207kts.

Yellow – A yellow arc starts at the maximum structural cruise (V_{NO}) and extends to the V_{NE}. This area is typically known as the caution range. In Figure 15, its 165kts to 207kts.

Green – The normal operating range. It starts at the power-off stalling speed (V_{SL}) and extends to the V_{NO}. In Figure 15, its 65kts to 165kts.

White – The range in which fully extended flaps may be used. It starts at the power-off stalling speed with flaps and gear extended (V_{SO}) and extends to the maximum flap extended speed (V_{FE}). In Figure 15, its 60kts to 100kts.

ASI Errors

Density error. The ASI is calibrated for normal sea level pressure of 29.92 inches of mercury (Hg) at a temperature of 15^{o}C. Temperature and pressure normally decrease with an increase in altitude, decreasing the density of the air and causing the ASI to read less than the true airspeed.

Position error. Results from the position of the pitot pressure source. Eddies formed by air moving over the aircraft and the angle of the pitot source to the airflow cause position error.

Lag error. A mechanical error that is the result of friction between the working parts of the instrument. This error is responsible for a slight delay between a change in airspeed occurring and the change being shown on the instrument.

Icing error. The error caused by a complete or partial blockage of the pitot pressure by ice. This error can be prevented or corrected by turning on the pitot head (if equipped) or descending to a lower altitude where the outside air temperature (OAT) is higher.

Water error. Water in the system can cause higher or lower than normal readings and may block the system completely. Water can be kept out of the system by covering the pitot spurce when the aircraft is parked. This will also keep dirt and insects from entering the system.

Airspeed Definitions

Indicated airspeed (IAS). The uncorrected airspeed read from the instrument dial.

Calibrated airspeed (CAS). The IAS corrected for instrument (lag) error and installation (position) error.

Equivalent airspeed (EAS). The CAS corrected for compressibility factor. This is very significant to aircraft operating above 10 000 feet and 250knots (kts).

True airspeed (TAS). The CAS (or EAS) corrected for density (pressure and temperature).

ALTIMETER

The altimeter is connected only to the static pressure port(s) and measures the pressure of the outside air. A sealed aneroid capsule inside the instrument case expands or contracts due to changes in the static pressure. The expansion or contraction is mechanically linked to the indicator’s needles and causes them to rotate around the dial to show the altitude.
The altimeter is read similar to a clock. The short wide needle indicates 1000’s of feet, the long skinny arm indicates 100’s of feet and the longest arm with the triangle at the tip indicates 10 000’s of feet. The altimeter in Figure 16 indicates approximately 1400ft. The window between the 2 and 3 shows the barometric pressure the altimeter is set to in inches of mercury (inHg)

Figure 16 – Altimeter

Altimeter Errors

Pressure error. Barometric pressure varies from place to place and this error is corrected by using an altimeter setting obtained from the nearest aviation facility (flight service station, control tower, etc.). All aircraft flying in the same area should be using the same altimeter setting.

When an aircraft flies into an area with a relatively lower pressure, if the altimeter setting is not corrected, the altimeter will read higher than the actual altitude. For example, the altimeter may be indicating 4 000 feet, while the actual altitude may be 3 000 feet. This could cause conflict with other aircraft, or even worse, cause the aircraft to come into contact with the ground.

Abnormally high pressure. Altimeters are calibrated for the standard atmosphere (15°C at sea level) and any deviation from that will cause an error. Extremely low temperatures may cause as much as 20 percent error in the altimeter, causing the altimeter to read higher than the actual altitude.

Mountain effect error. Increase wind speed through mountain passes or in mountain waves may cause a localized area of low pressure. Temperatures may also be affected, compounding the altimeter error.

Altimeter Definitions

Indicated altitude. The altitude displayed on the altimeter when it is set to the current barometric pressure.

Pressure altitude. The altitude displayed on the altimeter when it is set to the standard barometric pressure (29.92 inches of Hg).

Density altitude. The pressure altitude corrected for temperature.

Absolute altitude. The actual height above the Earth's surface (the altimeter set to field level pressure or field elevation).

VERTICAL SPEED INDICATOR (VSI)

The VSI is connected only to the static pressure port(s). The rate of change of the static pressure is transmitted to the needle to indicate if the altitude is increasing or decreasing.

Figure 17 - Vertical Speed Indicator

Even though the VSI will quickly indicate a climb or descent, it may take several seconds before the correct rate of descent is displayed. This delay is known as lag. An instantaneous VSI has a complicated system of pistons and cylinders instead of the simpler aneroid capsule found in most VSIs and does not experience lag.

THE GYROSCOPE

The gyroscope is a spinning wheel (rotor) in a universal mounting (gimbal) that allows its axle to be pointed in any direction.

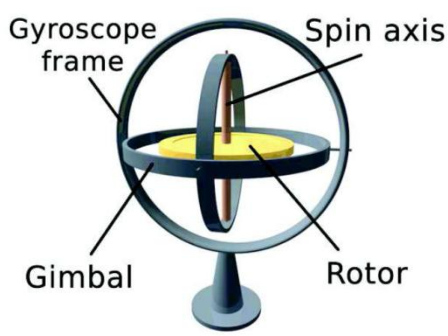

Figure 18 - Gyroscope

Gyroscopic Inertia

Also known as rigidity in space, gyroscopic inertia is the tendency of a rotating object to remain in its plane of rotation. This allows the spinning rotor to remain in place regardless of how the gumball is moved around it.

Precession

Precession is the tendency of a rotating body, when a force is applied perpendicular to its plane of rotation, to turn in the direction of its rotation 90 degrees to its axis and take up a new plane of rotation parallel to the force applied.

Power Sources

To work properly, the rotor must be kept spinning at a constant speed. The gyroscopic instruments may be powered by one or more power source.

Engine driven vacuum system. This gyroscope uses a vacuum pump powered by the engine to spin the rotor. It does not work if the engine is not running (ie prior to start-up or following an engine failure). A variation of this system is an engine driven air pump that uses positive air pressure to spin the rotor.

Venturi driven vacuum system. A venturi tube on the outside of the aircraft creates a vacuum to spin the rotor. Simple to install, it has no moving parts that could fail, but depends on airspeed of the aircraft and the tube causes additional drag. It can also become plugged with ice or debris.

Electrically driven gyroscopes. The rotor is spun by an electric motor allowing the gyroscope to work at high altitudes where vacuum systems are ineffective.

Care of Gyroscopic Instruments

Gyroscopic instruments are precision instruments and need to be cared for properly to prevent premature failure and damage. The air used to spin the rotor (vacuum or positive pressure) must be filtered to prevent dust and dirt from contaminating the system. The instruments need to be handled gently during installation and removal. Some gyroscopes must also be locked (caged) prior to aerobatics. Venturi driven systems are also susceptible to ice blockages.

HEADING INDICATOR (HI)

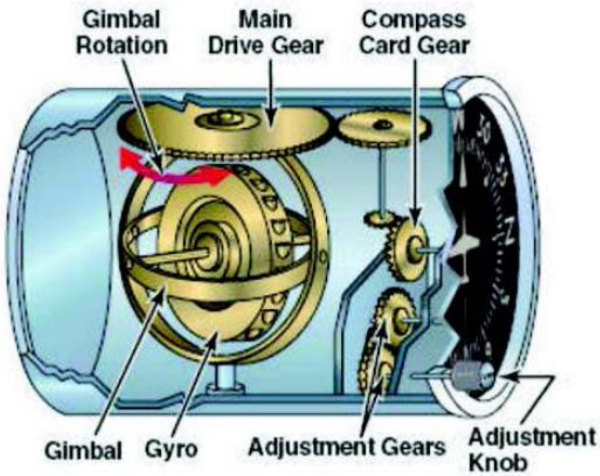

Figure 19 - Heading Indicator

The HI (directional gyro [DG]) is steady and accurate as it is not afflicted with any of the errors that apply to magnetic compasses (eg, northerly turning error, acceleration and deceleration errors). It remains constant without swinging or oscillating and provided accurate readings even in rough air. See EO M437.02 for more information on magnetic compasses.

Vacuum driven HI's may take up to five minutes for the rotor to reach operating speed and should not be used during this period. Venturi driven HI's cannot be used while taxiing or during takeoff. Once the rotor is spinning at the correct speed, the HI needs to be set to the current heading (by referencing the magnetic compass or runway heading).

Friction in the gyroscope causes a small amount of precession and will cause the reading to drift approximately three degrees over a period of 15 minutes. It is also subject to apparent precession. The rotation of the Earth gives the gyroscope an apparent motion relative to the Earth. This error varies with latitude. Apparent precession is zero at the equator and 15 degrees per hour at the poles. Precession errors are easily corrected by resetting the HI to the current heading (by referencing the magnetic compass during straight and level flight) every 15 minutes.

ATTITUDE INDICATOR (AI)

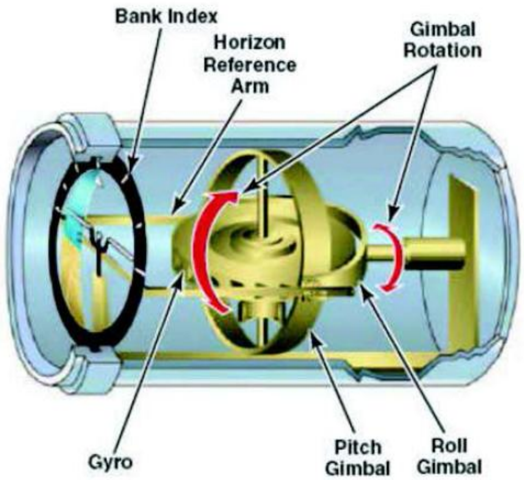

Figure 20 - Attitude Indicator

The AI (artificial horizon or gyro horizon) is designed to provide an artificial horizon for the pilot during periods of poor visibility (eg fog, clouds, rain, snow, night). The artificial horizon provides attitude information to the pilot (pitch and bank).

During acceleration or deceleration, precession will cause a slight indication of a climb or descent, respectively.

TURN AND BANK INDICATOR

Figure 21 - Turn and Bank Indicator

The turn and bank indicator (turn and slip) is a combination of two instruments and is also known as the needle and ball. The direction and rat of turn is indicated by the needle. The needle is controlled by a gyroscope. The ball is controlled by gravity. During a properly executed turn, centripetal and centrifugal forces are balanced with gravity and the ball stays in the centre. During a slipping turn there is not enough centrifugal force and the gravity will pull the ball in the direction of the turn. During a skidding turn there is not enough centripetal force and the ball is pulled in the opposite direction of the turn.

The turn and slip indicator does not indicate the amount of bank of the aircraft. It indicated the rate of turn and if the aircraft is skidding or slipping in the turn.

During a standard rate (rate one) turn, the aircraft turns at a rate of three degrees per second (360 degrees in two minutes).

The turn and bank indicator will also indicate if a wing is low during straight flight. If the needle is centred but the ball is not, then the wing on the side that the ball has moved to is low.

TURN COORDINATOR

Figure 22 - Turn Coordinator

The turn coordinator is an updated version of the turn and slip indicator and is able to display the rate of roll as well as the rate of turn.

What is gyroscopic inertia?

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What errors affect the HI?

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Which gyroscopic instrument can display the rate of roll as well as the rate of turn?

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ANGLE OF ATTACK (AOA) INDICATOR

Figure 23 - AOA Indicator

An aircraft will stall at different airspeeds depending on factors such as weight, load factor, and configuration. A stall will occur if the critical angle of attack is exceeded. The AOA indicator displays the relationship between the chord line of the wing and the relative airflow. Many indicators also have colour-coded ranges to alert the pilot that the critical AOA is being approached.

MACH INDICATOR

Figure 24 - Mach Indicator

The Mach indicator displays the ratio of its airspeed to the local speed of sound. The Mach number is calculated by dividing the airspeed by the speed of sound. A Mach number of 1 means that the aircraft is travelling at the speed of sound. The Mach indicator measures and correlates static and dynamic pressures.

Figure 25 - Example of a Cessna Instrument Panel

End of EO

PO 431 REVIEW

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PO 432 – DESCRIBE AERO ENGINE SYSTEMS
EO M432.01 – DESCRIBE FUEL SYSTEMS

THE FUEL SYSTEM

An aircraft fuel system stores and delivers the proper amount of fuel for all phases of flight, including:

- Normal flight;
- Violent manoeuvres;
- Sudden acceleration; and
- Sudden deceleration.

Fuel systems include the following parts:

- Fuel tanks;
- A fuel selector valve;
- Fuel lines and filters;
- A fuel quantity gauge; and
- Fuel primer.

Pressure Feed System

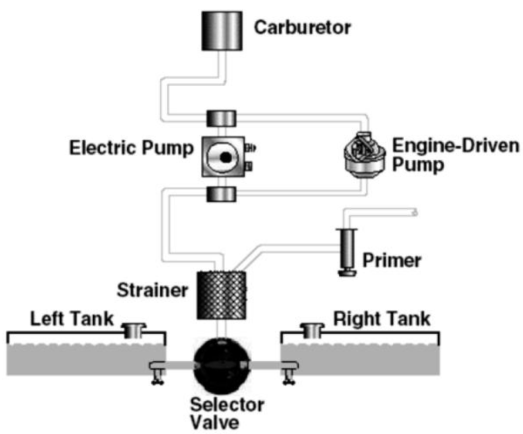

Figure 26 - Pressure Feed System

Aircraft with low-wing configurations and large aircraft with a large volume of fuel movement use an engine-driven fuel pump to provide the pressure to keep fuel flowing. This system includes:

- The basic pump;
- Auxiliary electric pump(s) for emergency situations;
- A booster pump to create the pressure required to start the fuel flowing before the engine is running; and
- The pressure gauge mounted on the cockpit panel used to read the pressure of fuel entering the carburetor.

Gravity Feed System

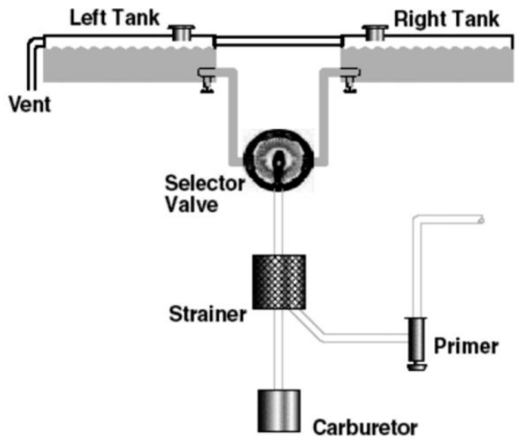

Figure 27 - Gravity Feed System

High-wing, low-powered light aircraft use the gravity feed system. The bottom of the fuel tank in the wing must be high enough to provide enough pressure for the fuel to travel past the fuel selector to the carburetor.

Fuel Selector Valve

The fuel selector valve is used by the pilot to select the desired fuel tank to draw fuel. The selector valve may also be used to shut off the flow of fuel from the tanks. Typically they have 4 settings: off, left, right, both. Some aircraft may have a reserve fuel tank, so the fuel selector valve will have an option for that too.

FUEL

Aviation fuel has been specially formulated for use in aircraft. It is available in several different types/grades. The approved fuel types are specified in the pilot operating handbook.

Fuel Types

Fuel used in modern high compression engines must burn slowly and expand evenly rather than explode quickly (detonation). High octane fuels meet this requirement. The octane rating of fuels is calculated by the ratio of octane and heptanes. For example 87 octane means 87% octane and 13% heptane.

Octane. A hydrocarbon which possesses minimum detonating qualities.

Heptane. A hydrocarbon which possesses maximum detonating qualities.

Higher octane fuels are treated with sulphuric acid, lye, etc, use to remove the gum, acid and other impurities.

Octane numbers can only go as high as 100. Beyond this, the performance number is the anti-knock value of the fuel. Fuel grades are expressed by two performance numbers, the first number indicated octane rating at lean mixture conditions, and the second number indicates octane rating at rich mixture condition. For example 100/130.

What fuel feed system does an aircraft with low-wing configuration use?

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For what is the fuel selector valve used?

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How are octane ratings of fuels calculated?

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CARBURETORS

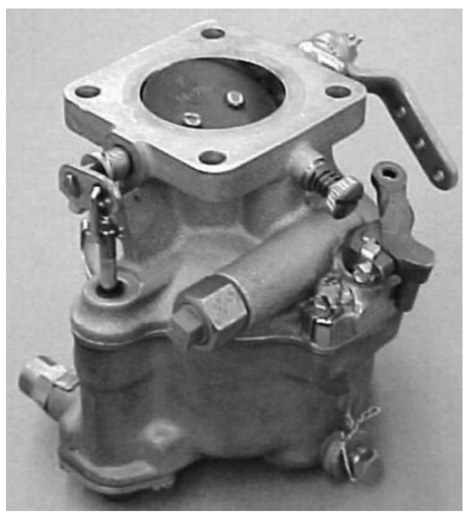


Figure 28 – Carburetor

The heat energy in an internal combustion engine is developed from the burning of a mixture of gasoline and air. The carburetor measures the correct quantity of gasoline, vaporizes fuel, mixes it with the air in the required proportion and delivers the mixture to the cylinder when the combustion occurs.

An engine will run hotter with a lean mixture than a rich mixture; as the lean mixture will burn slower and the cylinder walls are exposed to high heat for a longer time. A rich mixture burns quickly, exposing the cylinder walls to high temperatures for a shorter time, and the additional fuel in the fuel/air mixture cools the engine.

The carburetor involves numerous complex devices to control the mixture ratio. Two types of carburetors used include float carburetor or pressure carburetor.

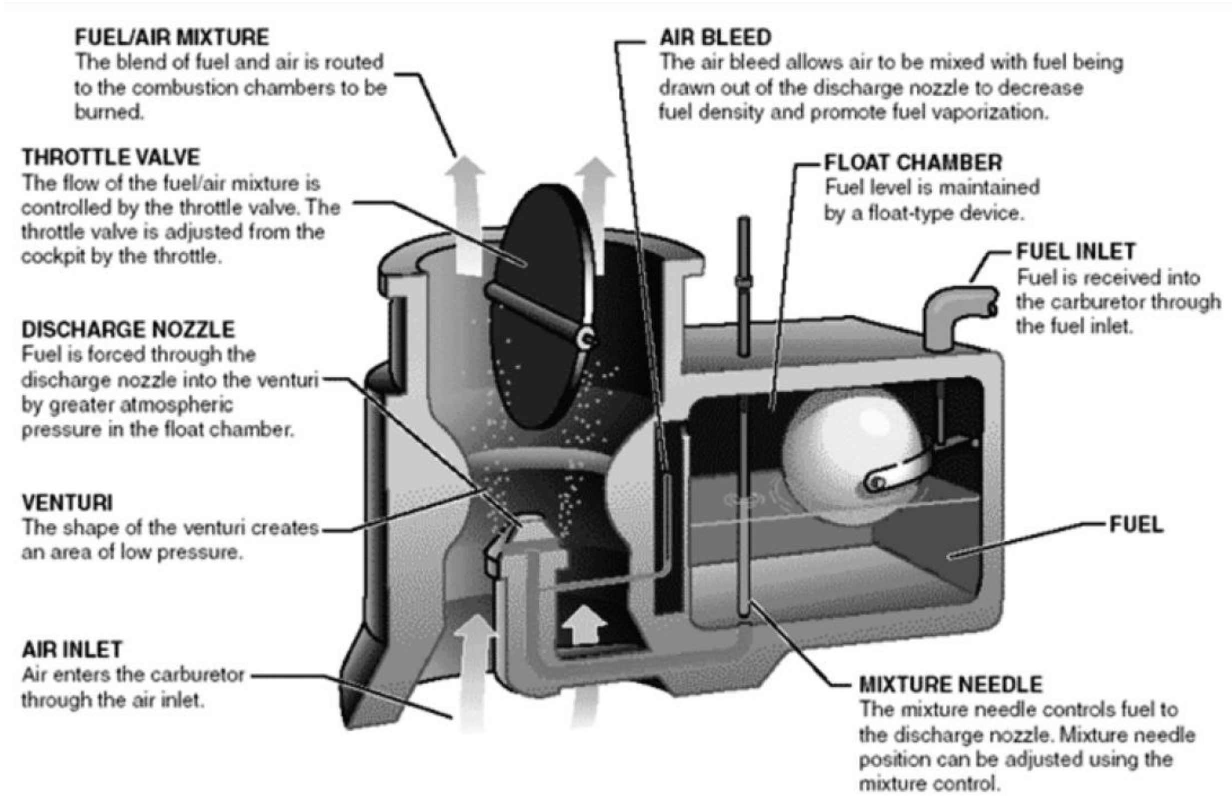


Figure 29 - Float Carburetor

Fuel flows though the fuel lines, enters the carburetor at the float valve and into the float chamber. A needle attached to the float, resting on the fuel within the chamber, opens and closes an opening at the bottom of the carburetor bowl. The float chamber is vented so the atmospheric and chamber pressure equalizes as the aircraft climbs and descends.

Air flows though an air filter, usually located at an air intake in the front part of the engine cowling. The filtered air flows into the carburetor through a venture (narrow throat in the carburetor). The air speed increases, creating a low pressure area which draws fuel at atmospheric pressure.

The air and vaporized fuel is regulated, in volume, by the throttle valve, enters the intake manifold and is distributed to the individual cylinders. The pilot is able to control the amount of fuel/air mixture from within the cockpit using the throttle control.

Mixture Control

The correct fuel/air proportions is set by weight and will be obtained at sea level as carburetors are normally calibrated for sea level operation.

As altitude increases, the density of the air decreases and a given volume of air weighs less. The proportion of air by weight to that of fuel becomes less, although the volume remains the same.

Because the carburetor is regulated by volume, the mixture at higher altitude becomes over-rich causing fuel waste and loss of power.

A mixture control is fitted to the carburetor that adjusts the amount of fuel being drawn from the nozzle, restoring the proper fuel/air mixture.

The general rules when using a manual mixture control are:

- Rich mixtures – high power settings, and
- Lean mixtures – cruise power settings.

Carburetor Icing

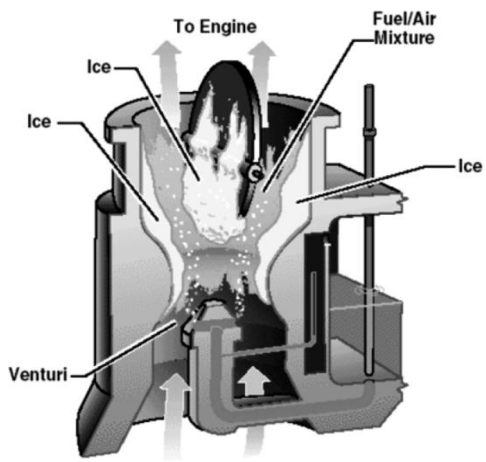


Figure 30 - Carburetor Icing

Typically as air velocity increases the temperature drops. With temperatures ranging from -5°C to 30°C and under certain moist atmospheric conditions, ice and form in the induction system closing off the flow of fuel to the engine. Ice can form on various surfaces of the carburetor especially on the throttle. Modern aircraft have incorporated a method of directing heated air into the carburetor air intake, activated by the carburetor heat handle in the cockpit. The heated air can prevent ice from forming, or melt ice that has already formed. The addition of heat results in a drop in engine power, however carburetor icing will result in no engine power.

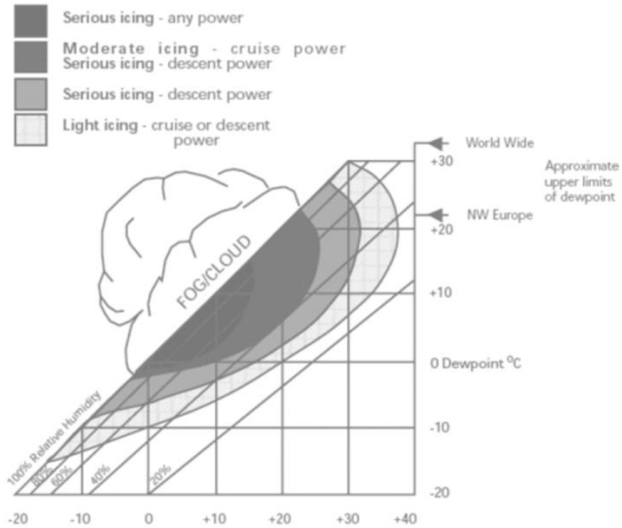


Figure 31 - Carburetor Icing Chart

How are the fuel/air proportions calculated?

____

What does the mixture control adjust?

____

What do modern aircraft have to melt ice that has formed?

____

FUEL INJECTION

With a fuel injection system, a control valve supplies pressurized fuel continuously to the induction system near the intake valve. The fuel is vaporized and sucked into the cylinder during the intake stroke.

Advantages of fuel injection include:

- More uniform distribution of fuel to all cylinders;
- Better cooling, through the elimination of lean hot mixtures to some of the more distant cylinders;
- Fuel savings through uniform distribution;
- Increased power since the carburetor heat air is eliminated; and
- Elimination of the hazard of carburetor icing.

Although carburetor icing has been eliminated with fuel injection, throttle ice can occur when the temperature is less than 5^{o}C. Impact ice can gather in bends in the system, intake tubes, and air filter.

What does the control valve do?

____

What are the advantages of fuel injection?

____

____

____

Where can impact ice gather?

____

End of EO

EO M432.02 – DESCRIBE PROPELLER SYSTEMS

The propeller provides the necessary thrust to pull, or in some cases push, the airplane though the air. The engine power rotates the propeller that generates thrust very similar to the manner in which a wing produces lift.

The propeller is a rotating airfoil designed to push air backwards as it moves forward along a corkscrew (helical) path. It meets the air at an angle of attack as it rotates, producing thrust (lift) and torque (drag).

Propeller torque is different than engine crankshaft torque in that propeller torque is drag. It is the resistance to the blades as they rotate, resulting in a tendency of the aircraft to roll in a direction opposite to the rotation of the propeller. Engine crankshaft torque is the turning moment produced at the crankshaft. When the propeller is revolving at a constant rpm, propeller torque and engine torque will be exactly equal and opposite.

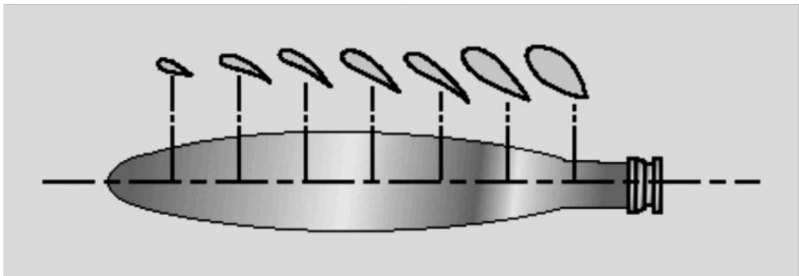


Figure 32 - Propeller Blade Shape

A typical propeller is twisted so the blade angles and tapers from the hub to the tip. The highest angle of incidence (pitch) is at the hub and the smallest pitch is at the tip.

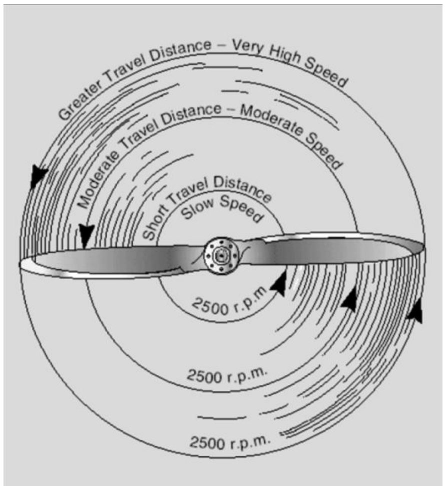


Figure 33 - Relationship of Travel Distance and Speed of Various Portions of the Propeller Blade

By means of the variation in speed and the angle of attack over airfoil sections, uniform thrust is maintained throughout most of the diameter of the propeller.

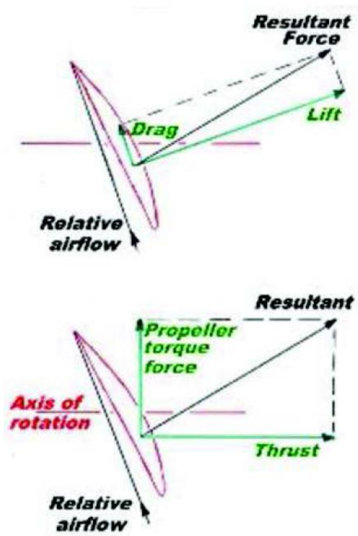


Figure 34 - Forces Acting on a Propeller Blade

Tractor propellers are propellers attached forward of the engine that pull from the front of the aircraft. Pusher propellers are propellers attached aft of the engine that push from behind the aircraft.

Pitch is the distance, in feet, a propeller travels forward in one revolution. Propeller pitch is the difference between theoretical pitch (geometric pitch) and practical pitch (effective pitch).

Theoretical Pitch is the distance travelled forward in one revolution if the propeller was working in a perfect fluid. This depends on the blade angle and the diameter of the propeller.

Practical pitch is the distance the propeller travels in air in one revolution. The forward motion is less than theoretical pitch.

The angle the blade, like the angle of incidence of a wing, governs the pitch. The propeller set in coarse pitch will travel a greater distance with each revolution. The aircraft will move forward at greater speed for a given rpm.

The propeller set in fine pitch will have less torque (drag) and will revolve at a higher speed around its axis. The engine will produce greater power. A fine pitch propeller will be good for taking off and climbing but a coarse pitch propeller will develop high cruise speed with comparatively low engine rpm giving good fuel economy.

What does the propeller provide?

____

What is propeller torque?

____

____

What is a fine pitch propeller good for?

____

FIXED PITCH PROPELLERS

In **fixed pitch propellers**, the blade angle cannot be adjusted by the pilot and is used on most training aircraft. The blade angle is set by the manufacturer to provide the best compromise for all flight conditions.

VARIABLE PITCH PROPELLERS

In an **adjustable pitch propeller**, the blade angle can be changed on the ground to adjust for varying flight situations such as changed takeoff and climb needs.

In a **controllable pitch propeller**, the blade angles can be adjusted by the pilot during flight. The propeller set in a fine pitch for takeoff allows the engine to develop maximum power. The propeller is then adjusted to a coarse pitch to accelerate at a rapid rate to the desired cruise speed.

In a **constant speed propeller**, the blade angle automatically adjusts to maintain a constant rpm as set by the pilot.

The mechanism for adjusting the pitch of the propeller includes:

- Mechanical;
- Hydraulic; and
- Electrical.

In a **mechanical variable pitch propeller**, the pilot adjusts this type of propeller by a control on the instrument panel. The control is directly linked to the propeller which has stop sets to govern the blade angle and travel.

In **hydraulic variable pitch propellers**, a hydraulically operated cylinder pushes or pulls on a cam connected to gears on the propeller blade. The mechanism can be counterweight or hydromatic.

The counterweight relies on oil pressure to move the cylinder that twists the blades of a controllable pitch propeller toward fine pitch. The control is adjusted by the pilot in the cockpit.

A constant speed propeller uses the oil pressure and counterweight principle to twist the blades to the proper pitch angle to maintain a constant rpm. The pilot uses the throttle and propeller control located in the cockpit. The throttle controls the power output of the engine and the propeller control regulated the rpm of both the propeller and the engine.

If oil pressure is lost during flight, the propeller will automatically go into an extreme coarse pitch position where the blades are streamlined and cease to turn (feathered). This system is used in multi-engine aircraft.

A powerful force called centrifugal twisting moment turns the blades toward the fine pitch position of a hydromatic constant speed propeller. The natural force eliminates the use of counterweights. Oil enters the piston chamber under high pressure which moves the piston aft and the blades move into coarse pitch. When the oil enters into the piston chamber under engine pressure, the blades move to fine pitch.

If oil pressure is lost during flight, the propeller will automatically go into fine pitch position, enabling the engine to develop the most power it can and achieve the best performance under the circumstances. This system is used in single-engine aircraft.

In **electric variable pitch propellers**, an electrical motor turns the blades through a gear speed reducer and bevel gears for an electrical variable pitch propeller. Flyweights open and close electric circuits. One circuit causes a right-hand rotation of the motor and the other causes a left-hand rotation. The rotation of the motor will adjust the blades toward a fine or coarse pitch as required. The pilot can set a two way switch to either manual or automatic operation.

Who sets the blade angle on a fixed pitch propeller?

____

How can the propeller pitch be adjusted?

____

____

What happens to the propeller if oil pressure is lost on a single-engine aircraft?

____

Feathering is used on multi-engine aircraft. When one engine is off, the propeller is feathered meaning the turning blades are in the extreme coarse pitch position and stop turning. This reduces drag on the blades, possible damage to the defective engine and stops excessive vibration.

Propeller reversing is used at slow speed to assist with stopping an aircraft once on the ground. The blade angle of a controllable pitch propeller is changed to a negative value. The reverse pitch uses engine power to produce a high negative thrust at slow speed. A pilot of a multi-engine aircraft can decrease the radius of a turn by using propeller reversing with the inside engine.

What is pitch?

____

Name two propeller types.

____

____

What type of aircraft use propeller feathering?

____

End of EO

EO M432.03 – DESCRIBE ENGINE INSTRUMENTS

OIL PRESSURE AND TEMPERATURE

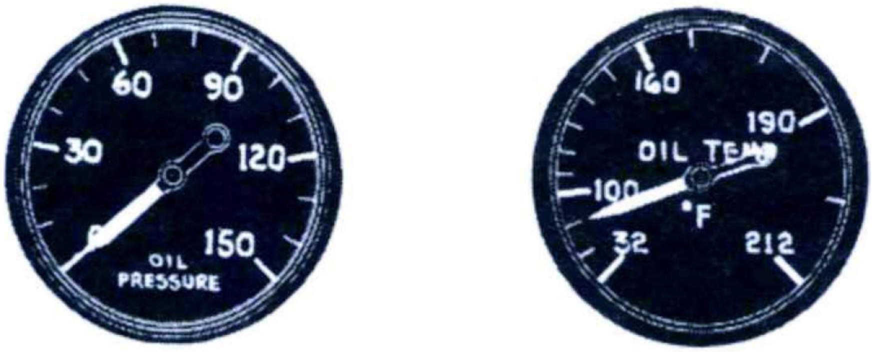


Figure 35 - Oil Pressure and Temperature Gauges

One of the principle engine instruments is the oil pressure gauge. It is usually positioned beside the oil temperature and fuel gauges. The instrument is calibrated in pounds per square inch (psi) and indicated the oil pressure supplied by the oil pump to lubricate the engine.

The gauge should be checked immediately after the engine has been started. As the oil warms, the reading should adjust to operational pressure. This may take up to 15 minutes. If the pressure remains high, the engine is not getting proper lubrication. High oil pressure pushes oil into the combustion chamber where it burns causing a smoky exhaust and badly carbonized piston heads, valve seats, cylinder heads, and more.

Low oil pressure causes more serious problems as no film of oil goes between the working surfaces of the engine. Metal against metal rubbing causes main bearings to wear out.

The oil temperature gauge records the temperature of the oil in degrees Fahrenheit or Celsius. As the oil warms during start-up, the pressure should read high and the temperature low. Both instruments should approach their normal readings as the oil warms.

An abnormal drop in oil pressure and rise in oil temperature indicates trouble. Also, no change in oil pressure but a change in oil temperature is a warning of excessive friction or overload in the engine.

CYLINDER HEAD TEMPERATURE

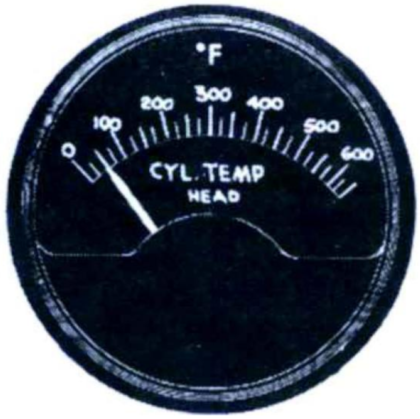


Figure 36 - Cylinder Head Temperature Gauge

The cylinder head temperature gauge shows the temperature of one or all engine cylinder heads. This reading shows the pilot the effectiveness of the engine cooling system. Extremely high cylinder head temperatures indicate an immediate sign of engine overload which can result in detonation, pre-ignition, and eventual engine failure.

Detonation is an abnormally rapid combustion due to the inability of fuel to burn slowly. Detonation is dangerous and expensive, causing high stress on engine parts and overheating.

Pre-ignition is the premature ignition of the fuel/air mixture due to glowing carbon particles. It is sometimes confused with detonation. Pre-ignition is often experienced when attempting to start a hot engine and results in a backfire.

TACHOMETER

Figure 37 – Tachometer

The tachometer (tacho=speed, meter=measurement/gauge) shows the speed at which the engine crankshaft is turning in hundreds of revolutions per minute (rpm). The tachometer records the engine hours of operation. The more common types of tachometers are mechanical (centrifugal or magnetic) and electrical (direct current or alternating current).

An aircraft with a fixed pitch propeller will only have a tachometer to read the engine power produced. It records the rpm at which the engine cranks and the propeller turns.

An aircraft with a controllable pitch or a constant speed propeller uses two gauges. The tachometer shows the rpm settings as controlled by the propeller control. The manifold pressure gauge shows the power produced by the engine.

The tachometer is marked with colour-coded arcs to indicate the proper range of engine operation, including:

- Green, indicating normal range of operation;
- Yellow, indicating the caution range and possible problems; and
- Red, indicating the maximum limit.

MANIFOLD PRESSURE

Figure 38 - Manifold Pressure Gauge

The manifold pressure gauge also has colour coded arcs displayed on the gauge to indicate the normal operating range and operation limits. The gauge indicated in inches of mercury the fuel/air pressure in the engine intake manifold at the point between the carburetor and the cylinders.

With an aircraft fitted with a constant speed propeller, the rpm setting will remain constant. The manifold pressure gauge is the only instrument to show any fluctuations in the engine power output. A reduction in manifold pressure can indicate carburetor icing.

When the engine is not running, the reading on the manifold pressure gauge will be atmospheric pressure.

Excessive manifold pressure raises the compression pressure, causing high stress on the pistons and cylinder assemblies. It also produces excessive temperature which may cause scoring on the pistons, sticking piston rings, and burned out valves.

When increasing power, increase the rpm first and then the manifold pressure.

When decreasing power, decrease the manifold pressure first and then the rpm.

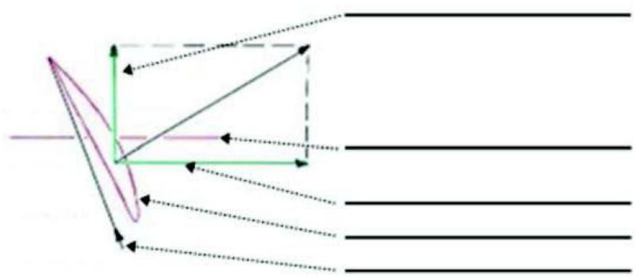
End of EO

PO 432 REVIEW

1. Where should the fuel tank be positioned in a gravity feed system?
2. What system do low-wing aircraft and large aircraft with a large volume of fuel use?
3. What does the fuel selector valve, used by the pilot, do?
4. A rich mixture is used for:
5. How is the fuel/air proportions regulated?
6. Which propeller would not be good for taking off and climbing?
7. What is maintained throughout most of the diameter of the propeller by means of the variation in speed and the angle of attack over sections of the propeller?
8. What is the distance a propeller travels forward in one revolution?
9. What colour-coded arcs are found on the tachometer?
10. What reading will register on the manifold pressure gauge when the engine is not running?
11. What occurs to an engine as the altitude increases and the air becomes less?
12. A feathered propeller is in:
13. In what units is the oil pressure gauge calibrated?

14. What does the tachometer show?

15. Label the following parts on the diagram below:
    a. Thrust
    b. Relative Airflow
    c. Propeller
    d. Axis of Rotation
    e. Propeller torque force



End of PO

PO436 – EXPLAIN ASPECTES OF METEOROLOGY

EO 436.01 – EXPLAIN WINDS

SURFACE WINDS

Wind is a major factor in flight planning and flight characteristics. Pilots must constantly be aware of the direction and speed of wind during the flight, especially when close to the ground during takeoff and landing.

Surface friction plays an important role in the speed and direction of surface winds.
The friction between the air and the ground slows the air down causing a lower wind speed than would be expected from the pressure gradient. The friction also changes the direction causing the wind to blow across the isobars toward the centre of a low pressure area and away from the centre of a high pressure area.

The effect of surface friction usually does not extend more than a couple of thousand feet into the air. At 3 000 feet above the ground, the wind blows parallel to the isobars with a speed proportional to the pressure gradient.

Hills and valleys substantially distort the airflow associated with the prevailing pressure system and the pressure gradient. Katabatic and anabatic winds and mountain waves are examples of wind phenomena in mountainous areas.

Katabatic and Anabatic Winds

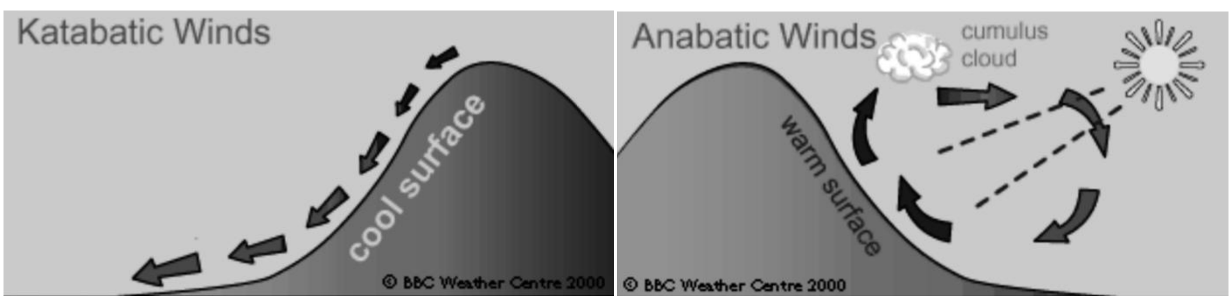


Figure 39 - Anabatic and Katabatic Winds

At night, the sides of hills cool by radiation. The air in contact with them becomes cooler and denser, and blows down the slope into the valley. A katabatic wind is the term for down slope winds flowing from high elevations down the slopes to the valleys below. If the slopes are covered with ice and snow, the katabatic wind can also carry the cold dense air into the warmer valleys during the day.

Anabatic wind occurs during the day when the slopes of hills, not covered by snow, are warmed. The air in contact with them becomes warmer and less dense, therefore flowing up the slope.

Mountain Waves

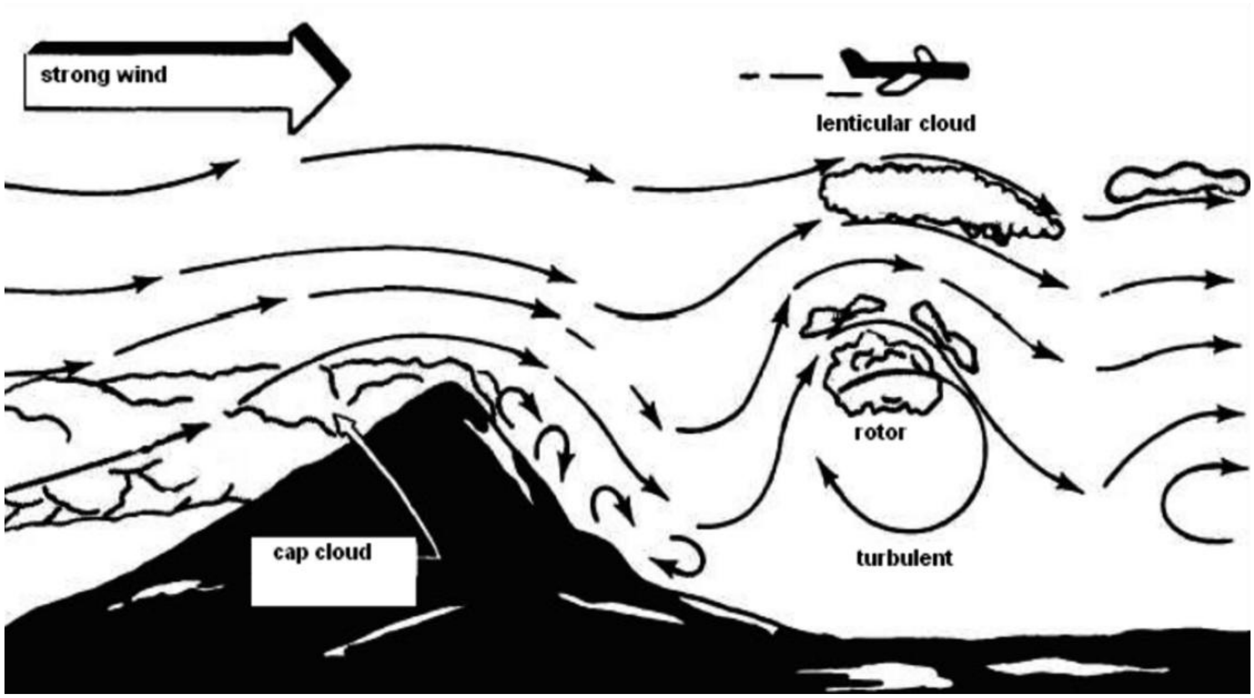


Figure 40 - Mountain Wave

Air flowing across a mountain range usually rises smoothly up the slope of the range. Once over the top, it pours down the other side with considerable force, bouncing up and down, creating eddies and turbulence. It also creates powerful vertical waves that may extend for great distances downwind of the mountain range. This phenomenon is known as a mountain wave. The most severe mountain wave conditions are created in strong airflows that are blowing at right angles to the mountain range in very unstable air.

If the air mass has high moisture content, clouds of a very distinctive appearance will develop, thereby serving as a warning to pilots. Orographic lift causes a cap cloud to form along the top of the ridge. Lenticular (lens shaped) clouds form in the wave crests aloft and lie in bands that may extend well above 40 000 feet. Rotor clouds resemble a long line of stratocumulus clouds and form in the rolling eddies downstream.

Mountain waves may cause many dangers to aircraft, such as:

- Common downdrafts of 2 000 feet per minute along the downward slope;
- Extremely severe turbulence in the air layer between the ground and the tops of the rotor clouds;
- Severe wind shear due to wind speed variation between the crests and troughs of the waves;
- Severe icing due to large supercooled droplets sustained in the strong vertical currents; and
- An altimeter error of more than 3 000 feet on the high side due to the increase in wind speed and accompanying decrease in pressure.

Gusts

A gust is a rapid and irregular change of wind speed and may be associated with a rapid change in wind direction. Gusts are caused by mechanical turbulence that results from friction between the air and the ground and by the unequal heating of the Earth's surface, particularly during hot summer afternoons.

Wind gusts are a hazard to gliders due to their light weight and relatively slow stalling speed. Therefore, the Air Cadet Gliding Program has a maximum permissible gust differential of 10 knots (12mph). Any gust differential beyond this will require an immediate shutdown of gliding operations.

Squalls

A squall is a sudden increase in the strength of the wind of longer duration than a gust and a like a gust, may be accompanied by a rapid change in wind direction. Squalls may be caused by the passage of a fast moving cold front or thunderstorm.

JET STREAMS

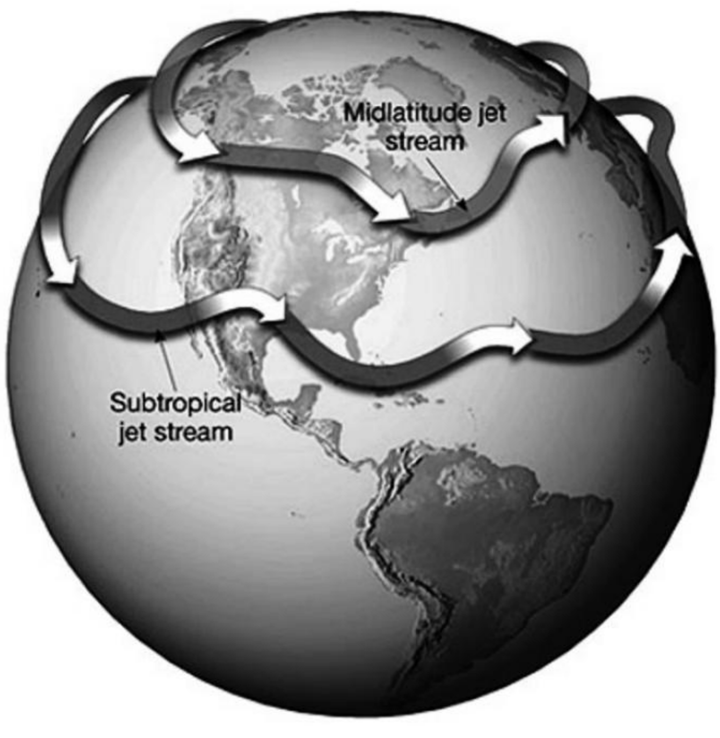


Figure 41 - The Jet Stream

Jet streams are narrow bands of exceedingly high winds that exist in the higher levels of the atmosphere at altitudes ranging from 20 000 to 40 000 feet or more. They flow from west to east and are usually 300 nautical miles wide and 3 000 to 7 000 feet thick. Winds in the central core of a jet stream are generally between 100 and 150 knots, although they may reach speeds as great as 250 knots.

The northern hemisphere has two such streams: the mid-latitude (polar) jet, which is the one usually affecting weather in North America, Europe and Asia, and the subtropical jet.

When the mid-latitude jet is farther north, in Canada, the weather to its south tends to be mild or at least less cold. When the stream swings south well within the United States, especially in winter, very cold, often harsh weather prevails at the surface on the northern side.

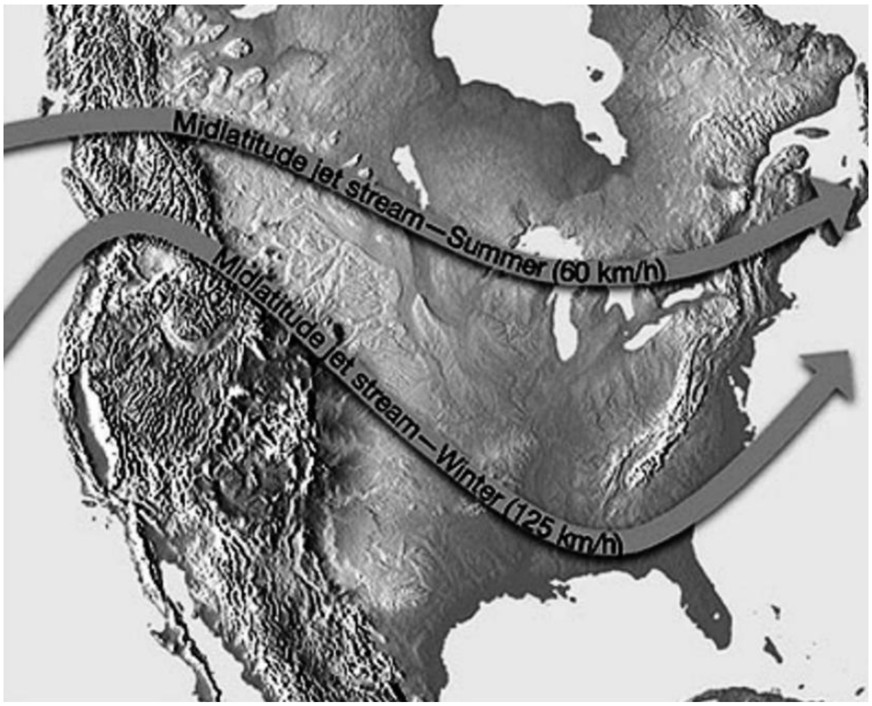


Figure 42 - Seasonal Mid-Latitude Jet Stream

Knowing the location of a jet stream is important when planning long range flights at high altitudes. For example, on an eastbound flight, a pilot would want to take advantage of the excellent tail winds a jet stream would provide. On a westbound flight, they would want to avoid the winds.

Clear Air Turbulence (CAT)

CAT is a bumpy, turbulent condition that occurs in a cloudless sky. It occurs at high altitudes, usually above 15 000 feet and is more severe near 30 000 feet. The most probable place to expect CAT is just above the central core of a jet stream.

CAT is almost impossible to forecast and can be severe enough to be a hazard to modern high-performance airplanes. Therefore, knowledge of areas in which CAT is most likely to occur is important for pilots to help minimize encounters with it.

End of EO

EO M436.02 – DESCRIBE AIR MASSES AND FRONTS

WEATHER IN AN AIR MASS

There are three main factors that determine the weather in an air mass:

- Moisture content;
- The cooling process; and
- The stability of the air.

Moisture Content

Continental air masses are very dry and little cloud develops. The high moisture content in maritime air may cause cloud, precipitation, and fog.

The Cooling Process

Even if the air is moist, condensation and cloud formation only occur if the temperature is lowered to the dewpoint. The cooling processes that contribute to condensation and the formation of clouds are:

- Contact with a surface cooling by radiation;
- Advection over a colder surface; and
- Expansion brought about by lifting.

Cloud formation within an air mass is not uniform. For example, clouds ma form in an area where the air is undergoing orographic lift, even though the rest of the air mass is clear.

The Stability of the Air

In stable air, stratus cloud and poor visibility are common, whereas in unstable air, cumulus cloud and good visibility are common.

Characteristics of Cold Air Masses and Warm Air Masses

Cold air masses (eg arctic and polar air masses) will typically have the following characteristics:

- Instability;
- Turbulence;
- Good visibility;
- Cumuliform clouds, and
- Precipitation in the form of showers, hail, and thunderstorms.

Warm air masses (eg tropical air masses) will typically have the following characteristics:

- Stability;
- Smooth air;

- Poor visibility;
- Stratiform clouds and fog; and
- Precipitation in the form of drizzle

FRONTS

A front is the transition zone between two air masses. The interaction of air masses along their frontal zones is responsible for weather changes.

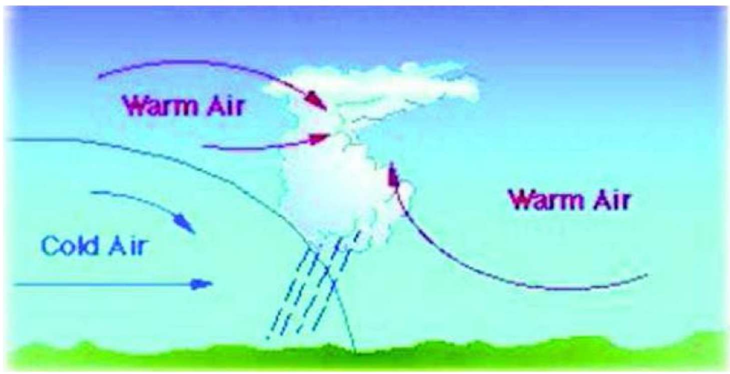


Figure 43 - Cold Front

In a cold front, the advancing cold air mass is denser and will slide underneath the warmer air.

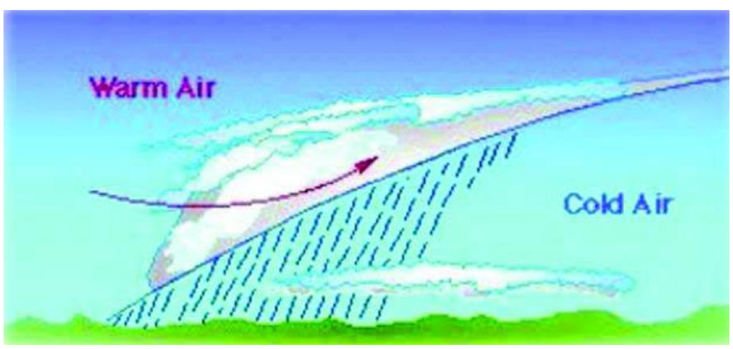


Figure 44 - Warm Front

In a warm, front the cold air mass is denser and therefore sinks, undercutting the advancing warm air which will ascend over the cold air

An air mass is a large section of the troposphere with uniform properties of temperature and moisture in the horizontal. An air mass can be several thousand kilometres across and takes on the properties from the surface over which it formed.

Formation over ice and snow of the arctic will be dry and cold. Formation over the South Pacific will be warm and moist. Formation over a large body of water is moist and is referred to as maritime air. An air mass over a large land area is dry and is referred to as continental air.

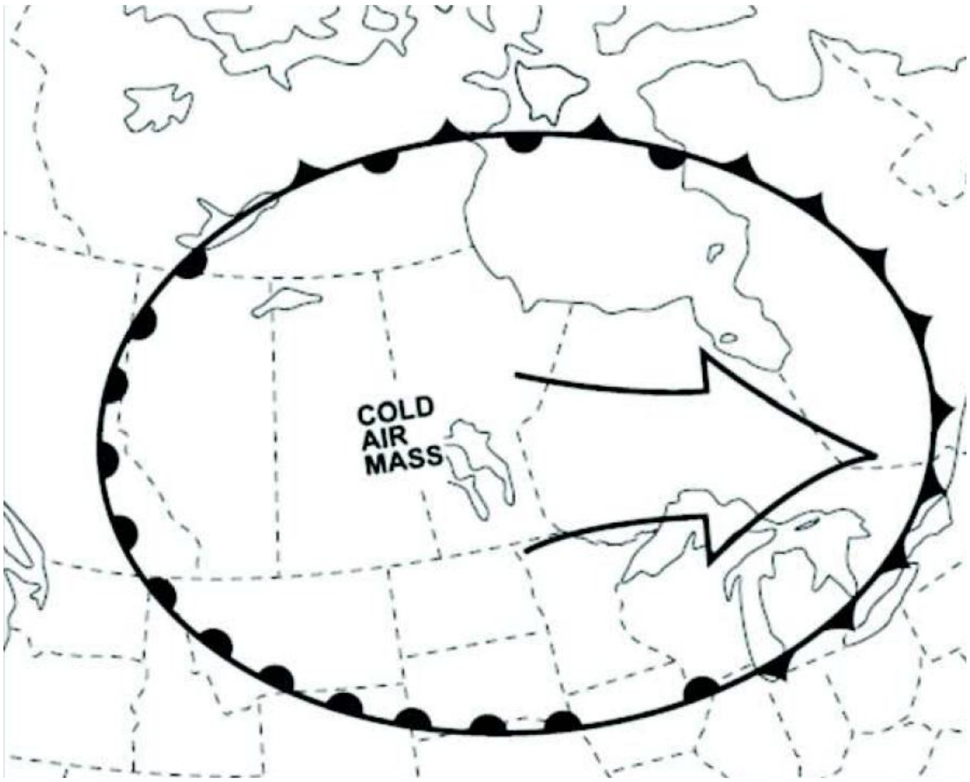


Figure 45 - Air Masses and Fronts

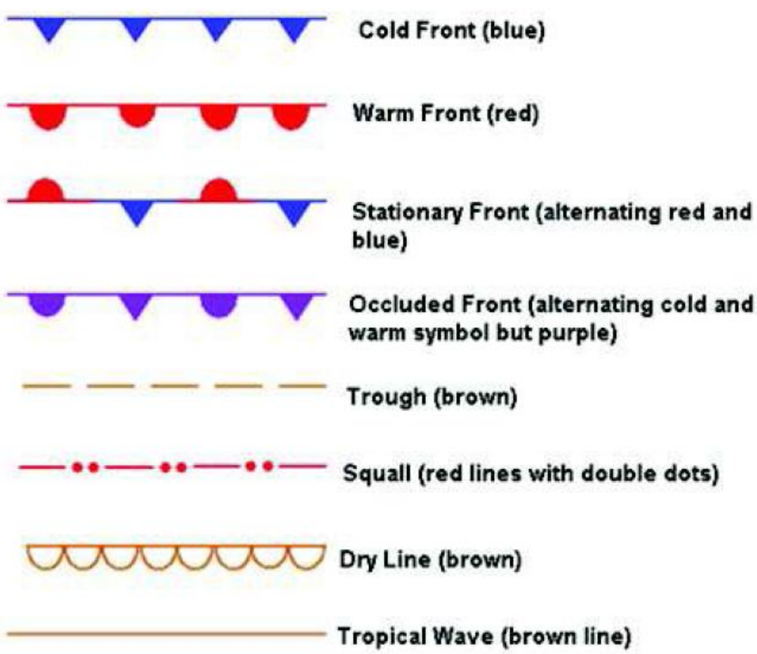


Figure 46 - Front Symbols

COLD FRONT

A cold front is the part of a frontal system along which cold air is advancing.

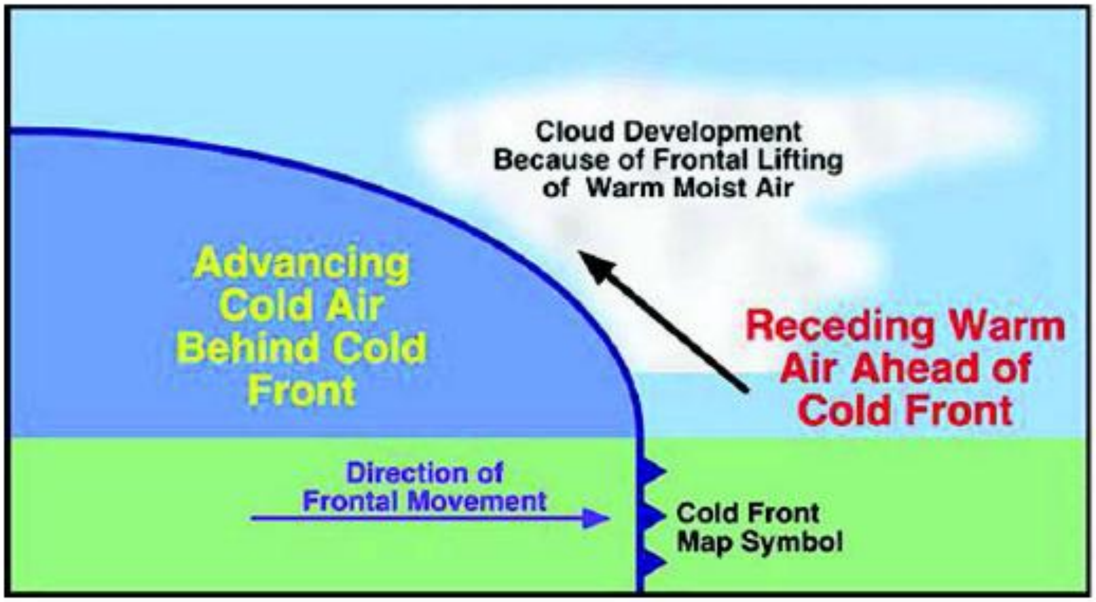


Figure E-1 Cold Front

Note. From Remote Sensing Tutorial by N. Short, 2005, *Federation of American Scientists.* Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

When a mass of cold air overtakes a mass of warm air, the cold air, being denser, stays on the surface and undercuts the warm air violently. The slope of the advancing cold front is quite steep as surface friction slows the air at the surface, allowing the upper air to catch up. The rapid ascent of warm air gives rise to a relatively narrow band (only about 50 nautical miles) of cumuliform cloud that frequently builds up into violent thunderstorms.

The severity of the weather depends on the moisture content and stability of the warm air mass that the cold air mass is undercutting and the speed of the advancing cold front. If the warm air is very moist and unstable, towering cumulus clouds and thunderstorms are likely to develop, bringing heavy showers in the form of rain, snow, or hail. A slower moving cold front advancing on more stable and drier air will produce stratus or altocumulus clouds with light or no precipitation.

A squall line, a continuous line of thunderstorms, sometimes develops ahead of a fast moving cold front. The weather brought about by a squall line is extremely violent, including rapid shifts in wind, heavy rain or hail, and thunder and lightning. Pilots should avoid squall lines at all costs.

A sharp fall in temperature, a rise in pressure, and rapid clearing usually occur with the passage of the cold front.

WARM FRONT

A warm front is the part of a frontal system along which cold air is retreating.

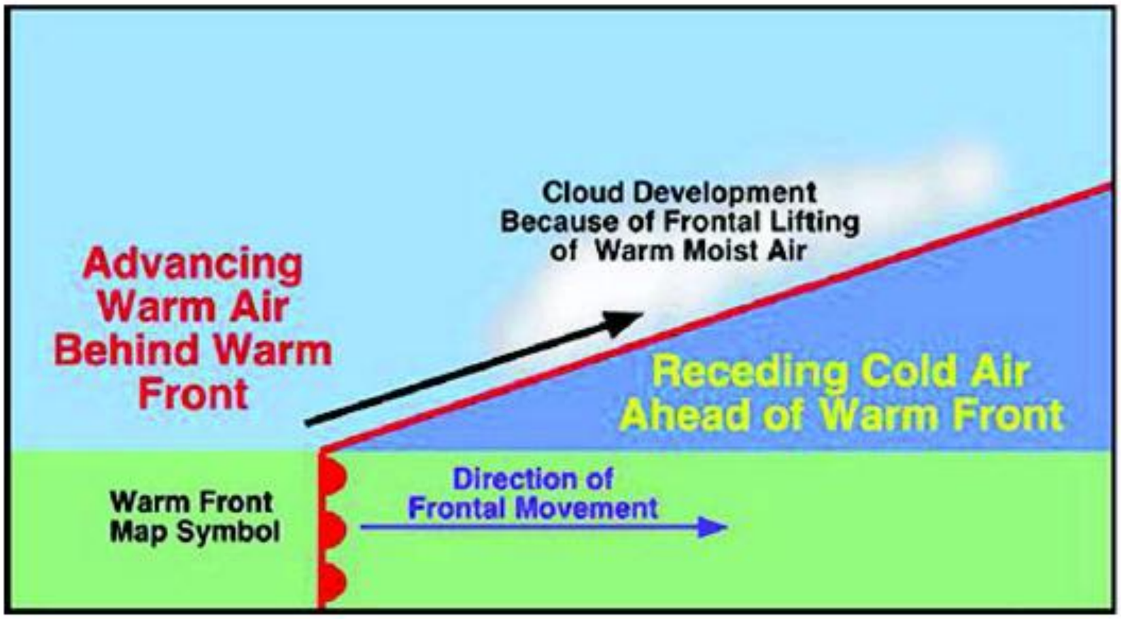


Figure F-1 Warm Front

Note. From Remote Sensing Tutorial by N. Short, 2005, *Federation of American Scientists*. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

As a mass of warm air advances on a retreating mass of cold air, the warm air, being lighter, ascends over the cold air in a long gentle slope. As a result of this long gentle slope and the relatively slow speed of warm fronts, the cloud formation associated with them may extend for 500 or more nautical miles in advance. If the warm air is moist and stable, these clouds develop in a distinctive sequence:

1. cirrus,
2. cirrostratus,
3. altostratus,
4. nimbostratus, and
5. stratus.

The clouds indicating the passing of a warm front can easily be remembered using the mnemonic "C-CANS".

If the warm air is moist and unstable, cumulonimbus and thunderstorms may be embedded in the stratiform layers, bringing heavy showers.

Warm fronts bring low ceilings and restricted visibility for a considerable length of time due to their slow movement.

In winter, when temperatures in the cold air are below freezing and temperatures in the lower levels of the warm air are above freezing, snow and freezing rain can be expected. Snow (SN) falls from the part of the warm air cloud that is high and therefore below freezing. Rain (RA) falls from the lower warm air cloud but becomes supercooled as it falls through the cold air mass. This creates freezing rain (FZRA) and ice pellets (PL). Therefore, icing is a problem associated with warm fronts in winter.

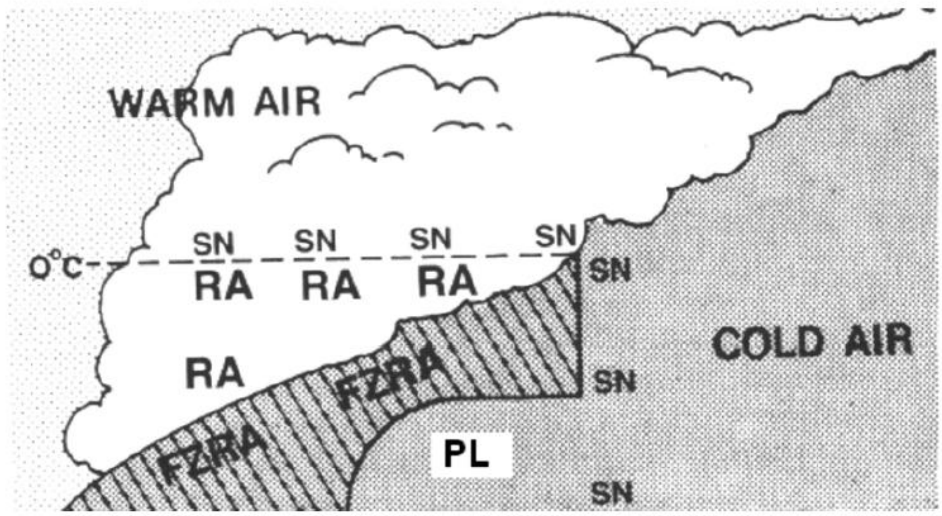


Figure F-2 Precipitation in a Warm Front in Winter

Note. From *From the Ground Up: Millennium Edition* (p. 145), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

The passing of the warm front is marked by a rise of temperature due to the entry of the warm air, and the sky becoming relatively clear.

STATIONARY FRONT

A stationary front is the part of a front along which the colder air is neither advancing nor retreating.

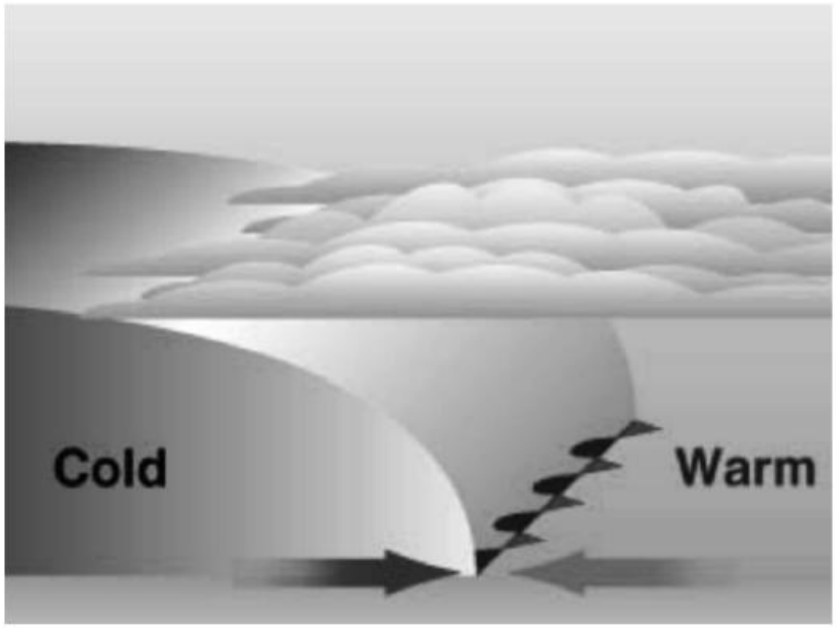


Figure G-1 Stationary Front

Note. From Geography for Kids, *KidsGeo.com*, Copyright 1998–2000. Retrieved October 17, 2008, from http://www.kidsgeo.com/geography-for-kids/0129-stationary-fronts.php

A stationary front occurs when the front does not move because the opposing air masses are of equal pressure. The weather conditions are similar to those associated with a warm front, (low cloud, and continuous rain or drizzle) although generally less intense and not so extensive. Usually a stationary front will weaken and eventually dissipate. Sometimes, however, it will begin to move after several days, becoming either a cold front or a warm front.

OCCLUDED FRONTS

A wave-like disturbance sometimes forms on a stationary front. This can develop into a small low known as a depression. As the depression forms, one section of the front begins to move as a warm front and the other section as a cold front. Over time, under certain atmospheric conditions, the cold front gradually overtakes the warm front and lifts the warm air entirely from the ground forming a single occluded front. Basically, the cold air catches up with itself as it flows around the low pressure area.

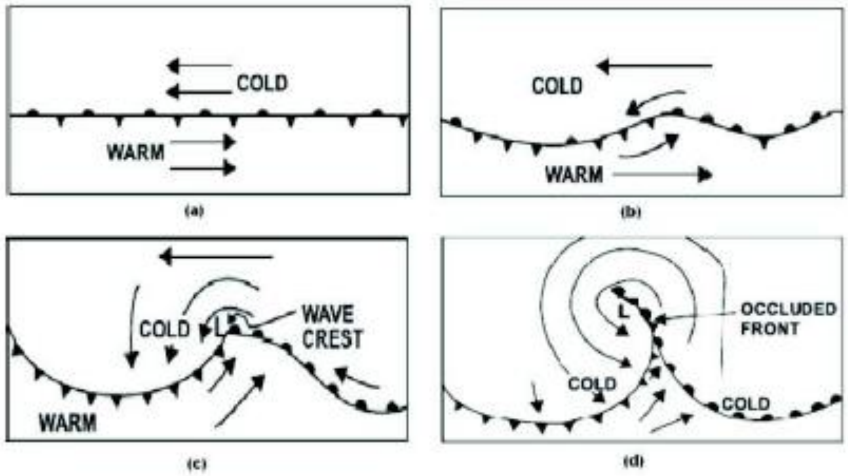


Figure H-1 Occluded Front Formation

Note. From *Air Command Weather Manual* (pp. 7-12 and 7-14), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

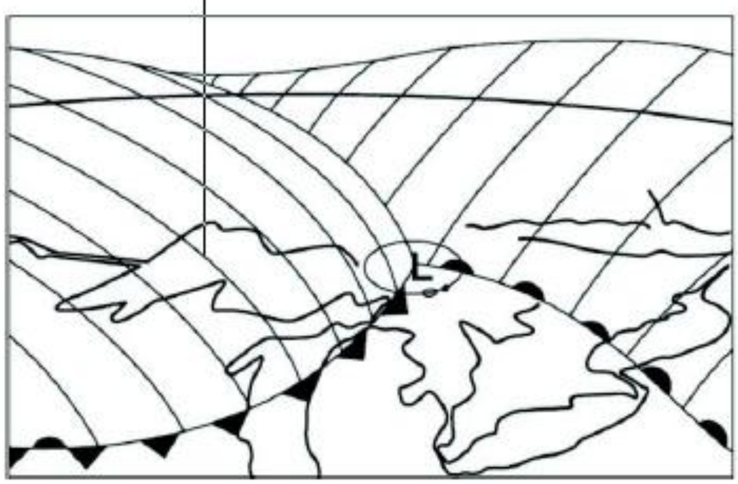


Figure H-2 Frontal Depression

Note. From *Air Command Weather Manual* (pp. 7-13), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

If the cold air is not as cold as the air it is overtaking (cool air advancing on cold air), the front is known as a warm occlusion.

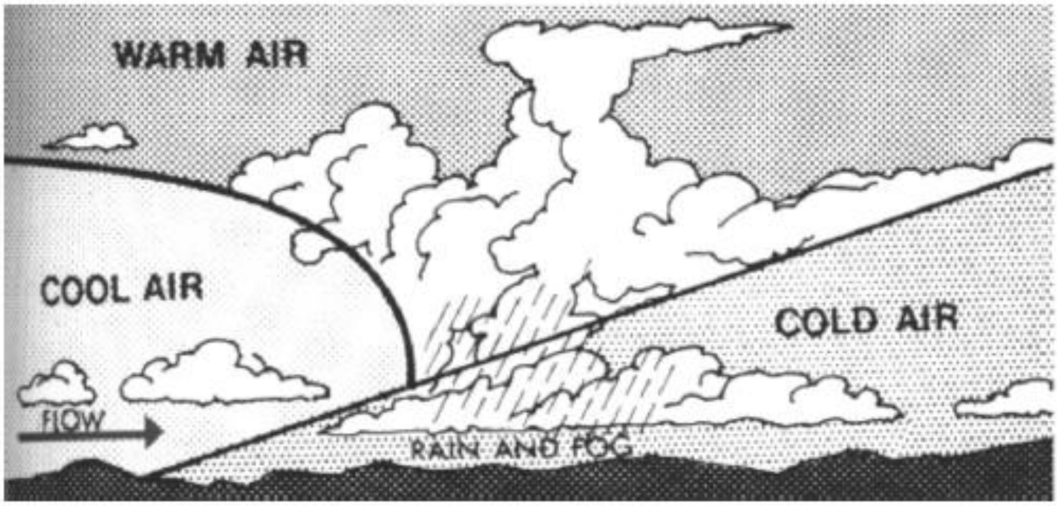


Figure H-3 Warm Occlusion

Note. From *From the Ground Up: Millennium Edition* (p. 143), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

If the cold air is colder than the air it is overtaking (cold air advancing on cool air), the front is known as a cold occlusion.

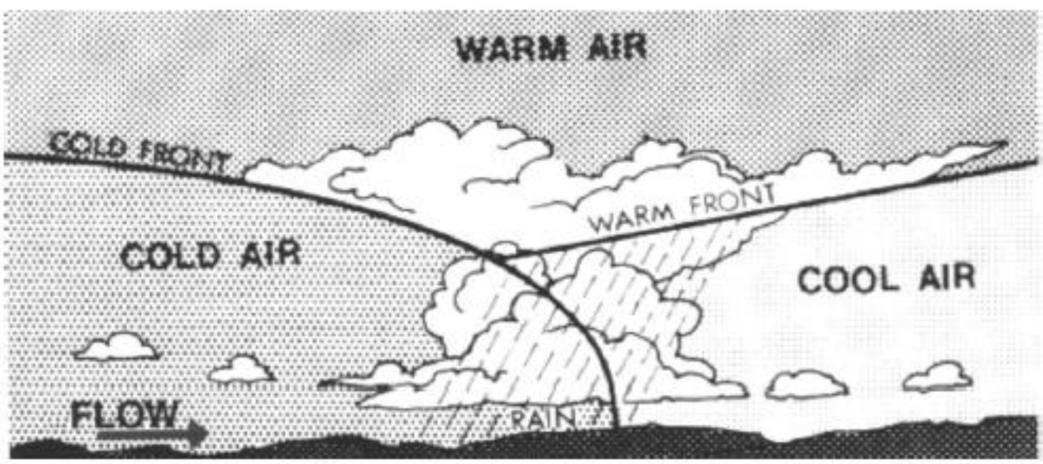


Figure H-4 Cold Occlusion

Note. From *From the Ground Up: Millennium Edition* (p. 143), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

In both warm occlusions and cold occlusions, three air masses are present: a cool air mass, a cold air mass, and a warm air mass lying wedge-shaped over the colder air. The wedge-shaped mass of warm air is known as a trowal.

Both warm occlusions and cold occlusions have much the same characteristic as warm fronts, with low cloud and continuous rain. If the warm air is unstable, cumulonimbus clouds may develop; they are more likely to occur and bring about heavy turbulence, lightning, and icing in a cold occlusion.

UPPER FRONTS

An upper cold front can form in two ways:

- A cold front advancing across the country may encounter a shallow layer of colder air resting on the surface. The cold front will then leave the ground and ride up over the colder, heavier air.

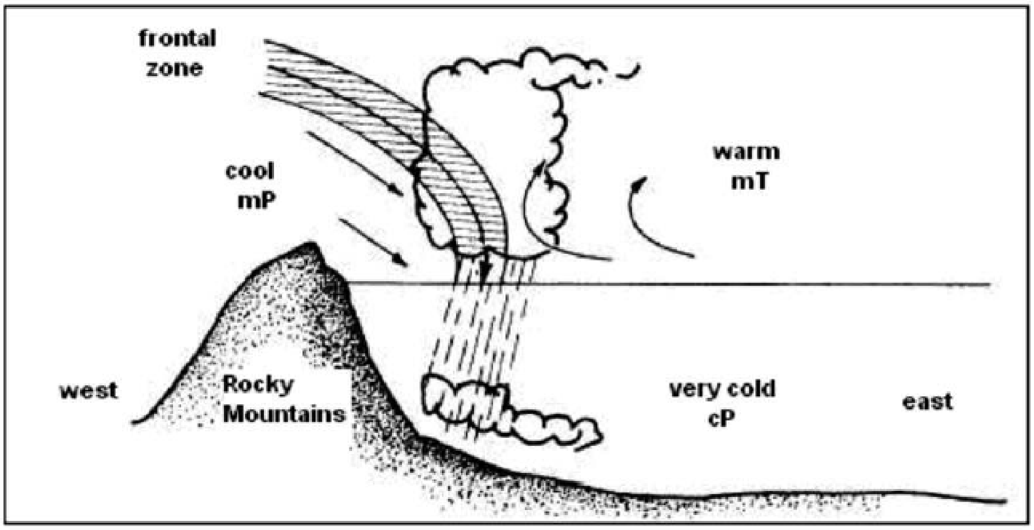


Figure I-1 Upper Cold Front

Note. From Integrated Publishing, *Aerographer / Meteorology*, Copyright 2003 by Integrated Publishing. Retrieved October 20, 2008, from http://www.tpub.com/content/aerographer/14312/css/14312_121.htm

- The structure of the advancing cold front is such that the cold air forms a shallow layer for some distance along the ground in advance of the main body of cold air. This causes the frontal surface of the main mass of cold air to be very steep. The line along which the frontal surface steepens is also known as an upper cold front.

An upper warm front can form in two ways:

- An advancing warm front rides up over a layer of cold air trapped on the ground. A change of air mass is not experienced on the ground because the front passes overhead.
- The surface of the cold air that is retreating ahead of an advancing warm front is almost flat for some distance ahead of the surface front and then steepens abruptly. The line along which the surface of the retreating cold air steepens sharply is also called an upper warm front.

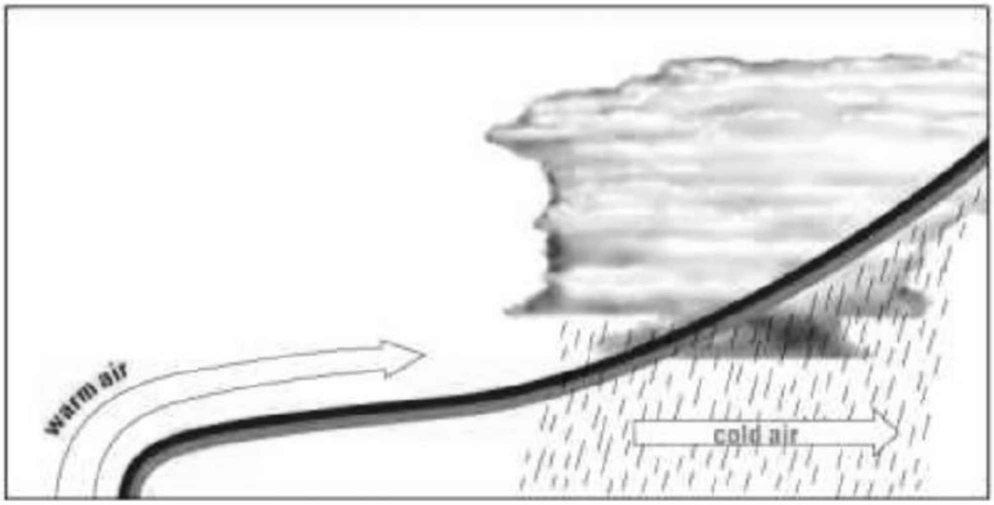


Figure I-2 Upper Warm Front

Note. From Weather and Frontal Systems, 2004, *Meteorological Services of Canada*. Copyright 2004 by Environment Canada. Retrieved October 20, 2008, from http://www.qc.ec.gc.ca/meteo/Documentation/Temps_fronts_e.html

Weather in upper fronts can be particularly hazardous in winter. Similar to warm fronts, rain from the warmer air falls through the layer of cold air on the surface causing freezing rain and icing conditions.

PO437 – EXPLAIN ASPECTS OF AIR NAVIGATION

EO M437.01 – DEFINE AIR NAVIGATION TERMS

MERIDIANS OF LONGITUDE

Meridians of longitude are semicircles joining the true/geographic poles of the Earth.

Longitude is measured from 0 to 180 degrees east and west of the prime meridian. The prime meridian is the meridian which passes though Greenwich, England and is numbered zero degrees. The meridian on the opposite side of the Earth to the prime meridian is the 180th and is called the International Date Line (the time changes a day).

Longitude is measured in degrees (^{o}), minutes (’), and seconds (”). There are 60 minutes in a degree and 60 seconds in a minute.

When dealing with longitude and latitude, seconds and minutes are not measurements of time, but rather divisions of a degree. This can be compared to the way that a metre is divided into 100 cm, and each centimetre is divided into 10 mm.

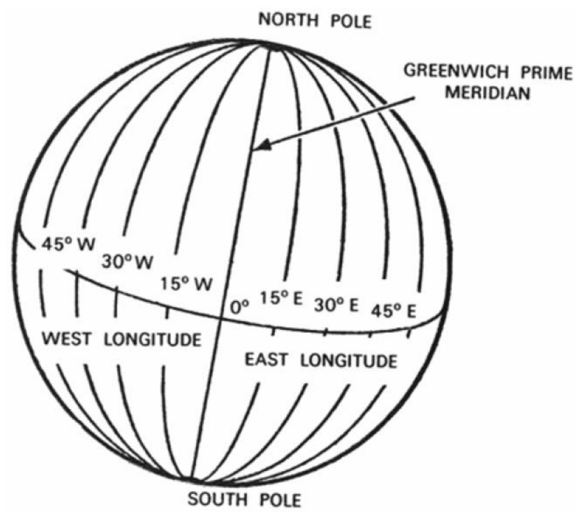


Figure 47 - Meridians of Longitude

PARALLELS OF LATITUDE

Parallels of latitude are circles on the Earth’s surface that lie parallel to the equator.

The **Equator** is an imaginary line on the surface of the Earth equidistant from the poles.

Latitude is measured from 0 to 90 degrees north and south of the equator, which is numbered zero degrees. Like longitude, latitude is measured in degrees, minutes, and seconds.

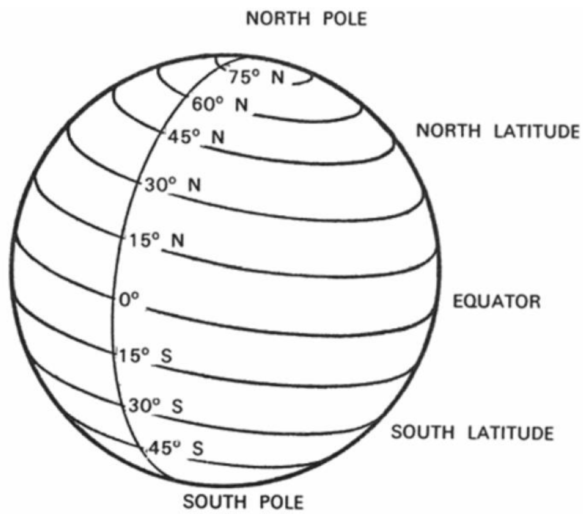


Figure 48 - Parallels of Latitude

GEOGRAPHICAL CO-ORDINATES

Geographical co-ordinates are the intersection of lines of latitude and longitude. Geographical co-ordinates mark the position of places (cities, towns, airports, etc) on a chart.

On a chart, there are black lines representing longitude and latitude, every 30 minutes. Small marks represent 1 minute. There are slightly larger marks for 5 minute and 10 minute increments.

Co-ordinates express latitude first, in degrees north or south of the equator and longitude second, in degrees east or west of the prime meridian. For example, the geographical coordinates of the military airport at Trenton, ON are 44°07'N, 77°32'W. Try it using Figure 49 - VNC Chart Showing Trenton ON.

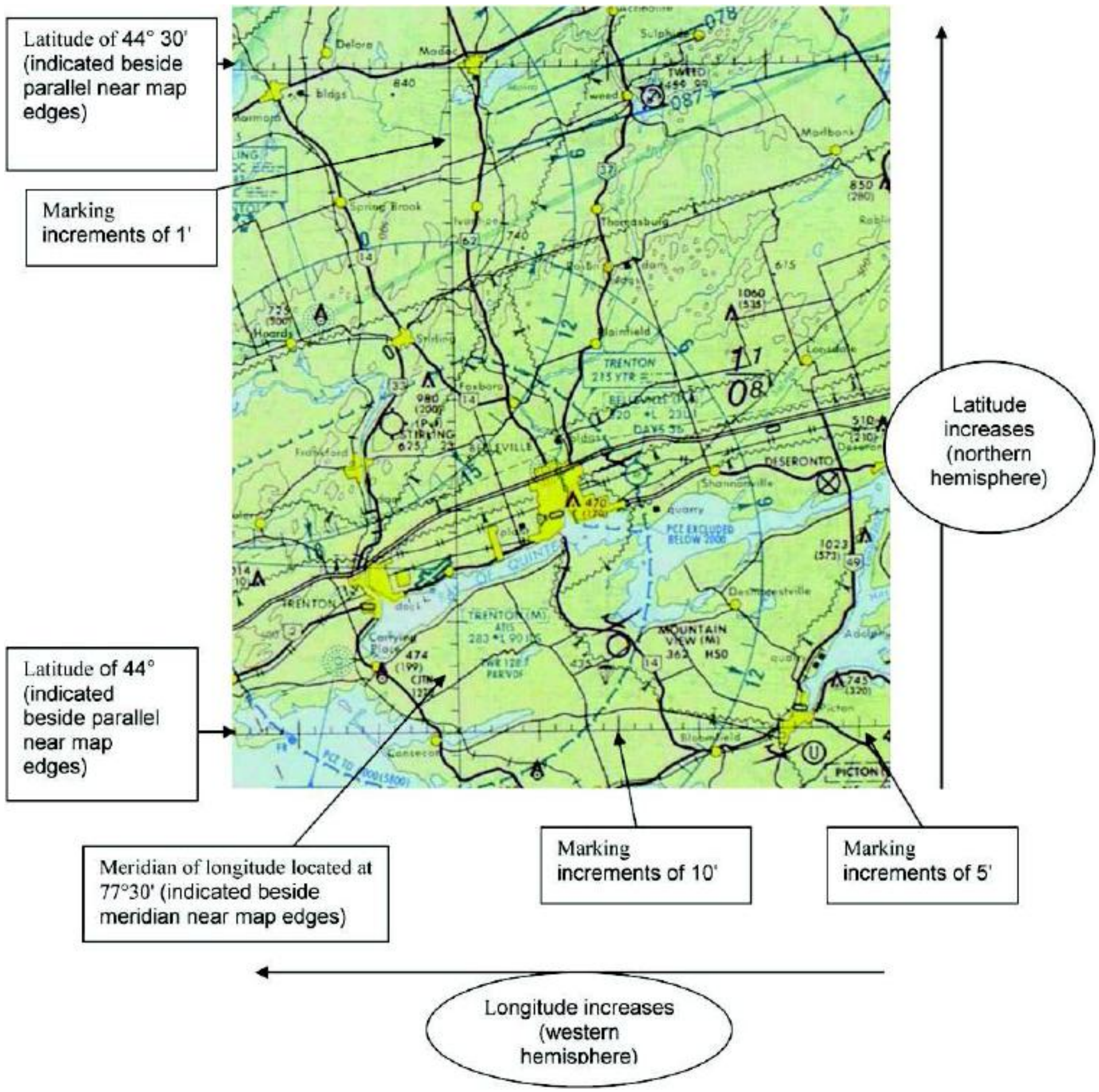


Figure 49 - VNC Chart Showing Trenton ON

THE RELATIONSHIP BETWEEN TIME AND LONGITUDE

The Earth rotates about its axis as it revolves in an elliptical orbit around the Sun. This creates the illusion that the Sun is revolving around the Earth. The time between one apparent passage of the Sun over a meridian of longitude is called an apparent solar day and varies throughout the year. To provide a convenient method of measuring time, it has been averaged to a mean solar day, divided into 24 hours. During the mean solar day, the Sun is assumed to travel once around the Earth, thereby travelling through 360 degrees of longitude. Hence, mean time can be expressed in terms of longitude and vice versa.

For example:

- 24 hour = 360 degrees of longitude
- 1 hour = 15 degrees of longitude
- 1 minute = 15 minutes of longitude
- 1 second = 15 seconds of longitude
- 360 degrees of longitude = 24 hours
- 1 degree of longitude = 4 minutes
- 1 minute of longitude = 4 seconds
- 1 second of longitude = 1/15 second

Local Mean Time (LMT) is the mean time on any particular meridian

Co-ordinated Universal Time (UTC) is an atomically measured global standard time, calculated from midnight on the zero meridian. UTC is also referred to as Zulu (Z) time.

UTC is the LMT for the prime meridian.

The LMT of any place east of the prime meridian is ahead of UTC. For example, 1200 hours LMT in Cairo, Egypt is 1000Z.

The LMT of any place west of the prime meridian is behind UTC. For example 1200 hours LMT in Halifax, Nova Scotia is 1600Z.

The world is divided into 24 time zones, each 15 degrees of longitude (one hour) wide. When travelling westward into a new time zone, time is turned back one hour. When travelling eastward into a new time zone, time is turned ahead one hour. One exception to this is Newfoundland Standard Time, which is ½ hour ahead of Atlantic Standard Time.

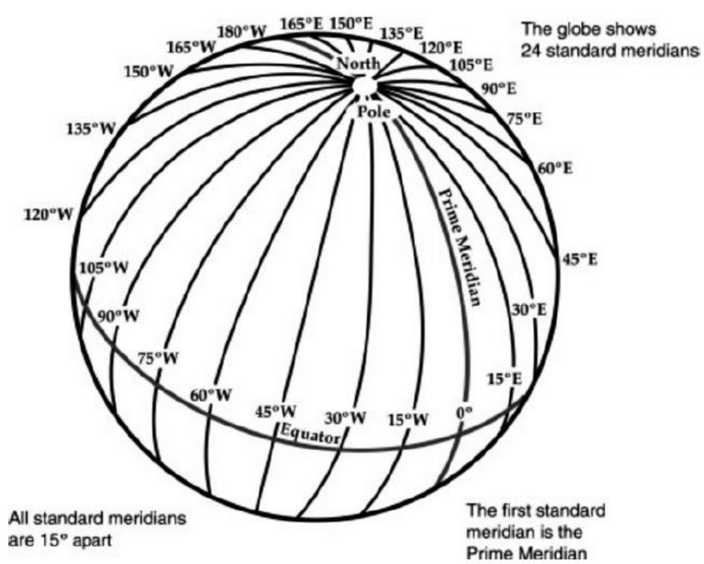


Figure 50 - Meridians of Longitude

Sir Sandford Fleming, as Canadian railway planner and engineer, outlines a plan for worldwide standard time in the late 1870s. Following this initiative, in 1884, delegated from 27 nations met in Washington D.C. for the Meridian Conference and agreed on a system basically the same as that now in use.

GREAT CIRCLES

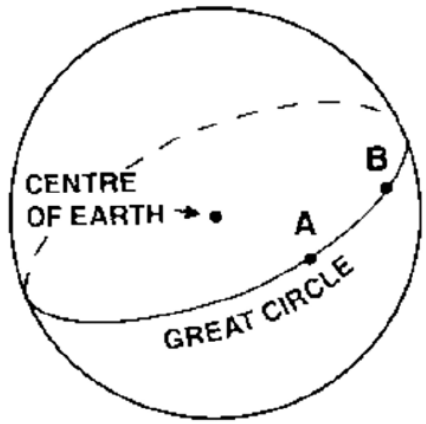


Figure 51 - Great Circle

A **Great circle** is a circle on the surface of a sphere that passes through the centre of the sphere cutting it into two equal parts.

The equator is a great circle. The meridians of longitude are semi great circles as they run from pole to pole and do not completely encircle the Earth.

Only one great circle can be drawn through two places that at not diametrically opposite each other. The shortest distance between these two points is the shorter arc of the great circle joining them. Therefore, most long-distance flights are flown over great circle routes.

A great circle does not cross the meridians it meets at the same angle. Therefore, the heading must be changed at frequent intervals to enable the airplane to maintain a great circle route.

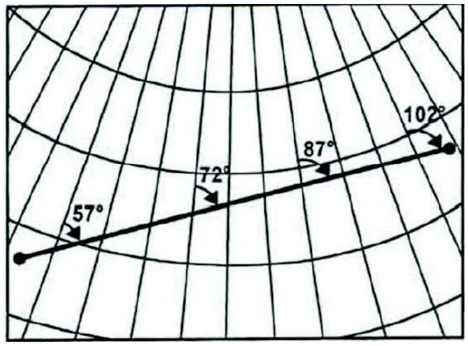


Figure 52 - Great Circle

RHUMB LINES

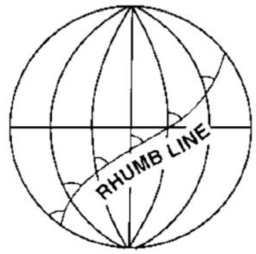


Figure 53 - Rhumb Line

A **Rhumb line** is a curved line on the surface of the Earth, cutting all the meridians it meets at the same angle.

All parallels of latitude are rhum lines. The meridians of longitude and the equator are rhumb lines as well as great circles.

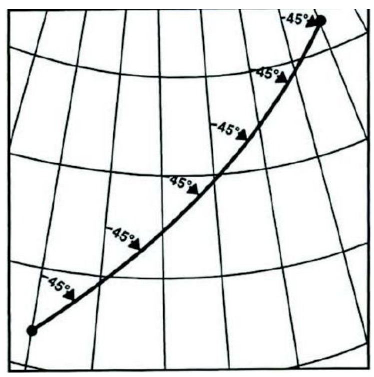


Figure 54 - Rhumb Line

When two places are not situated on the equator or on the same meridian of longitude, the distance measured along the rhumb lines joining them will not be the shortest distance between them. The advantage of the rhumb line route is that the direction is constant, allowing a navigator to follow a constant heading.

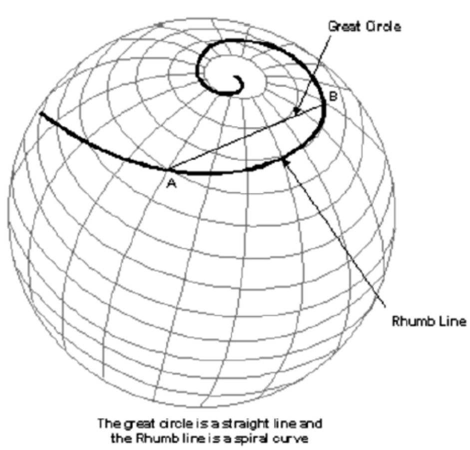


Figure 55 - Great Circle and Rhumb Line

There is a difference in distance following the “convenient” rhumb line rather than the shortest route.

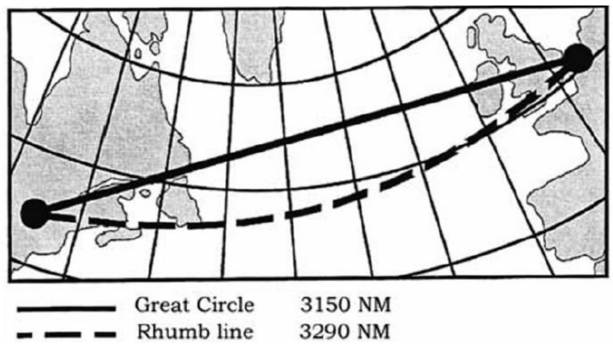


Figure 56 - Great Circle and Rhumb Line Comparison

HEADINGS AND BEARINGS

Direction is measured in degrees clockwise from north, which is zero degrees (or 360 degrees). East is 90 degrees, south is 180 degrees, and west is 270 degrees.

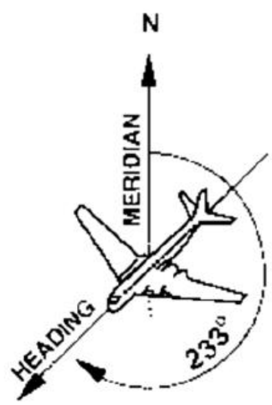


Figure 57 – Heading

The **true heading** is the angle between the meridian of longitude over which an airplane if flying and the line representing the direction the airplane’s nose is pointing, measured clockwise from the meridian.

The direction of any point on the surface of the Earth from an observer is known by measuring the bearing.

The **bearing** is the angle between the meridian of longitude and the great circle that joins the observer to the object, measured clockwise from the meridian.

Headings and bearings are found using a compass

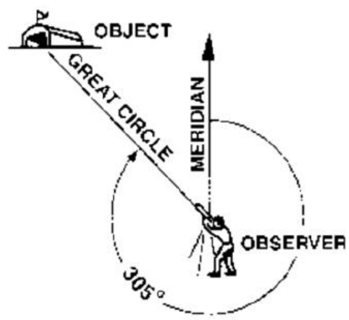
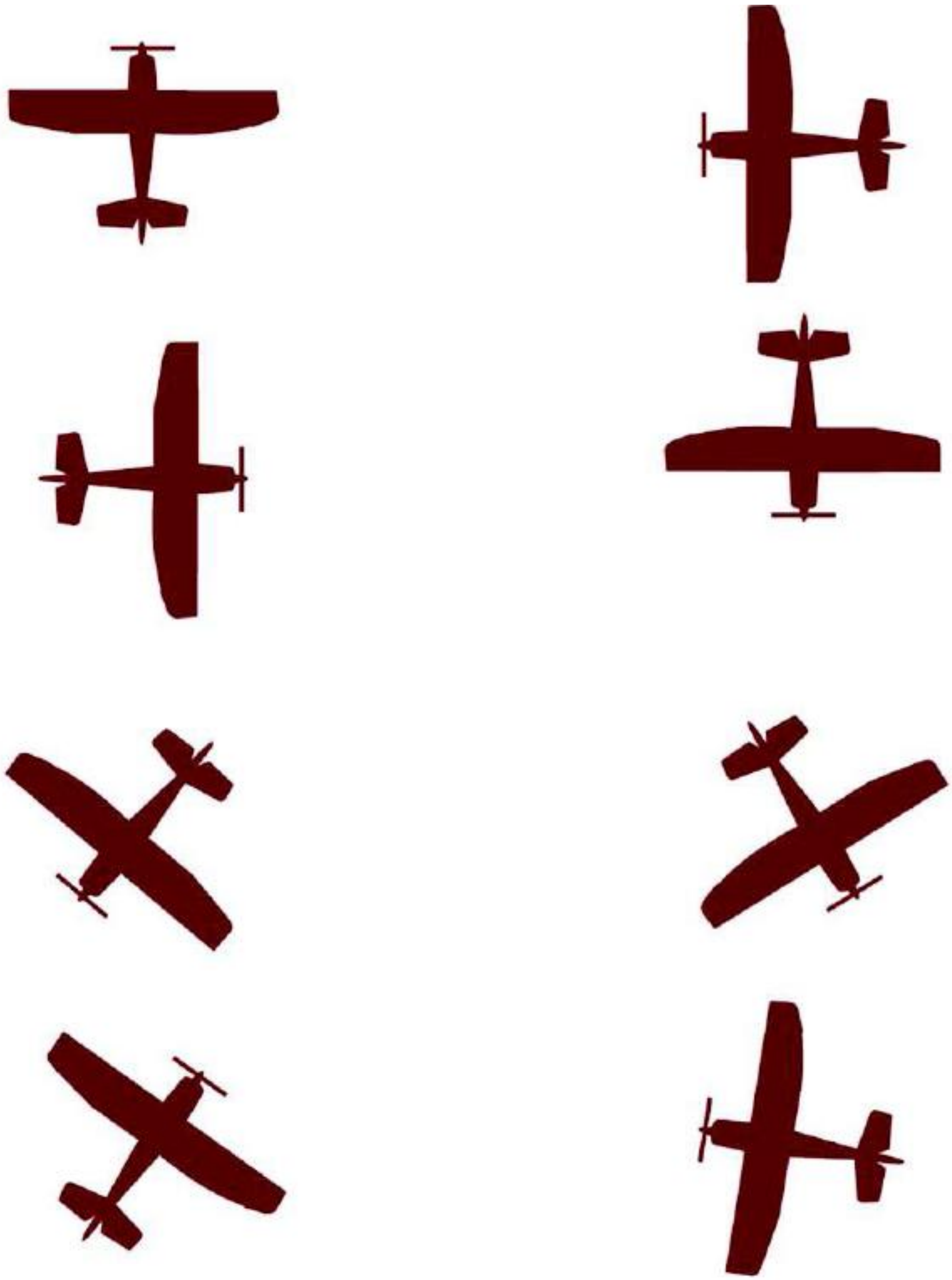
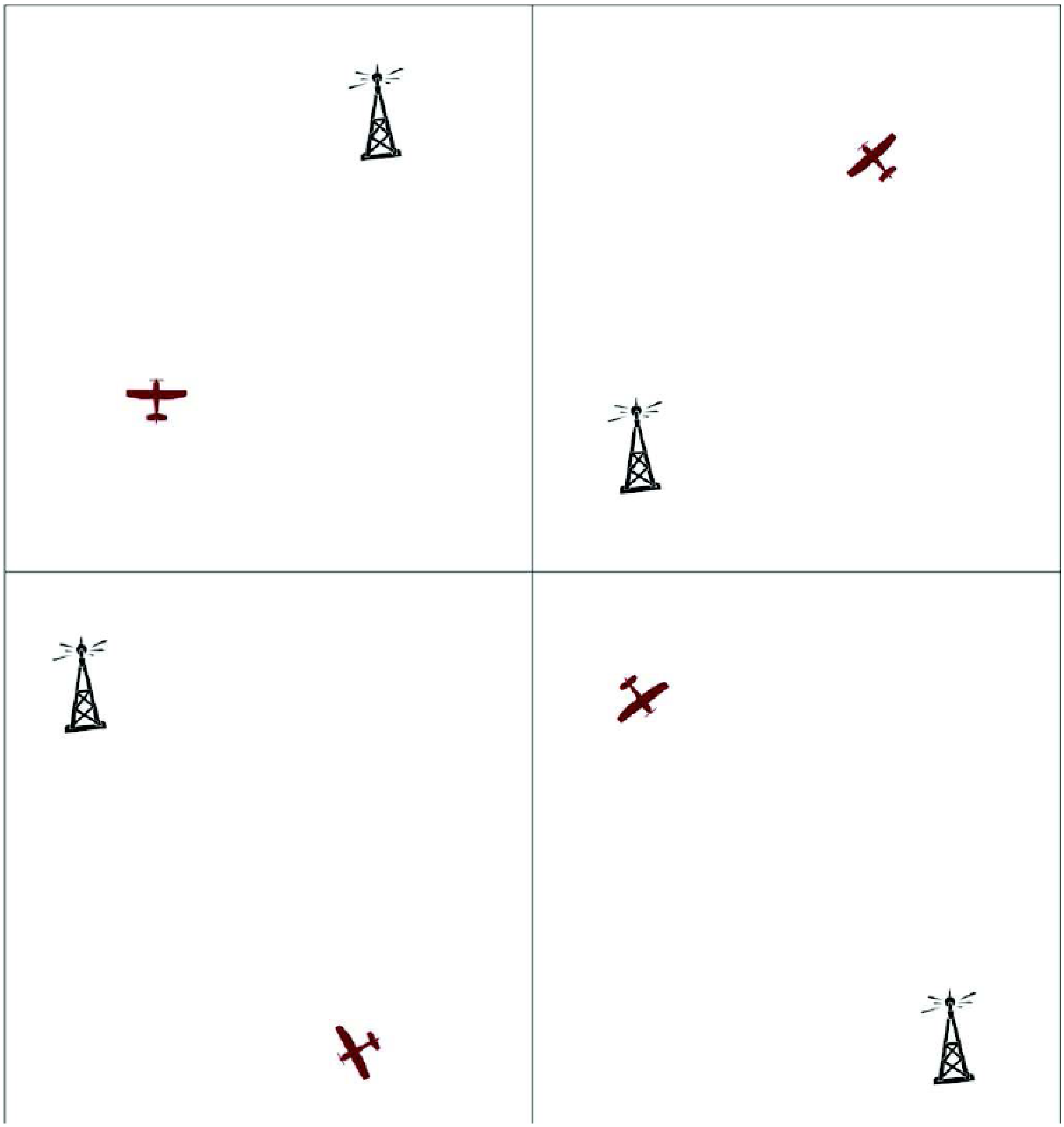


Figure 58 – Bearing

What is the heading of each aircraft? The top of the page is north.



What is the bearing of the tower from the aircraft? The top of the page is north.



End of EO

EO M437.02 – DESCRIBE THE MAGNETIC COMPASS

THE EARTH'S MAGNETISM

The Earth is a giant magnet that has a north and south pole. There are lines of force generated by currents of molten iron that flow within the Earth. The lines of force flow between the poles, creating a magnetic field that surrounds the Earth. The compass needle is affected by the lines of force, causing the magnetic needle to point to magnetic north.

Points of a Compass Rose

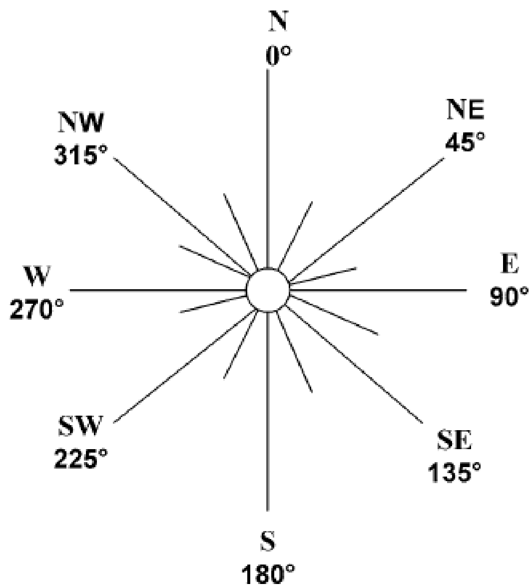


Figure 59 - Points on a Compass Rose

The main cardinal points are north, south, east, and west. The inter-cardinal points are northeast, southeast, southwest, and northwest.

MAIN PARTS OF THE MAGNETIC COMPASS

The **lubber line** is a painted while line that indicates the direction the airplane is heading. It is in line with or parallel to the longitudinal axis of the airplane. It is at this location that the compass card is read.

The **compass card** contains the numbers. It is attached to the pivot and moves within the compass bowl. The compass card is read at the lubber line through a window.

The **compass bowl** encompasses the entire compass assembly, including the liquid. The compass bowl is made of brass, which is a non-magnetic material.

The **pivot** allows the compass card to rotate freely.

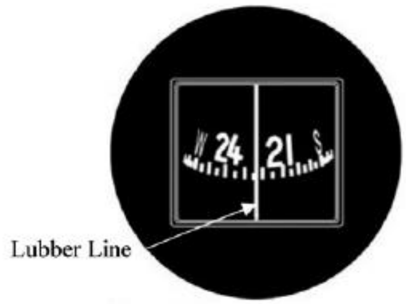


Figure 60 – Lubber Line

The **magnetic needle** is a needle that always points to magnetic north.

The **liquid** is contained in the compass bowl and is used to lubricate the pivot, reduce the weight of the compass card and magnets, and limit the movement that may be caused by turbulence. The liquid is either alcohol or white kerosene because they are transparent and have a low freezing point and a high boiling point.

VARIATION

True north and magnetic north do not have the same location. The two poles can be located far apart because magnetic north is continuously moving at a very slow rate. This is a significant concern for navigation because geographical coordinated are based on true to geographic north whereas a magnetic compass points to magnetic north.

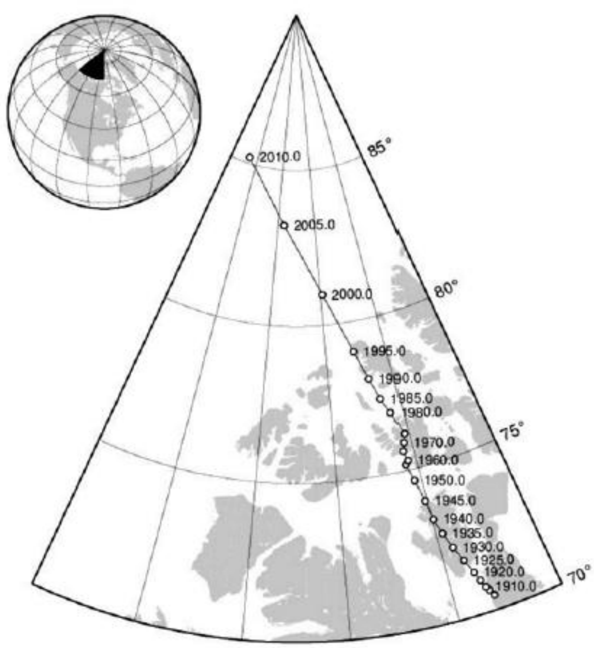


Figure 61 - Location of the Magnetic North Pole

Variation is the angle between true north and magnetic north. It is also known as magnetic declination. This angle is taken into consideration during flight planning.

Agonic lines join places of zero magnetic variation. This is to say that both true north and magnetic north lie in a straight line relative to these places.

Isogonic lines join places of equal magnetic variation. If an observer were to move along this invisible line, the angle between true and magnetic north would remain the same.

Aeronautical navigation charts use true north and display variation information. Pilots must convert the true headings to magnetic headings in order to navigate using the charts and magnetic compass.

The following rhymes can help pilots remember how to apply variation to true headings:

- "Variation West, Magnetic Best"; and
- "Variation East, Magnetic Least".

In other words, ADD westerly variation to a true heading to calculate the magnetic heading. SUBTRACT easterly variation from a true heading to calculate the magnetic heading.

COMPASS ERRORS

Deviation

The magnetic compass is affected by anything metal that is in close proximity to it. When mounted in an aircraft, it is affected by the surrounding metal in the aircraft's frame and engine, as well as electrical equipment. The compass does not point to magnetic north, but is deflected slightly by the magnetic fields associated with the surrounding metal. The direction that the magnetic needle will point when affected by the running engine and working electrical equipment is unique to the aircraft. It is referred to as compass north. The angle between magnetic north and compass north is deviation.

Since deviation cannot be eliminated, the amount of deviation on a given heading is determined so that a pilot can compensate for this compass error. This occurs by swinging the compass. The aircraft is lined up on a known magnetic heading with its engine running and all electrical equipment working. The direction is read from the compass and compared to the known magnetic heading. After this is taken on many headings, a compass correction card (For Steer Card) is prepared and placed in the aircraft near the compass.

For	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
Steer	359°	30°	60°	88°	120°	152°	183°	212°	240°	268°	300°	329°

Figure 62 - Compass Correction Card

Deviation must be added to or subtracted from the magnetic heading to calculate the compass heading.

When the magnetic heading is between the headings listed on the compass correction card, interpolate (estimate) the amount of deviation by using the two nearest magnetic headings that are listed.

Magnetic Dip

The magnetic lines of force of the Earth's magnetic field are horizontal at the equator, but bend down into the poles. This causes the north-seeking end of the needle to dip towards the ground. This error is more pronounced the close the compass is to the poles.

Magnetic dip can be reduced, but not eliminated, by the design of the compass.

Northerly Turning Error

During a turn, centripetal and centrifugal forces combine with the inertial influence of the liquid in the compass bowl to affect the movement of the compass needle. This error is most apparent on north and south headings. The amount of the error is greatest over the poles and least over the equator.

On turns from north, northerly turning error causes the compass to lag. On turns from south, northerly turning error causes the compass to lead.

Acceleration and Deceleration Errors

Acceleration or deceleration of the aircraft affects the magnetic compass and the inertia causes a turning moment when the aircraft is on an east or west heading. Once the airspeed as stabilized, the compass will again read correctly.

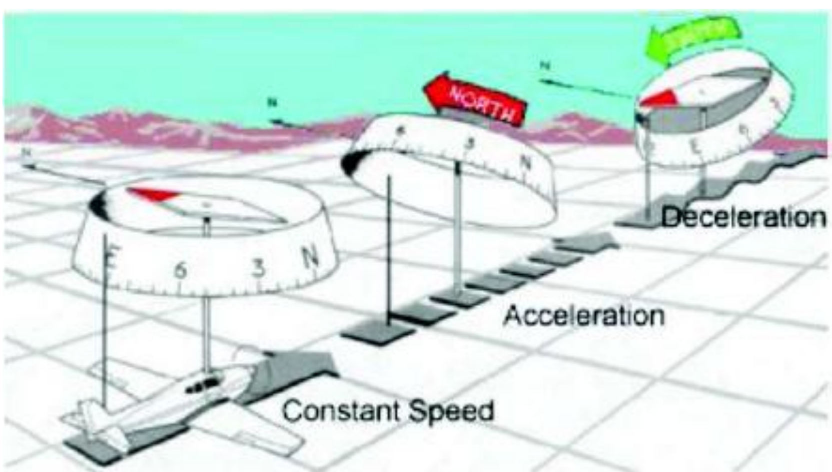


Figure 63 - Acceleration and Deceleration Errors

On east and west headings:

- Acceleration causes the compass to register a turn toward the north; and
- Deceleration causes the compass to register a turn toward the south

Fill in the missing values.

	Variation	True Heading	Magnetic Heading
1.	8° west	120°	
2.	2° east	270°	
3.	11° east	010°	
4.	15° west	350°	
5.	22° east	180°	
6.		090°	101°
7.		085°	080°
8.		359°	005°
9.		254°	266°
10.		122°	118°
11.	9° east		113°
12.	3° west		357°
13.	15° west		345°
14.	12° east		124°
15.	2° west		180°

For	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
Steer	359°	30°	60°	88°	120°	152°	183°	212°	240°	268°	300°	329°

Fill in the missing values.

	Magnetic Heading	Compass Heading
1.	020°	
2.	161°	
3.	345°	
4.		080°
5.		215°

End of EO

End of PO