

# 690 Lakeshore Squadron

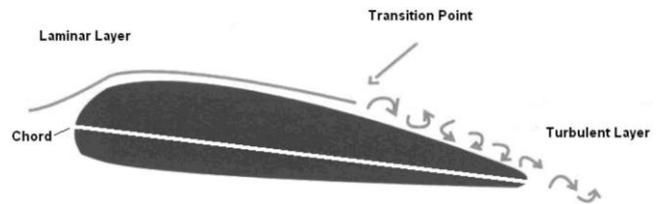
## Study Guide – Level 4 Aviation Subjects.

### M431 – Principles of Flight

#### AIRFOILS

**Chord.** An imaginary straight line joining the leading and trailing edges of the wing. 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 thick airfoils, while aircraft designed to fly fast have thin airfoils.

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.



- Low camber
- Low drag
- High speed
- Thin wing section
- Race planes
- Fighters
- Interceptors

#### 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.



- Deep camber
- High lift
- Low speed
- Thick wing section
- Transports
- Freighters
- Bombers



- Deep camber
- High lift
- Low speed
- Thin wing section
- Transports
- Freighters
- Bombers



- Low lift
- High drag
- Reflex trailing edge wing section
- Very little movement of centre of pressure
- Good stability



- Symmetrical wing section (cambered top and bottom)
- Very little movement of centre of pressure
- Good stability



- GA(W)-1 airfoil
- Thicker for better structure and lower weight
- Good stall characteristics
- Camber is maintained farther rearward which increases lifting capability over more of the airfoil and decreases drag

#### Planform

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

rectangular, elliptical (rounded), and delta (swept).

**Aspect ratio.** 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.

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

flight visibility, takeoff and landing characteristics, and amount of drag in level flight.

#### 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.

The twist in the wing causes the tip and root to stall at 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, can still be effective during the early part of the stall. Decreasing the angle of incidence at the wing tip is called wash-out and increasing the angle is called wash-in.

## **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,  
using wing tip plates or winglets, and  
drooping the wing tips.

### **Wing Fences**

Wing fences are vertical surfaces attached to the upper surface of the wing. 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.

### **Slats**

Auxiliary airfoils that automatically move out in front of the leading edge at high angles of attack are known as slats. 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 that they are passageways built into the wing. Slots can either be full- or partial-span. Slots 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 increased 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. 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).

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 degrees) and are usually recommended for takeoff. In some aircraft, landing with full flaps and a crosswind is not recommended as the flaps may disrupt the airflow over the tail surfaces and make it difficult to control the aircraft during the ground roll.

## **SPOILERS**

Spoilers are devices on a wing that are used to decrease the 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. Most gliders have speed brakes that extend out of the bottom of the wing.

## **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.**

The increase in air pressure caused by the forward motion of the aircraft through the air.

### **Static pressure.**

The atmospheric pressure outside the aircraft, not affected by turbulence or motion.

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 buildup in the pitot tube.

## **AIRSPPEED 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 Markings**

The ASI has colour-coded markings to indicate operating ranges and speeds.

**Red.** A red line indicates the never exceed speed ( $V_{NE}$ ).

**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.

**Green.** The normal operating range. It starts at the power-off stalling speed ( $V_{SL}$ ) and extends to the  $V_{NO}$ .

**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 flaps extended speed ( $V_{FE}$ ).

### **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 degrees Celsius. 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 heat (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 source 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 the compressibility factor. This is very significant to aircraft operating above 10 000 feet and 250 knots (kt).

**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.

### **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.

"From high to low—look out below". 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 a conflict with other aircraft, or even worse, cause the aircraft to come into contact with the ground.

**Abnormally high pressure.** Cold, dry air masses are capable of producing barometric pressures in excess of 31.00 inches of Hg (the limit of the altimeter setting scale in most altimeters). In this case, the actual altitude will be higher than the altitude indicated on the altimeter.

**Abnormally cold temperature.** Altimeters are calibrated for the standard atmosphere (15 degrees Celsius 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.** Increased 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.

### **Altitude 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).

## **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.

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.

### **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 gimbal 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.** A vacuum pump powered by the engine. It does not work if the engine is not running (eg, prior to startup, 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 the airspeed of the aircraft and the tube causes additional drag.

**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)**

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 provides accurate readings even in rough air.

Vacuum driven HIs may take up to five minutes for the rotor to reach operating speed and should not be used during this period. Venturi driven HIs can not 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)**

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). 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 SLIP INDICATOR**

The turn and slip indicator (turn and bank) is a combination of two instruments and is also known as the needle and ball. The direction and rate 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 indicates 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 slip indicator will also indicate if a wing is low during straight flight. If the needle is centered but the ball is not, then the wing on the side that the ball has moved to is low.

## **TURN CO-ORDINATOR**

The turn co-ordinator 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.

## **ANGLE OF ATTACK (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**

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 one means that the aircraft is travelling at the speed of sound. The Mach indicator measures and correlates static and dynamic pressures.

## **M432 – Aero engines**

### **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**

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 pumps 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**

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 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.

A fuel selector valve can be operated manually or electrically depending on the installation.

### **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 heptane.

**Octane.** A substance which possesses minimum detonating qualities.

**Heptane.** A substance which possesses maximum detonating qualities.

Proportion of octane to heptane is expressed as a percentage. For example 73 octane means 73 percent octane and 27 percent heptane.

Higher octane fuels are treated with sulphuric acid, lye, etc, used 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 for octane numbers above 100. Fuel grades are expressed by two performance numbers the first number indicates octane rating at lean mixture conditions, and the second number indicates octane rating at rich mixture condition.

Grade 100 / 130 indicates:

lean mixture performance number of 100, and  
rich mixture performance number of 130.

### **CARBURETORS**

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 mix 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.

#### **Float Carburetor**

Fuel flows through 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 through 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 venturi (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.

Forward movement of the throttle opens the throttle valve, which increases the fuel / air mixture, and increases the power being produced by the engine.

Aft movement of the throttle closes the throttle valve, which reduces the volume of fuel / air mixture, and decreases the power being produced by the engine.

#### **Mixture Control**

The correct fuel / air mixture 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 will become less although the volume remains the same. 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 mix.

The general rules when using a manual mixture control are:

rich mixtures—high power settings, and

leaner mixtures—cruise power settings.

#### **Carburetor Icing**

Distribute the handout located at Attachment B to each cadet.

With temperatures ranging from minus 5 degrees Celsius to plus 30 degrees Celsius and under certain moist atmospheric conditions, ice can 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 hot air handle in the cockpit. This heated air can prevent ice from forming or melt ice that has already 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 saving through uniform distribution, increased power since the heat carburetor air is eliminated, and elimination of the hazard of carburetor icing. Throttle ice can occur when the temperature is less than 5 degrees Celsius. Impact ice can gather in bends in the system, impact tubes, and air filter.

## **PROPELLER SYSTEMS**

The propeller provides the necessary thrust to pull, or in some cases push, the airplane through 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 backward 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 in 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.

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.

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

Tractors are propellers attached forward of the engine that pull from the front of the aircraft.

Pushers are propellers attached aft of the engine that push from behind the aircraft.

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

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

The angle of 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.

## **FIXED PITCH PROPELLERS**

**Fixed pitch propeller.** The blade angle can not 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**

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

**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.

**Constant speed propeller.** The blade angles automatically adjust themselves to maintain a constant rpm as set by the pilot.

The mechanism for adjusting the pitch of the propeller includes:

mechanical,  
hydraulic, and  
electrical.

**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.

**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 a 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 pitch 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 regulates 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.

**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 another 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.

### **FEATHERING AND PROPELLER REVERSING**

Feathering is used on multi-engine aircraft. When one engine is off, the propeller is feathered meaning the turning blades are 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.

### **ENGINE INSTRUMENTS**

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 indicates 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.

#### **the 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.** 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.** The premature ignition of the 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.

The tachometer 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 tachometer, are mechanical including centrifugal, or magnetic and electrical, which include 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 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 indicates 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 of the existing 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 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.

## **M436 – METEOROLOGY**

### **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.

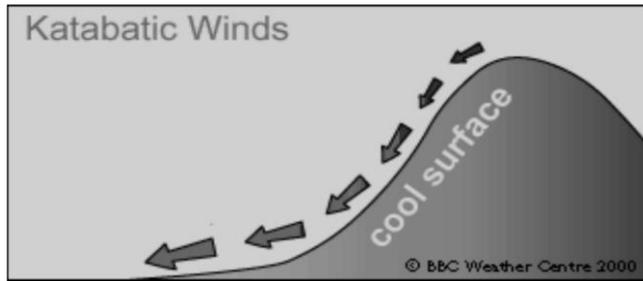
Surface friction plays an important role in the speed and direction of surface winds. The friction between the air and the ground slows the air down causing a lower wind speed than would be expected from the pressure gradient. The friction also changes the direction causing the wind to blow across the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

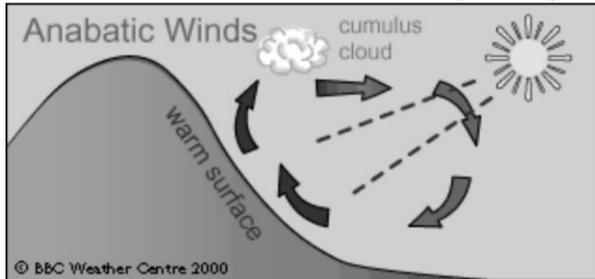
Hills and valleys substantially distort the airflow associated with the prevailing pressure system and the pressure gradient. Katabatic and anabatic winds and mountain waves are examples of wind phenomena in mountainous areas.

#### **Katabatic and Anabatic Winds**

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 valleys below. If the slopes are covered with ice and snow, the katabatic wind can also carry



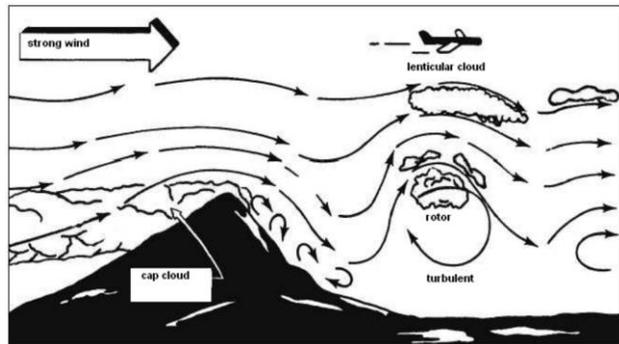
the cold dense air into the warmer valleys during the day.



### Mountain Waves

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.

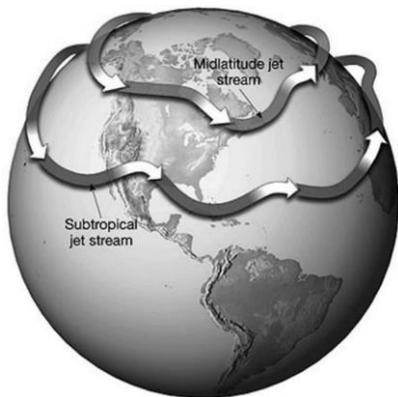
### Gusts

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 (12 mph). 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 like a gust, may be accompanied by a rapid change of wind direction. Squalls may be caused by the passage of a fast moving cold front or thunderstorm.

### JET STREAMS



Jet streams are narrow bands of exceedingly high speed 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 (U.S.), especially in winter, very

cold, often harsh weather prevails at the surface on the northern side. 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.

**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 may 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.

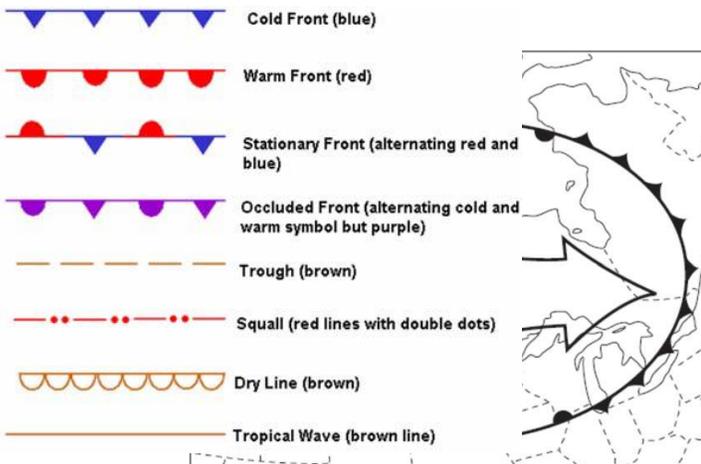
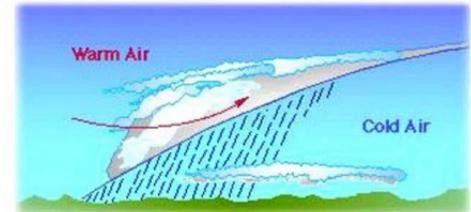
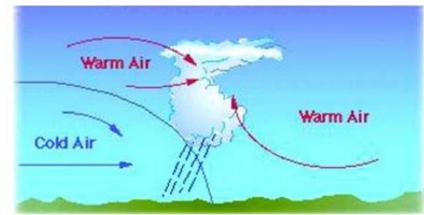
Warm air masses (eg, tropical air masses) will typically have the following characteristics:

- stability,
- smooth air,
- poor visibility, stratiform clouds and fog, and

precipitation in the form of drizzle.

## FRONTS

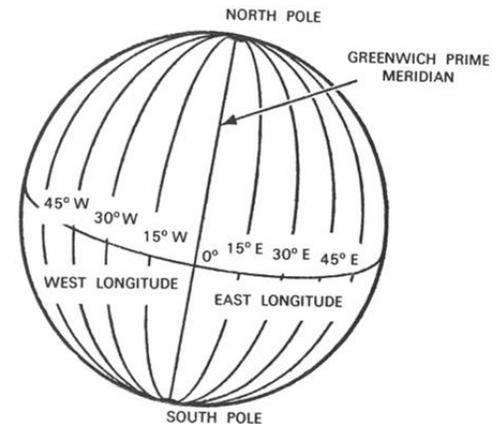
A front is the transition zone between two air masses. The interaction of air masses along their frontal zones is responsible for weather changes. The cold air mass is more dense and therefore sinks, undercutting the warm air which will ascend over the cold air. An air mass is a large section of the troposphere with uniform properties of temperature and moisture in the horizontal. An air mass can be several thousands of kilometers 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.



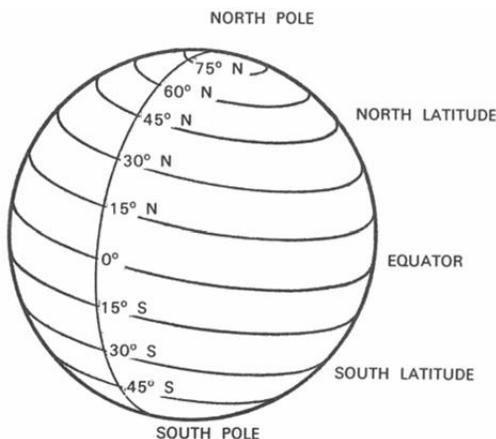
## AIR NAVIGATION

### MERIDIANS OF LONGITUDE

**Meridians of longitude.** Semicircles joining the true / geographic poles of the Earth. Longitude is measured from 0–180 degrees east and west of the prime meridian. The prime meridian is the meridian which passes through Greenwich, England and is numbered zero degrees. The Meridian on the opposite side of the Earth to the prime meridian is the 180<sup>th</sup> and is called the international date line (the time changes a day). Longitude is measured in degrees ( ° ), 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 centimeter is divided into 10 mm.



### PARALLELS OF LATITUDE



**Parallels of latitude.** Circles on the Earth's surface that lie parallel to the equator.

**Equator.** An imaginary line on the surface of the Earth equidistant from the poles. Latitude is measured from 0–90 degrees north and south of the equator, which is numbered zero degrees. Like longitude, latitude is measured in degrees, minutes, and seconds.

Remember the difference between latitude and longitude using one of the following mnemonics:

Lat is flat / fat; longitude is long.

Latitude is like climbing up a ladder because it is north / south; longitude is like swinging across because it is east / west.

## GEOGRAPHICAL CO-ORDINATES

**Geographical co-ordinates.** The intersection of lines of latitude and longitude. Geographical co-ordinates mark the position of places (eg, cities, towns, airports) 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, Ont. are 44°07' N, 77°32' W.

## 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 hours = 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

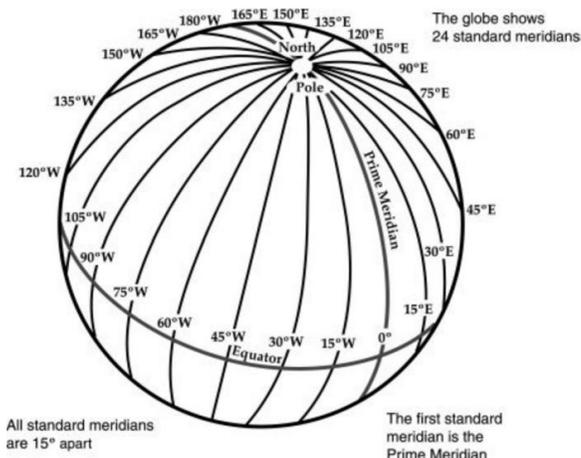
**Local mean time (LMT).** The mean time on any particular meridian.

**Co-ordinated universal time (UTC).** An atomically measured global standard time, calculated from midnight on the zero meridian. UTC is also referred to as Zulu (Z) time. UTC replaced Greenwich mean time (GMT) which was the universally accepted standard for the measurement of time until December, 1985.

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 is 1000Z.

The LMT of any place west of the prime meridian is behind UTC. For example, 1200 hours LMT in Halifax 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 1/2 hour ahead of Atlantic Standard Time.

Part of our heritage: Sir Sandford Fleming, a Canadian railway planner and engineer, outlined a plan for worldwide standard time in the late 1870s. Following this initiative, in 1884, delegates 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.

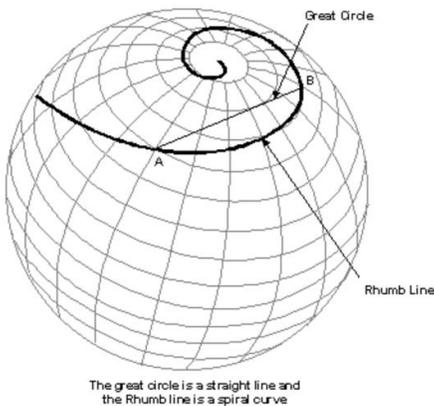
## GREAT CIRCLES

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

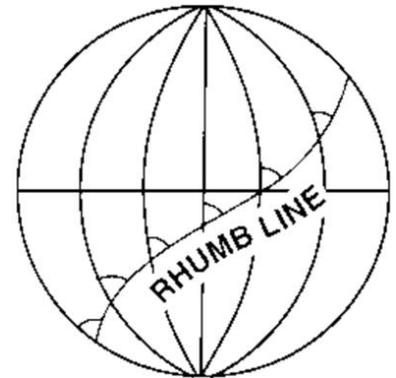
The equator is a great circle. The meridians of longitude are semi-great circles as they run from pole to pole and do not completely encircle the Earth. Only one great circle can be drawn through two places that are not diametrically opposite each other. The shortest distance between these two points 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.

### RHUMB LINES

A curved line on the surface of the Earth, cutting all the meridians it meets at the same angle. All parallels of latitude are rhumb lines. The meridians of longitude and the equator are rhumb lines as well as great circles.



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.



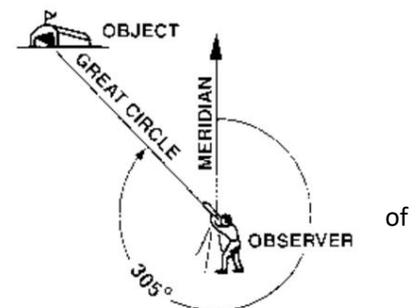
### HEADINGS AND BEARINGS

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.



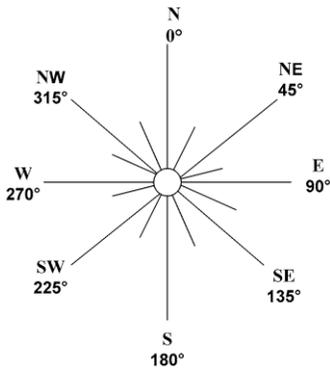
**True heading.** The angle between the meridian of longitude over which an airplane is flying and the line representing the direction the airplane's nose is pointing, measured clockwise from the meridian. The direction of any point on the surface the Earth from an observer is known by measuring the bearing.

**Bearing.** The angle between the meridian of longitude passing through the observer and the great circle that joins the observer to the object, measured clockwise from the meridian. Headings and bearings are found using a compass.



### THE EARTH'S MAGNETISM

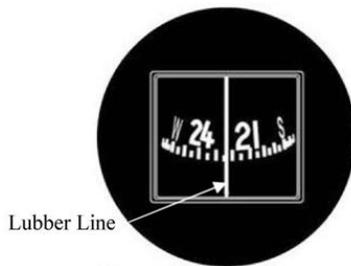
The Earth is a giant magnet that has a north and south pole. There are lines of force generated by currents of molten iron that flow within the Earth. The lines of force flow between the poles, creating a magnetic field that surrounds the Earth. The compass needle is affected by the lines of force, causing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



## Points of a Compass Rose

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



Lubber Line

**Lubber line.** The lubber line is a painted white 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.

**Compass card.** 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.

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

material.

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

**Magnetic needle.** The magnetic needle always points to magnetic north.

**Liquid.** The compass bowl is filled with liquid to lubricate the pivot, reduce the weight of the compass card and magnets, and limit 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 coordinates are based on true or geographic north whereas a magnetic compass points to magnetic north.

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

**Isogonic lines.** 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.

## 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 is prepared and placed in the aircraft.

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 closer 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 the 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 has stabilized, the compass will again read correctly.

On east and west headings:

Acceleration causes the compass to register a turn toward north, and

Deceleration causes the compass to register a turn toward south.