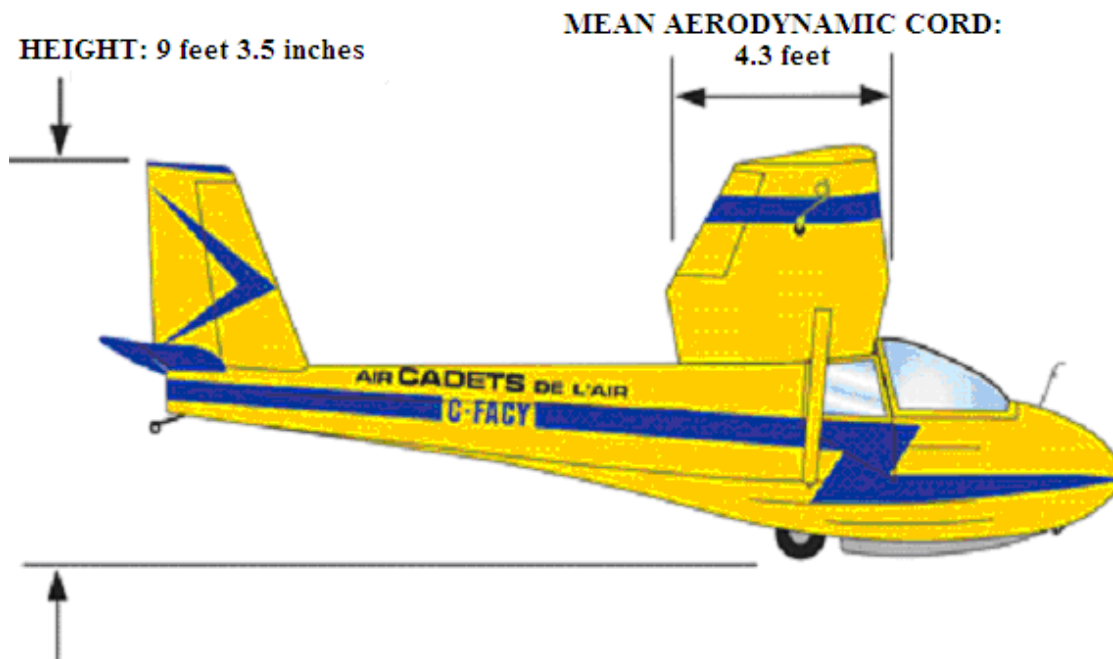


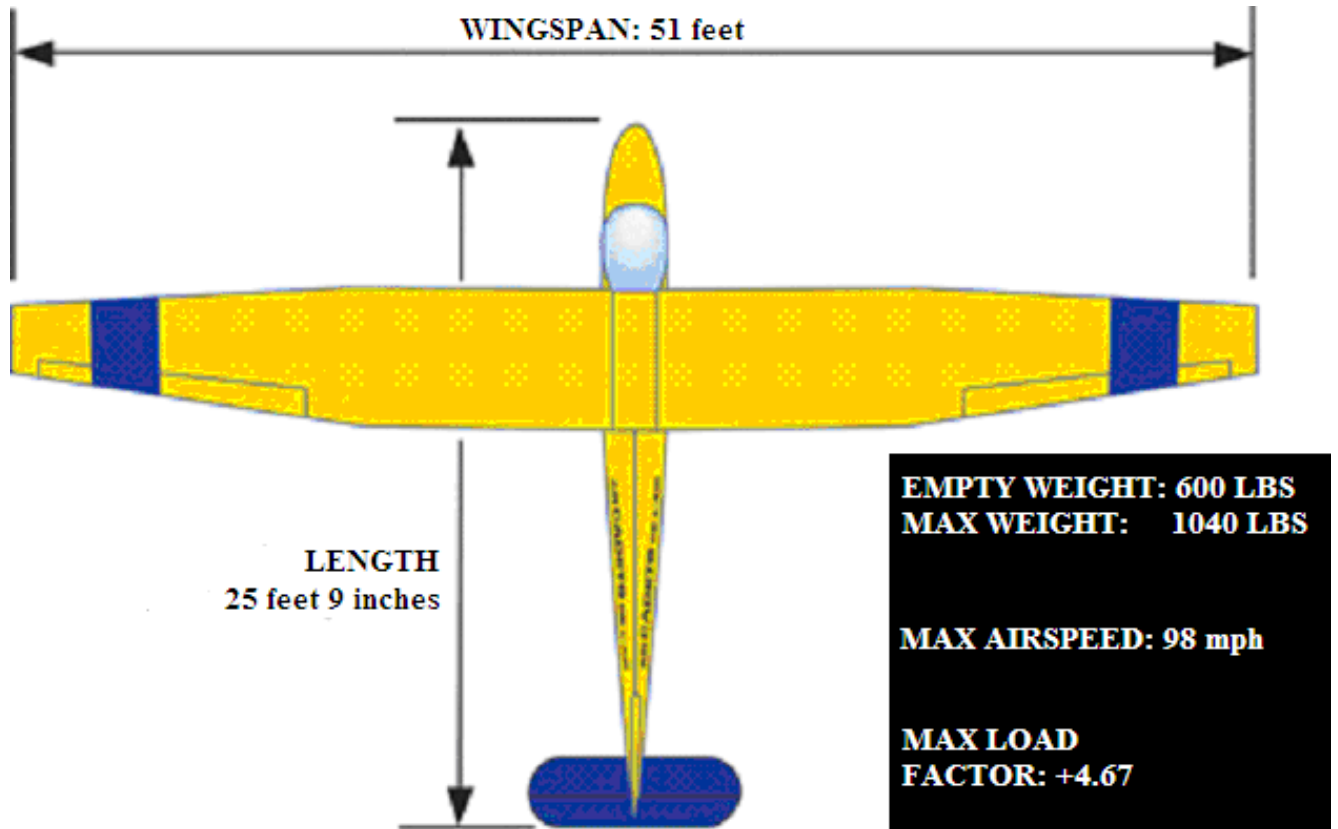


# Cadet Flying Scholarship Study Guide 2013/2014



Eastern Region Air Operations  
RCSU(Eastern) St. Jean Garrison PO Box 100  
Richelain, QC J0J 1R

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RECORD OF CHANGES

Identification of Change		Date Entered	Signature
Number	Date		
0	2004/08/06	Original Document	OPS AIR Cadets
1	2005/03/30	2005/03/30	OPS AIR Cadets
2	2005/09/01	2005/09/01	OPS AIR Cadets
3	2005/12/08	2005/12/08	OPS AIR Cadets
4	2006/08/16	2006/08/16	OPS AIR Cadets
5	2007/08/13	2007/08/13	OPS AIR Cadets
6	2008/08/15	2008/08/15	OPS AIR Cadets
7	2009/08/12	2009/08/12	OPS AIR Cadets
8	2010/08/17	Original Document	OPS AIR Cadets
9	2012/08/14	Original Document	OPS AIR Cadets
10	2013/08/14	Original Document	OPS AIR Cadets
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## **Foreword to the Flying Scholarship Course Study Guide**

Good day to all!

It is with great pleasure I present to you today the wonderful world of aviation. When, like you, I began my career in the Air Cadets I never dreamed for a moment that one day I would become a glider flight instructor and private pilot; even more remarkable, today I am the officer in charge of my squadron's Flying Scholarship program taking young cadets and helping turn them into pilots. I advise you, speaking from my personal experience, to grab this chance to become one of us: the pilots!

In the span of my career I have become one of a community of privileged people. We are privileged because we know the freedom to be found in mid-air, supported only by the winds, in the realm belonging only to the birds until the human race spread wings and took to flight. Some of my best friends have left behind their dreams of yellow gliders and pushed their imagination and their effort outward towards their destiny in outer space.

If you are successful in your bid to become a pilot, you will join this elite community who have overcome their fears and expanded the limits of their confidence. Seize the opportunity before you, and become a fellow of the Wright brothers, Jean Mermoz and St-Exupéry. Follow the spirit of Billy Bishop, Romeo Vachon and Rodolphe Pagé and “slip the surly bonds of Earth” to gaze over the same countryside and watch the same sunsets as Marc Garneau and Yuri Gagarin. Claim your piece of aeronautical heritage; this future belongs to you.

The determination which has led you to undertake your studies as a new pilot means releasing the pilot locked within you waiting to get out, and conquering new ground where you will grow in discipline, because that is what it takes to come safely back to earth. You will develop other invaluable skills: problem solving, teamwork and a taste for pushing your limits. Try as you might to stay the same, the experience cannot help but change you forever.

This manual includes all the theory required to be successful at the national exam. For each subject, there are review exercises and sample exam questions to help you prepare.

On behalf of the team of officers who have contributed to the creation of this study guide, I wish you all the best as you reach for the sky!

The Flying Scholarship Team.

## **The benefits of studying theory**

The following anecdote demonstrates the wisdom behind our emphasis on a solid base of theory before beginning practical training, and the utility of pre-flight briefings at the RGS. This anecdote comes from an expert flight instructor who has worked for many years with us at ERGS. Here is his tale:

The owner of the school where I'm working now has been flying gliders and airplanes since the Forties. 35 000 flights in gliders, 7 000 hours on tow; he could never wear a shirt with sleeves long enough to sew on all the badges he has earned. He has the SAC Diamond Badge #80 and has been operating a commercial flying school since 1965.

Anyhow, during the Sixties, he tried an experiment with a line-boy who worked for him. He taught him how to fly by giving him nothing but theory (60 to 100 hours worth). They spent many hours sitting in the 2-33 practicing manoeuvres on the stick and watching and critiquing the takeoffs and landings of other pilots. At last the instructor went up, in calm conditions, with his student for one single flight, where the instructor sat in the back, said nothing and watched (just like a pre-solo check!). The young man flew a perfect flight from take-off to landing. The instructor sent him solo on the second glider flight of his life!!!!

While the results of a comparable experiment might not be the same for every student learning to fly, the theory presented is an essential foundation for pilot training. Often under-valued by young people anxious to begin their training in the air as quickly as possible, the knowledge absorbed on the ground is an essential and integral part of the development of situational awareness and good judgement in student pilots. As we say: The truly skilled pilot is one who uses his superior knowledge and judgement to avoid placing himself in a nasty situation, rather than one who must use his superior reactions and skills to get himself out of a nasty situation.

Make maximum use of the time you have to study on the ground. The more you learn on the ground, the less you will have to learn from your mistakes in the air. You will be able to get the most out of your lessons in the air and have a truly unforgettable experience.

Happy Learning!

From the Flight Instructors of RGS.

## Introduction

A solid understanding of the material presented in this guide is essential for success at the National Selection Exam, which is a major pre-requisite for the glider pilot's license. Students must also read the sections pertaining to the subjects below in the book From The Ground Up in order to ensure a thorough grasp on all sections covered by the exam.

Here is the list of subjects evaluated by the National Exam:

Air Law	401
Navigation	403
Radio	404
Meteorology	405
Airframes, instruments and Theory of Flight	406
Engines (For the Power Scholarship)	410

The National Exam is composed of 40 questions for glider and 50 questions for the power course (the 10 extra questions pertaining to principles of flight specific to powered flight). The exam is multiple choice. The pass mark is 50%. All candidates who pass the exam also pass before an interview board, normally composed of an officer representing Cadet Air Operations and two civilians from the Air Cadet League. The following points are used to evaluate candidates during the selection process for the scholarship courses: the interview mark; the exam mark; their level of academic achievement at school; completion of Level 4 or 5 of the Air Cadet Training Program; and the narrative written by the candidate. These scores are compiled and a list made of the best overall scores. The ranking of each candidate determines who will be selected for the Power or Glider Scholarship, according to how many scholarships are available for the current year.

You will find the answers to the exams, at the end of each PO, in the instructor guide.

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# **401 – Air Regulations**

## **401.01 – Basic Air Regulations and Aircraft Registration**

### **1 - The AIM, CFS and their Contents**

The Transport Canada Aeronautical Information Manual (TC-AIM) has been developed to consolidate pre-flight reference information of a lasting nature into a single primary document. It provides flight crews with a single source for information concerning rules of the air and procedures for aircraft operation in Canadian Aviation Regulations (CARs) of interest to pilots. It has however no legal value and juridical questions must be referred directly to CARs.

To ensure that information in the possession of pilots is current; updates will be published twice a year in April and October. It is the responsibility of each pilot to ensure that their document is up to date.

Subscriptions to the TC AIM are available to all pilots holding a valid Canadian Pilot's Licence. In addition, copies can be purchased from Transport Canada. This resource is also available for free online at:

<http://www.tc.gc.ca/CivilAviation/publications/tp14371/menu.htm>.

**The Canada Flight Supplement** is a joint civil/military publication issued every 56 days. It contains information on land and some water aerodromes and is used as a reference for the planning and safe conduct of air operations. Only aerodromes that provide an advantage for the aviation community are published. Typically this includes aerodromes that: are open to the public, are used by more than one aircraft and that have a telephone available to the users of that aerodrome

The information contained in this supplement is current only to the date of submission for printing. A NOTAM may amend or cancel the information in this document; therefore, the NOTAM must be consulted to ensure that current information is used for flight operation.

## **2 – Definitions**

**Aircraft:** any machine capable of deriving support in the atmosphere from the reactions of the air.

**Airplane:** Power-driven heavier-than-air aircraft which derives its lift from aerodynamic reactions on surfaces which remain fixed under given conditions of flight.

**Heavier than air aircraft:** aircraft supported in the atmosphere by lift derived from aerodynamic forces.

**Glider:** heavier-than-air aircraft not equipped with a motor, which derives its lift from aerodynamic reactions on surfaces which remain fixed under given conditions of flight.

**Aerodrome:** Any area of land, water (including the frozen surface thereof) or other supporting surface used or designed, prepared, equipped or set apart for use either in whole or in part of the arrival and departure, movement or servicing of aircraft and includes any buildings, installations and equipment in connection therewith.

**Airport:** An aerodrome in respect of which a Canadian Aviation document is in force.

**Controlled Airport:** An airport at which an ATC unit is provided and in service.

**Maneuvering Area:** That part of an aerodrome intended to be used for the taking off and landing of aircraft and for the movement of aircraft associated with takeoff and landing, excluding aprons. (Runways and Taxiways)

**Movement Area:** That part of an aerodrome intended to be used for the surface movement of aircraft, and includes the maneuvering area and aprons.

**Apron:** That part of an aerodrome, other than the maneuvering area, intended to accommodate the loading and unloading of passengers and cargo; the refueling, servicing, maintenance and parking of aircraft; and any movement of aircraft, vehicles and pedestrians necessary for such purposes.

**Take off:** for an aircraft other than a dirigible balloon, the act of leaving the surface, including the take-off roll and the operations immediately preceding and following this act.

**Landing:** in the case of an aircraft other than a dirigible balloon, the act of touching down on a surface, including the operations which immediately precede and follow this act.

**Air Traffic Control Clearance:** Authorization by an air traffic control unit for an aircraft to proceed within controlled airspace under specified conditions.

**Air Traffic Control Instruction:** A directive issued by an air traffic control unit for air traffic control purposes.

**Certificate of Registration:** A certificate issued to the owner of an aircraft with respect to the registration and registration markings for that aircraft.

**Certificate of Airworthiness:** A conditional certificate of fitness for flight issued in respect of a particular aircraft.

**Airworthy:** In respect to an aeronautical product, in a fit and safe state for flight and in conformity with the applicable standards of airworthiness.

**Flight Itinerary:** Specified information relating to the intended flight of an aircraft, which is filed either with ATC or with a responsible person, who agrees to inform the authorities should the aircraft fail to arrive.

**Flight Plan:** Information, relating to the intended flight of an aircraft, which must be transmitted as a Flight Plan in application of Section III, Sub-Part 2, Part VI.

**Daylight:** means the time between the beginning of morning civil twilight and the end of evening civil twilight; (amended 2003/06/01)

**Night:** means the time between the end of evening civil twilight and the beginning of morning civil twilight; (amended 2003/06/01)

**Pilot Licence:** document permitting the holder to act as a flight crew member of an aircraft.

**Minister:** The Minister of Transportation.

**Ceiling:** The lowest height at which a broken or overcast condition exists, or the vertical visibility when an obscured condition such as snow, smoke or fog exists, whichever is the lower.

**Owner:** the person holding legal possession and responsibility for an aircraft.

**Track:** The projection on the earth's surface of the path of an aircraft, the direction of which path at any point is usually expressed in degrees from North (True, Magnetic or Grid).

**Heading:** the direction in which the longitudinal axis of the aircraft is pointing, usually expressed in degrees from north (either true, magnetic or compass).

**Air Traffic Control Service:** Services, other than flight information services, provided for the purpose of:

- a. preventing collisions between: aircraft; aircraft and obstructions; and aircraft and vehicles on the maneuvering area; and
- b. expediting and maintaining an orderly flow of air traffic.

**Flight time:** Time calculated from the moment the aircraft begins to move under its own power with the intention of taking off until the moment that the aircraft comes to a stop at the end of the flight.

**Air Traffic:** All aircraft in flight and aircraft operating on the maneuvering area of an aerodrome.

**Airport Traffic:** All traffic on the maneuvering area of an airport and all aircraft flying in the vicinity of an airport.

**Air Traffic Control Unit:**

- a. An area control centre established to provide air traffic control service to Instrument Flight Rules (IFR) flights and Controlled Visual Flight Rules (CVFR) flights;
- b. a terminal control unit established to provide air traffic control service to IFR flights and controlled VFR flights operating within a terminal control area; or
- c. an airport control tower unit established to provide air traffic control service to airport traffic; as the circumstances require.

**VFR:** Visual Flight Rules: regulations concerning flight conducted with constant visual contact with the ground.

**IFR:** Instrument Flight Rules

**Visibility:** term used to describe the transparency of the atmosphere.

**Visual Signals:** Signals used to communicate with someone with visual means. The most common visual signals includes: air to ground signals, interception signals and search and rescue signals.

**Ground Visibility:** The visibility at an aerodrome as contained in a weather observation reported by: (a) an Air Traffic Control (ATC) unit; (b) a Flight Service Station (FSS); (c) a Community Aerodrome Radio Station (CARS); (d) a radio station that is ground-based and operated by an air carrier; or (e) an Automated Weather Observation System (AWOS).

**Flight Visibility:** The average range of visibility at any given time forward from the cockpit of an aircraft in flight.

**VFR Flight:** flight made in accordance with Visual Flight Rules.

**Special VFR:** ATC-authorized flight in controlled airspace under VFR rules when existing meteorological conditions are below VFR minima, in accordance with Section VI of Sub-Part 2 of Part VI.

**Control Zone (CZ):** Controlled airspace of defined dimensions extending upwards from the surface of the earth up to and including 3 000 feet AAE unless otherwise specified.

## **Abbreviations:**

**AAE:** Above Aerodrome Elevation

**AGL:** Above Ground Level

**ASL:** Above Sea (mean) Level

**AIM:** Aeronautical information manual

**FSS:** Flight Service Station

**ICAO:** International Civil Aviation Organization

**VMC:** Visual meteorological conditions

**ATC:** Air Traffic Controller

**ATS:** Air Traffic Services

### **3 - Aircraft Registration in Canada**

No civil aircraft, other than a hang glider or model aircraft shall be flown in Canada unless it is registered in accordance with the Canadian Aviation Regulations (CARs), Part II, or under the laws of an International Civil Aviation Organization (ICAO) member state, or a state that has a bilateral agreement with Canada concerning interstate flying.

No aircraft except a hang glider or model aircraft shall be flown in Canada unless it bears nationality and registration markings painted or permanently affixed on the aircraft and has attached a fireproof identification plate inscribed with the registration and manufacturing information.

Canadian nationality markings consist of the capital letter(s) C, or CF prefixed to the registration letters.

Any change in aircraft ownership including change of address must be communicated to Transport Canada in writing within 7 days of the transaction.

### **4 - Markings in aircrafts and weight and balance placards**

**602.60 (1)** No person shall conduct a take-off in a power-driven aircraft, other than an ultra-light airplane, unless the following operational and emergency equipment is carried on board:

- a. a checklist or placards that enable the aircraft to be operated in accordance with the limitations specified in the aircraft flight manual, aircraft operating manual, pilot operating handbook or any equivalent document provided by the manufacturer.

**605.05** No person shall conduct a take-off in an aircraft in respect of which markings or placards are required by the applicable standards of airworthiness unless the markings or placards are affixed to the aircraft or attached to a component of the aircraft in accordance with those standards.

<http://www.tc.gc.ca/AviationCivile/Servreg/Affaires/RAC/Partie6/menu.htm>

All aircraft must have the following placards displayed:

- a. Compass correction (« For/Steer ») card;
- b. Weight and Balance (maximum and minimum pilot weight, front and rear seat)
- c. Fireproof plate with: Aircraft registration and nationality

### **Weight-and-Balance and Placards**

Each aircraft must have a weight and balance graph. The graph permits the pilot to determine acceptable loading of passengers, fuel and cargo. Aircraft loading must be checked before every flight.

## **401.02 – Aerodromes, Rules of the Air and VFR flight**

### **1- Lighting and Markings**

#### **Runway numbering**

Runway numbers in the Southern Domestic Airspace correspond to their magnetic orientation, rounded to the nearest 10°. Thus the runway numbered 09 is facing approximately 090° magnetic. Every orientation between 085° and 094° bears the 09 mark.

#### **Aerodrome lighting**

Aerodrome Beacon: White strobe flashing at 20 to 30 beats per minute.



**Runway Edge Lights:** These are variable intensity white lights at the runway edges along the full length of the runway spaced at 200-foot intervals, except at intersections with other runways. The units are light in weight and mounted in a frangible manner.

**Taxiway edge lights:** Taxiway edge lights are blue in color and are spaced at 200-foot intervals. Where a taxiway intersects another taxiway or a runway, two adjacent blue lights are placed at each side of the taxiway. The intersection of taxiway and aprons is indicated by two adjacent yellow lights at taxiway/apron corners. Centre line taxiway lights (if fitted) are green in color and are installed on the taxiway surface. They are spaced at 200-foot intervals with less spacing on taxiway curves.

**Runway threshold lights:** green lights placed across the beginning of the runway on either side of the centerline.

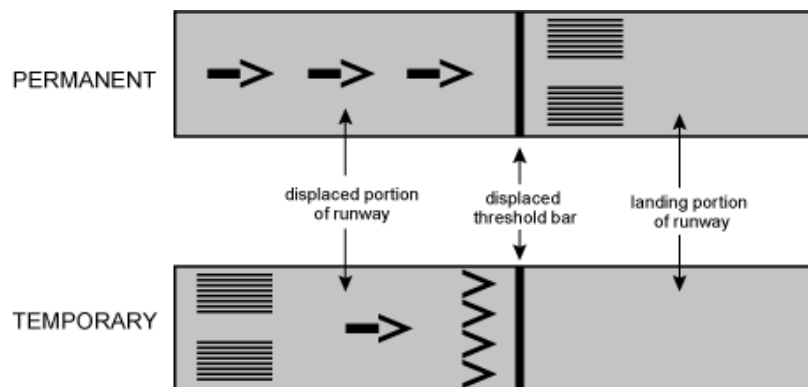
**Runway end lights:** Red lights placed across the end of the runway on either side of the centerline.

**Obstacles:** Minimum requirements dictate that obstacles be identified by red lights.

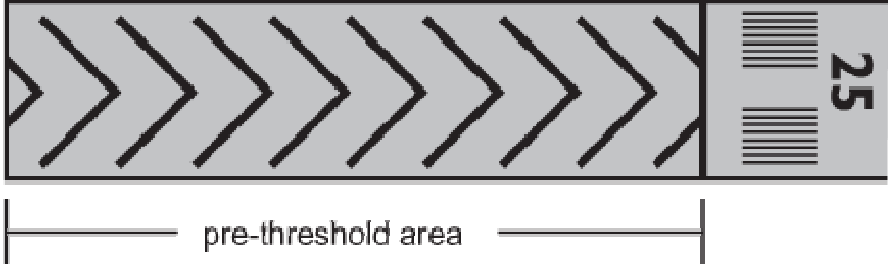
### Markings

Runway markings vary depending on runway length and width. The color of the markings is white.

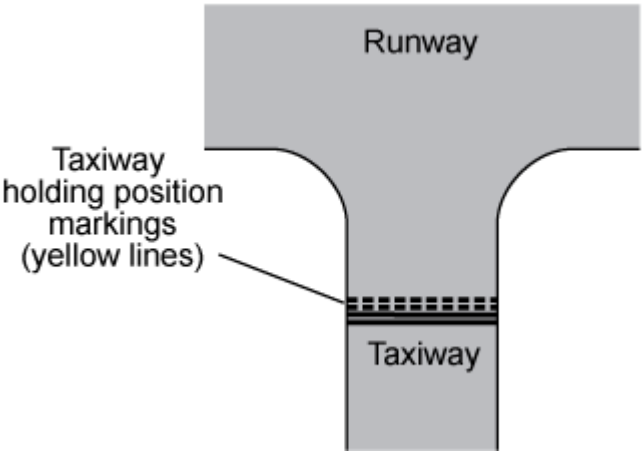
**Displaced Threshold:** Indicated by arrows pointing to the displaced threshold line. The landing area of the runway begins after the new threshold line.



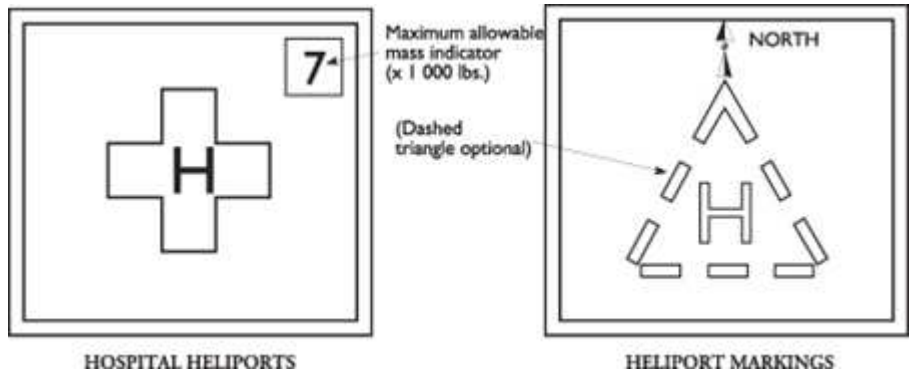
**Stopway:** The paved area preceding a runway threshold prepared and maintained as a stopway may be marked with yellow chevrons. This area is not available for taxiing, the initial takeoff roll or the landing rollout; it must not be included in runway length calculations. The chevron markings may also be used on blast pads and extra length in case of a discontinued take off.



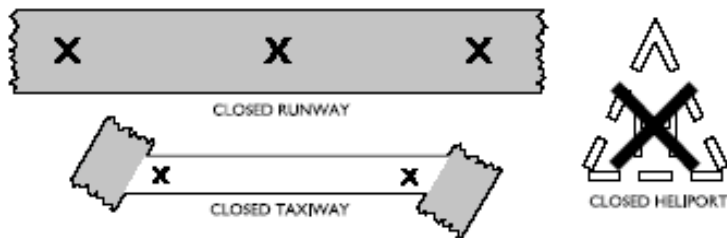
**Taxiway exit and hold lines:** Located 200 feet from the edge of the runway, these markings are made up of a solid line on the taxiway side and a dashed line on the runway side painted across the taxiway. These yellow markings tell the pilot where to wait while waiting for clearance or for traffic to land.



**Heliport:** Identified by the capital letter H painted in white in the centre of the takeoff / landing area. If it is necessary to make the H more visible it will be surrounded by a square made up of dashed lines. Hospital heliports are marked by a red capital H on a white cross.



**Closed markings:** Runways, taxiways or portions thereof, and helicopter takeoff and landing areas that are closed to aircraft operations are marked by white or yellow X's, 20 feet in length. Snow covered areas may be marked by X's formed by conspicuously colored dye. When a runway, taxiway or helicopter takeoff and landing area is permanently closed all markers and markings except the X's are removed.

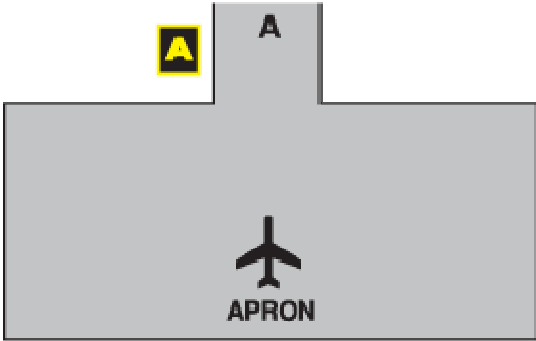


**Unserviceable Area Markings:** Unserviceable portions of the movement area other than runways and taxiways are delineated by markings such as marker boards, cones, or red flags and, where appropriate, a flag or suitable marker is placed near the centre of the unserviceable area. Red flags are used when the unserviceable portion of the movement area is sufficiently small for it to be by-passed by aircraft without affecting the safety of their operations.

**Location Sign:** A location sign has a yellow inscription on a black background and is used to identify the taxiway which the aircraft is on or is entering. A location sign never contains arrows.



**Location sign**



**Apron to taxiway intersection**

**Direction Sign:** A direction sign has a black inscription on a yellow background and is used to identify the intersecting taxiways toward which an aircraft is approaching. The sign is, whenever possible, positioned to the left-hand side of the taxiway and prior to the intersection. A direction sign will always contain arrows to indicate the approximate angle of intercept. Direction signs are normally used in combination with location signs to provide the pilot with position information. The location sign will be in the centre or datum position. In this configuration, all information on taxiways that require a right turn are to the right of the location sign and all information on taxiways that require left turns are to the left of the location sign.



**Direction**

**Location**

**Direction**

**No Entry Sign:** A no entry sign will be located on both sides of a taxiway into which entry is prohibited. It consists of a white circle bisected by a white horizontal crossbar on a red background.



**Wind Direction Indicators:** Runways greater than 1 200 m in length will have a wind direction indicator for each end of the runway. It will be located 150 m in from the runway end and 60 m outward, usually on the left side.

Runways 1 200 m in length and shorter will have a wind direction indicator centrally located so as to be visible from approaches and the aircraft parking area. Where only one runway exists, it will be located at the mid-point of the runway 60 m from the edge.

For night operations the wind direction indicator will be lighted.

No person may walk, stand, park a vehicle or aircraft or cause an obstruction on the movement area of an aerodrome unless permission has been given by:

- a. the aerodrome operator; or
- b. ATC or the appropriate flight information station.

## 2 - Visual Signals

### Aircraft Position Lights:

- Red light on left wing visible through 110° over a distance of 2 miles.
- Green light on right wing visible through 110° over a distance of 2 miles.
- White light on the tail visible through 140° over a distance of 2 miles.
- A red or white anti-collision strobe visible through 360°.

### **Visual Signals to Aircraft In Flight:**

- **Steady Green Light:** Cleared to land.
- **Steady Red Light:** Yield to another aircraft and remain in the circuit.
- **Flashing Green Light:** Return for landing.
- **Flashing Red Light:** Aerodrome dangerous; do not land.
- **Red Pyrotechnic Flare:** Do not land for the time being.

### **Visual Signals to Aircraft on the Ground:**

- **Flashing Green Light :** Cleared to Taxi
- **Steady Green Light:** Cleared for take-off
- **Flashing Red Light:** Clear the landing area in use.
- **Steady Red Light:** Stop
- **Flashing White Light:** Return to your starting point on the aerodrome.
- **Flashing Runway Lights:** Advises vehicles and pedestrians to vacate runways immediately.

### **Red and green pyrotechnic flares (U.S.A):**

**Launched at 10-second intervals meaning:** you are in danger, or you are in a restricted area.

### **Distress signals:**

- **Distress:** a situation of grave or imminent danger where immediate assistance is required.
- **Morse Code:** S-O-S ... --- ...
- **Red flares:** launched individually at short intervals.
- **Standard signal:** composed of three fires forming a triangle near the crash site.
- **Irregular flashing:** of all available lights.

**Ground-to-Air Signals:**

Message	Symbol
REQUIRE ASSISTANCE	V
REQUIRE MEDICAL ASSISTANCE	X
NO or NEGATIVE	N
YES or AFFIRMATIVE	Y
PROCEEDING IN THE DIRECTION	↑
ALL IS WELL	LL
REQUIRE FOOD AND WATER	F
REQUIRE FUEL AND OIL	L
NEED REPAIRS	W

**Interception Signals:**

No person shall give an interception signal or an instruction to land except:

- a. A peace officer.
- b. A person authorized to do so by the Minister

The Minister may authorize a person to give an interception signal or an instruction to land if such authorization is in the public interest and is not likely to affect aviation safety.

The pilot-in-command of an aircraft who receives an instruction to land shall, subject to any direction received from an air traffic control unit, comply with the instruction.

The pilot-in-command of an intercepting aircraft and the pilot-in command of an Intercepted aircraft shall comply with the rules of interception set out in the Canada Flight Supplement.

**3 - Rules of the Air**

No person shall operate an aircraft unless in accordance with VFR or IFR procedures or in accordance with special regulations set forth by the Minister.

No person shall create a hazard to persons or property on the surface by dropping an object from an aircraft in flight. (CAR 602.23)

It is forbidden to carry dangerous goods except in accordance with the Law on the Transport of Dangerous Materials.

No person shall operate an aircraft in such a reckless or negligent manner as to endanger or be likely to endanger the life or property of any person. (CAR 602.01)

No person shall operate an aircraft that is towing an object unless the aircraft is equipped with a tow hook and release control system that meet the applicable standards of airworthiness. (CAR 602.22)



## **Minimum Altitudes**

Except at an airport or military aerodrome, no person shall conduct a take-off, approach or landing in an aircraft over a built-up area or over an open-air assembly of persons unless that aircraft will be operated at an altitude from which, in the event of an engine failure or any other emergency necessitating an immediate landing, the aircraft can land without creating a hazard to persons or property. In any case, altitude must never be less than 1000' above the highest obstacle within a 2000' radius centered on the aircraft. (CAR 602.12)

Unless otherwise authorized by the appropriate air traffic control unit, no pilot-in-command shall operate an aircraft at an altitude of less than 2,000 feet over an aerodrome except for the purpose of landing or taking off. (CAR 602.96)

Other than over a built-up area or assembly of person, except for the requirements of take-off or landing, the minimum altitude shall not be less than 500' above the highest obstacle within a radius of 500' centered on the aircraft.

An aircraft may be flown over a sparsely populated area or a body of water as long as the aircraft passes over all people, boats, vehicles and structures at no less than 500', and no person or property is endangered.

It is forbidden to over-fly the following installations below 2000' AGL:

- a. fur or poultry farms
- b. herds of reindeer, caribou, moose or musk-oxen
- c. national, provincial and municipal parks, preserves and wildlife sanctuaries

It is forbidden to use an aircraft over a disaster area or within 5 NM of a disaster area at an altitude lower than 3000 feet above ground. A notice-to-aviators (NOTAM) need not necessarily be published for this requirement to be in force. Notwithstanding, by virtue of article 601.16 of the CARs, Transport Canada can issue a NOTAM to further restrict airspace around a forest fire. Pilots must remember to check NOTAMs prior to flying near a forest fire.

There are certain exceptions to the altitude minimums above for aircraft engaged in special activities, like fire-fighting, crop spraying, police work, etc.

### **Aerobatic Maneuvers**

-No person operating an aircraft shall conduct aerobatic maneuvers (CAR 602.27):

- a. over a built-up area or an open-air assembly of persons;
- b. in controlled airspace, except in accordance with a special flight operations certificate;
- c. when flight visibility is less than three miles; or
- d. below 2,000 feet AGL, except in accordance with a special flight operations certificate.

### **Restrictions Regarding Passengers**

No person shall enter or leave an aircraft in flight except with the permission of the pilot-in-command of the aircraft.

No pilot-in-command of an aircraft shall permit a person to enter or leave the aircraft during flight unless the person leaves for the purpose of making a parachute descent.

No pilot-in-command of an aircraft shall permit, and no person shall conduct, a parachute descent from the aircraft:

- a. in or into controlled airspace or an air route; or
- b. over or into a built-up area or an open-air assembly of persons.

No person operating an aircraft with a passenger on board shall conduct an aerobatic maneuver unless the pilot-in-command of the aircraft has engaged in: (CAR 602.28)

- a. at least 10 hours dual flight instruction in the conducting of aerobatic maneuvers or 20 hours conducting aerobatic maneuvers; and
- b. at least one hour of conducting aerobatic maneuvers in the preceding six months.

### **Right of Way**

The pilot-in-command of an aircraft that has the right of way shall, unless imminent risk of collision exist maintain its heading, speed and altitude.

The pilot-in-command of an aircraft that has the right of way shall, if there is any risk of collision, take such action as is necessary to avoid collision.

Where the pilot-in-command of an aircraft is aware that another aircraft is in an emergency situation, the pilot-in-command shall give way to that other aircraft.

When two aircraft are converging at approximately the same altitude, the pilot-in-command of the aircraft that has the other on its right shall give way, except as follows:

- a. a power-driven, heavier-than-air aircraft shall give way to airships, gliders and balloons;
- b. an airship shall give way to gliders and balloons;
- c. a glider shall give way to balloons; and
- d. a power-driven aircraft shall give way to aircraft that are seen to be towing gliders or other objects or carrying a slung load.

When two gliders, flown at different altitudes, have converging trajectories, the pilot-in-command of the glider at higher altitude shall give way to the glider at lower altitude.

Where two aircraft are approaching head-on or approximately so and there is a risk of collision, the pilot-in-command of each aircraft shall alter its heading to the right.

When two gliders are converging at the same altitude and there is risk of a collision, the glider which has the other on its right shall give way.

An aircraft that is being overtaken has the right of way and the pilot-in-command of the overtaking aircraft, whether climbing, descending or in level flight, shall give way to the other aircraft by altering the heading of the overtaking aircraft to the right, and no subsequent change in the relative positions of the two aircraft shall absolve the pilot-in-command of the overtaking aircraft from this obligation until that aircraft has entirely passed and is clear of the other aircraft.

Where an aircraft is in flight or maneuvering on the surface, the pilot-in-command of the aircraft shall give way to an aircraft that is landing or about to land.

The pilot-in-command of an aircraft that is approaching an aerodrome for the purpose of landing shall give way to any aircraft at a lower altitude that is also approaching the aerodrome for the purpose of landing.

The pilot-in-command of an aircraft at a lower altitude shall not overtake or cut in front of an aircraft at a higher altitude that is in the final stages of an approach to land.

No person shall conduct or attempt to conduct a take-off or landing in an aircraft until there is no apparent risk of collision with any aircraft, person, vessel, vehicle or structure in the take-off or landing path.

#### **4 - VFR, SVFR, NVFR, CVFR**

**VFR:** Flight with visual reference to the ground

**SVFR:** Special VFR flight, exist mainly for returning to an airport when weather conditions are inferior to VFR minimums but visibility is not lower than 1 SM (for fixed-wing aircraft). Aircraft must remain clear of cloud and in visual contact with the ground at all times. These are required for SVFR:

- a. a clearance must be issued by an Air Traffic Control Unit and flight in these conditions must remain inside a control zone; and
- b. Special VFR requires the aircraft to remain clear of cloud and in visual contact with the ground. The aircraft shall fly no lower than 500 feet over the ground, save for landing and taking off.

**NVFR** : VFR flight by night. Aircraft operating at night must be equipped with the following instruments, approved and serviceable:

- a. an airspeed indicator;
- b. a precision barometric altimeter;
- c. a magnetic compass;
- d. a turn and bank indicator;
- e. a gyroscopic compass or heading indicator (if the flight will range beyond the immediate area of the aerodrome);
- f. a light source to illuminate the instruments;
- g. a reliable time-piece;
- h. a flashlight, and;
- i. the aircraft must be equipped with a two-way radio in serviceable condition to ensure bilateral communication.

Operation at night, on the ground or in flight, requires that aircraft be equipped with a system of navigation lights and an anti-collision beacon.

If passengers are to be carried onboard, a serviceable landing light.

**CVFR**: VFR flight in class B airspace.

The pilot in CVFR flight must conform to IFR rules save that he / she must remain in VMC and:

- a. a flight plan must be filled;
- b. two-way radio equipment is mandatory, and;
- c. the aircraft must be equipped with radio-navigation equipment.

## 5 – Required Equipment for Day VFR with a Glider

605.21 No person shall operate a glider in day VFR flight unless it is equipped with the following equipment:

- a. an altimeter;
- b. an airspeed indicator;
- c. a magnetic compass or magnetic direction indicator;
- d. a timepiece, and;
- e. a radio-communication system adequate to permit two-way communication on the appropriate frequency when the glider is operated within Class C or Class D airspace; an MF area; or the ADIZ.

## 6 - Weather Minima for VFR Flight

Airspace	Minimum Flight Visibility	Distance from cloud
Controlled Airspace	3 miles	Horizontally : 1 miles Vertically : 500'
Control Zone	Same as within controlled airspace but with a 500' AGL minimum altitude	
Uncontrolled Airspace, 1000' AGL and above	1 mile (day) 3 miles (night)	Horizontally : 2000' Vertically : 500'
Uncontrolled Airspace, below 1000' AGL	2 miles (day) 3 miles (night)	Clear of cloud

### Weather Minima for Special VFR (Control Zones only)

Type of Aircraft	Minimum Flight Visibility	Distance from cloud
Aircraft except helicopters	1 mile	clear of cloud
Helicopter	1/2 mile	clear of cloud

## 401.03 – Licences and Documentation

### 1- Requirements for Obtaining a Glider Pilot Licence

A glider pilot Licence is issued to a person who has met the following criteria:

- a. **age:** 16 years
- b. **medical category:** 1, 3 or 4
- c. **validity period** (including pilots over 40 years): 60 months
- d. **knowledge:** 15 hours of theory, 60% on the TC GLIDE exam.
- e. **skills:** flight test (letter from examiner)
- f. **minimum experience:** 6 hours total, including 1 hour Dual, 2 hours Solo, 20 take-offs and landings.

### 2 - Licence and Medical Validity and Recency Requirements

#### Medical Certificate

Licence	Minimum age	Medical category	Validity (- 40 years)	Validity (+ 40 years)
Student pilot permit	14	1, 3 or 4	60 months	60 months
Glider Pilot	16	1, 3 or 4	60 months	60 months
Balloon Pilot	17	1 or 3	60 months	24 months
Private Pilot	17	1 or 3	60 months	24 months
Commercial Pilot	18	1	12 months	6 months



## **Medical Exam**

All holders of Canadian pilot or air traffic controller Licences and holders of the gyroplane permit must undergo a periodic medical examination to determine their medical fitness in order to exercise the privileges of their permit or Licence. This medical examination will normally be carried out by a designated civil aviation medical examiner. A medical certificate is valid up to the first day of the next month at the end of the validity period.

Example: date of examination 15 SEP 2008; validity 5 years: Expire 1st OCT 2013.

## **Physically Fit**

When the examination has been completed, the examiner will make a recommendation of fitness and will forward the documentation to the Regional Aviation Medical Officer (RAMO) at the appropriate regional office for review. If the person is already holder of a Canadian pilot permit, Licence, or air traffic control Licence and is, in the opinion of the examiner, medically fit, the examiner will extend the medical validity of the holder's permit or Licence for the full validity period by signing and stamping the back of the medical certificate.

Licences and permits may be replaced if:

- a. The document has been lost or destroyed. Charges apply.
- b. There has been a change of legal name.
- c. There has been a change of citizenship. No cost; proof of citizenship required.
- d. There has been a change of address. (The Ministry of Transport must be informed within 7 days of the change.)

The frequency of medical examinations depends on the age of the applicant and the type of permit or Licence applied for. For some examinations, supplementary tests, such as an audiogram or an electrocardiogram (ECG), may be required.

## **Recency Requirements**

**401.05 (1)** Notwithstanding any other provision of this Subpart, no holder of a flight crew permit, Licence or rating, other than the holder of a flight engineer Licence, shall exercise the privileges of the permit, licence or rating unless:

- a. the holder has acted as pilot-in-command or co-pilot of an aircraft within the five years preceding the flight; or
- b. within the 12 months preceding the flight:
  - (1) the holder has completed a flight review, in accordance with the personnel licensing standards, conducted by the holder of a flight instructor rating for the same category of aircraft,
  - (2) the flight instructor who conducted the flight review has certified in the holder's personal log that the holder meets the skill requirements for the issuance of the permit or licence set out in the personnel licensing standards, and
  - (3) the holder has successfully completed the appropriate examination specified in the personnel licensing standards.

**401.5 (2)** Notwithstanding any other provision of this Subpart, no holder of a flight crew permit or licence, other than the holder of a flight engineer licence, shall exercise the privileges of the permit or licence in an aircraft unless the holder:

- a. has successfully completed a recurrent training program in accordance with the personnel licensing standards within the 24 months preceding the flight; and
- b. where a passenger other than a flight test examiner designated by the Minister is carried on board the aircraft, has completed, within the six months preceding the flight:
  - (1) in the case of an aircraft other than a glider or a balloon, in the same category and class of aircraft as the aircraft, or in a Level B, C or D simulator of the same category and class as the aircraft, at least:

- (i) five night or day take-offs and five night or day landings, if the flight is conducted wholly by day, or
  - (ii) five night take-offs and five night landings, if the flight is conducted wholly or partly by night,
- (2) in the case of a glider, at least:
- (i) five take-offs and five landings in a glider, or
  - (ii) two take-offs and two landings in a glider with the holder of a flight instructor rating - glider and obtained a certification of competence to carry passengers on board a glider from that holder in accordance with the personnel licensing standards.

### **3 - Privileges Conferred by the Glider Pilot Licence**

**401.24** The holder of a pilot licence - glider may, under day VFR, act as:

- a. pilot-in-command of a glider in which no passenger is carried on board;
- b. pilot-in-command of a glider in which passengers are carried on board where
  - (1) the glider is launched by a method of launch endorsed by the holder of a flight instructor rating - glider in the holder's personal log pursuant to subsection 401.18(1) or (2), and
  - (2) the method of launch has been used by the holder for not less than three previous solo flights.

### **4 - Mandatory Documents On Board Aircraft in Flight**

- Certificate of Registration
- Certificate of Airworthiness
- Annual Airworthiness Information Report
- Weight and Balance
- Operator's Handbook
- Proof of Insurance
- Journey Log

- Interception Orders
- Licences and Validation Certificate (Medical)

Exceptions granted to the ACGP: The annual airworthiness report is not required to remain on board. The Journey Log is not required for local flight.

## **5 - Journey Log and Aircraft Technical Log**

### **Journey Log**

The Journey Log must be carried on a board the aircraft if the pilot in command intends to stop at an airfield other than the point of departure or if the flight exceeds 25NM from the point of departure. Flight times, air times and details on the flight and any defects are recorded in the Journey Log. It should be kept for at least one year when full (CARs 605.94(3))

Items to check before flight (9 items):

- Hours remaining before the next inspections
- 100 hour inspection performed within 12 months prior to the flight
- no snags
- Compass calibrated within 12 months prior to the flight.
- First aid kit inspected within 12 months prior to the flight
- Fire extinguisher inspected within 12 months prior to the flight
- ELT inspected within 12 months prior to the flight
- ELT battery replaced within 24 months prior to the flight
- Calibration of the transponder, the recording altimeter, the static port and dynamic port within 24 months prior to the flight, if the flight is carried out within Class A, B, C or D airspace in which a transponder is required.

## **Technical Log**

All maintenance, installations, modifications and repairs must be recorded in the Technical Log. The Technical Log is composed of a log for the airframe, a log for each motor, a log for each propeller and a log for installations and modifications. The technical log **MUST NOT** be carried on board.

## **6 - Crediting of time**

**Dual-control aircraft:** The pilot-in-command of a flight or any portion of a flight in a dual control aircraft shall be designated prior to takeoff. There shall be a satisfactory method of intercommunication between pilots in all aircraft under dual control. Flight time for pilots may be credited either as dual, pilot-in-command (solo) or co-pilot. Only the pilot designated as pilot-in-command may be credited with pilot-in-command (solo) flight time.

**In-Flight Instruction (non-Licensed pilots):** Only a pilot holding a valid instructor rating may give in-flight instructions. When receiving in-flight instruction from an authorized flying instructor, a student pilot may be credited with dual flight time only. An instructor may be credited with pilot-in-command flight time when giving in-flight instruction to a student pilot.

**In-flight Instruction (Licensed Pilots):** The flight time acquired may be credited to the pilot-in-command as pilot-in-command time, and as dual flight time to the pilot receiving the training.

**Flight Time Credit:** If the applicant holds a glider pilot Licence, 5 hours shall be credited; up to five hours of glider PIC time to the total flying experience.

The applicant for or holder of a permit, Licence or flight crew qualification must keep a personal logbook in accordance with the issuing standards of personnel Licences, with regards to the following points:

- a. experience acquired relating to the issuing of permits, Licence or qualifications;
- b. knowledge recency requirements.

The personal log must be kept up to date in accordance with section 1 a and 1.b. It must contain the name of the holder and the following information with regards to each flight:

- the date of the flight;
- the type and registration markings of the aircraft;
- the flight crew post occupied by the holder;
- the flight conditions : day, night, VFR and IFR;
- if in an airplane or helicopter, the points of departure and arrival;
- if in an airplane, all takeoffs and landings at points between departure and arrival;
- flight time;
- in the case of a glider, the launch method employed.

It is forbidden for anyone to make an inscription in a personal logbook unless the person is the holder of the logbook in question or has been authorized by the person in question.

## **6 - Airworthiness and Certificate of Airworthiness**

It is the responsibility of the owner or pilot to ensure that Canadian registered aircraft are fit and safe for flight prior to being flown.

**Certificate of Airworthiness (C of A):** Certificates of airworthiness are issued for aircraft that fully comply with all standards of airworthiness

**Flight Permit:** Issued for experimental aircraft or for a specific purpose.

**Annual Airworthiness Information Report:** Certifies that the information regarding Airworthiness is correct. No independent certification, inspection or flight test is required. The date of the most recent inspection as well as the last incident of damage to the aircraft, the total flight time of the aircraft as well as the owner's signature must be included.

**Airworthiness (4 items):**

- Maintained in accordance with the calendar of maintenance
- 100-hour inspection or annual inspection within the 12 months prior to the flight.
- Airworthiness Directives have been respected
- There are no deficiencies in the Journey Log, nor any found during the pre-flight inspection.

**Cancellation of Certificate of Airworthiness (5 items):**

- Aircraft destroyed
- Aircraft exported
- Certificate destroyed
- Aircraft used other than as approved in the POH
- Maintenance not performed or improperly performed

## **8 - Flight Plans and Flight Itineraries**

**Flight Plan**

A VFR flight plan must be filed for all flights conducted further than 25 NM from the departure aerodrome, unless a Flight Itinerary has been filed.

A flight plan shall be filed with an air traffic control unit, a flight service station or a community aerodrome radio station.

The purpose of a flight plan is to allow the authorities to determine with greater precision where you are going, how much time you estimate it will take, the number of people on board etc in case an emergency response is required.

Flight plans must be closed within one hour of your estimated time of arrival at the destination or before the specified time of SAR initiation in the flight plan.

## **Flight Itinerary**

A flight itinerary must be filed for all flights exceeding 25 NM from the departure aerodrome, unless a flight plan has been filed.

A flight itinerary may be filed with a "responsible person" - means an individual who has agreed with the person who has filed a flight itinerary to ensure that the following are notified in the manner prescribed in this Division, if the aircraft is overdue, namely:

- a. an air traffic control unit, a flight service station or a community aerodrome radio station, or
- b. a Rescue Coordination Centre.

A flight itinerary is less specific than a flight plan; the only precise information is the ETA and destination.

Flight itineraries must be closed within 24 hours following your estimated time of arrival at destination or before the search and rescue initiation time specified in the itinerary when different from 24 hours.

## **9 – Pilots Responsibilities Regarding Flight Planning, Pre-flight Inspections and Weight and Balance**

### **Flight Planning**

Before undertaking a cross-country flight, the pilot must be sure to have:

- adequate and current aviation maps ;
- carefully prepared navigation
- flight plan or flight itinerary filed
- weather information obtained by bulletin or by briefing from a Flight Information Station
- NOTAMs.
- determine aircraft's performances



- calculate weight and balance
- performed a complete passenger and crew briefing.

### **Pre-flight inspection**

Pre-flight inspections must be performed in accordance with the manufacturer's manual, checklists and school procedures before each flight. Verify the validity and conformity of documents carried on board with the requirements before flight and carry them on board.

### **Weight and Balance**

A weight and balance calculation using the graphs and tables in the POH must be carried out to ensure that the centre of gravity is within permissible limits and to determine if the aircraft is adequately loaded in accordance with the principles of FLIGHT SAFETY.

## **10 - Arrival reports**

An arrival report must be made to ATC, an FSS or CARs (Community Aerodrome Radio station) within 60 minutes of the estimated time of arrival indicated on the flight plan, 24 hours of the last estimated time of arrival for a flight itinerary or at the latest the SAR dispatch time indicated on the flight itinerary. It must include:

- aircraft registration
- type of Flight Plan (IFR or VFR)
- departure aerodrome,
- date and time of arrival
- arrival aerodrome

## 401.04 – Airspace

### 1 - Canadian Airspace

Class	Height	VFR Permitted	IFR permitted	ATC Clearance required	Transponder required	2-way radio required
A	18000' and over	-----	x	x	x	x
B	12500' to 18000'	x	x	x	x	x
C	Varied	x	x	x	x	x
D	Varied	x	x	Separation for IFR only	If indicated as a transponder zone	x
E	Varied	x	x	Separation for IFR only	If indicated as a transponder zone	-----
F	Advisory or Restricted airspace ( CYA or CYR )					
G	The remaining uncontrolled airspace (airspace not classified as A, B, C D, E or F)					

- Class C and D airspace revert to Class E when the ATC unit is not operational.
- Canadian Domestic Airspace includes all airspace over the continental territory of Canada
- Low-level airspace includes all airspace below 18000' (not included) ASL.
- Upper level airspace includes all airspace from 18000' ASL (included) and up.

## **2 - Air Traffic Control**

**Role of ATC:** Prevent collisions and accelerate the flow of air traffic.

Flight information services and Air Traffic Control services are offered through the Area Control Centers (ACC) and Terminal Control Units (TCU) and air traffic control towers inside a control zone. The range of services provided includes but not limited to:

- Airport control service
- Area control service
- Terminal control service
- Terminal radar service
- Alerting Service
- Airspace Reservation service
- Aircraft Movement Information service
- Customs Notification service (ADCUS)
- Flight Information service

## **3 - Canadian Airways**

### **Airway:**

Airways are established between specified radio-navigation aids. Air traffic control services are always provided.

### **Air Route:**

Routes are established between specified radio-navigation aids. Air traffic control service is not provided.

## **4 - VFR Cruising Altitudes**

The following cruising altitudes apply to all VFR traffic below 18 000 feet ASL. Flight altitudes are calculated with reference to MAGNETIC TRACK in the Southern Domestic Airspace and TRUE TRACK in North Domestic Airspace. These rules apply from 3000' AGL and above.

000°-179°                      ODD thousands plus 500 feet (ASL)  
ex: 3500' ASL, 5500' ASL

180°-359°                      EVEN thousands plus 500 feet (ASL)  
ex: 4500' ASL, 6500' ASL

## **5 - Altimeter Setting**

### **Altimeter Setting Region**

The Altimeter Setting Region is an airspace of defined dimensions below 18 000 feet ASL (18000 not included), within the Southern Domestic Airspace, where the pilot must calibrate the altimeter of the aircraft using the current altimeter setting of the aerodrome or if that is not available, to the aerodrome elevation prior to taking off. Pilot will see to get a current altimeter setting when airborne with the nearest station able to provide that information.

### **Standard Pressure Region**

Includes all airspace of the Canadian Domestic Airspace above 18 000 feet ASL (included) and all airspace outside the Altimeter Setting Region. The altimeter must be calibrated to 29.92" Hg for cruise flight. In fact, standard pressure region is everywhere outside the low level south domestic airspace.

### **Transition between altimeter setting and standard pressure**

The pilot must change calibration once established in the Standard Pressure Region. On a climb, the pilot will change calibration immediately after passing through 18 000' ASL. On a descent, the pilot will change calibration immediately prior to passing through 18 000' ASL. The same principle applies when crossing horizontally from one region to another. Changes in altimeter setting always take place in the standard altimeter setting region.

## **401.05 - Canadian Aviation Regulations**

### **1 - Aircraft Operation and Equipment**

**Aircraft Equipment:** see lesson 401.02

#### **Arrival procedures, controlled airport**

**Controlled airports:** Pilots must establishing and maintain radio communication with the appropriate control tower BEFORE entering its control zone (class D and above). It is recommended to establish initial contact at least 5 minutes before requesting a clearance or before entering the zone.

**Initial Clearance:** On initial contact, the controller will inform the pilot about the runway in use, the direction and strength of the winds, the altimeter setting and will brief him on all other pertinent information. Then the controller will authorize the pilot to enter in the circuit at a specified stage of that circuit and will provide a sequence number if the aircraft is not first in for landing. A clearance to enter class C and above airspace is required as opposed to a class D airspace where only establishing communication with ATC is required before entering.

**Landing Clearance:** The pilot must obtain a landing clearance before landing at a controlled airport.

## **NORDO Aircraft procedures**

**Light signals:** see lesson 401.02.02

**Aerodrome circuit:** The pilot must approach the aerodrome traffic circuit from the upwind side of the runway to join the circuit on the crosswind leg at circuit altitude, at a point situated about halfway between the two ends of the runway, so as to integrate the aircraft in the circuit on the downwind leg.

**Final Approach:** Before turning for final approach, the pilot must confirm visually that no aircraft is performing a straight-in approach.

**Landing Clearance:** Authorization to land will be given when the aircraft is established on final approach. If the pilot does not receive this clearance, he must go around and fly another circuit.

## **RONLY aircraft procedures**

The same procedures apply to RONLY as to NORDO. The airport controller may request the pilot to acknowledge a message in a particular fashion (rocking wings, flashing landing light, pressing IDENT on the transponder, etc.)

## **Uncontrolled airport**

Aircraft operating from uncontrolled aerodromes must monitor a common frequency (MF), which is generally 123.2 MHz. Pilots must broadcast their intentions when arriving or departing the aerodrome on this frequency.

Takeoff and landing are normally performed on the runway closest to the wind. Since this decision is ultimately the responsibility of the pilot and since the pilot is responsible for the safety of the aircraft, he may choose to use another runway if it is necessary for safety considerations.

Aircraft must normally enter the downwind or crosswind leg at an altitude of 1000' AAE. When joining the circuit from the upwind site, pilots must plan their descent in order to over-fly the runway in level flight at 1000' AAE or at the published circuit altitude. Unless otherwise specified in the CFS, all turns in the circuit should be left turns.

If it is necessary to over-fly the aerodrome before joining the circuit, it is advisable to do so at an altitude 500' higher than circuit altitude. Descent to circuit altitude must normally occur on the side of the runway opposite the traffic circuit or well clear of the circuit.

**602.101** The pilot-in-command of a VFR aircraft arriving at an uncontrolled aerodrome that lies within an MF (mandatory frequency) area shall report:

- a. before entering the MF area and, where circumstances permit, shall do so at least five minutes before entering the area, giving the aircraft's position, altitude and estimated time of landing and the pilot-in-command's arrival procedure intentions;
- b. when joining the aerodrome traffic circuit, giving the aircraft's position in the circuit;
- c. when on the downwind leg, if applicable;
- d. when on final approach; and
- e. when clear of the surface on which the aircraft has landed.

**ATTENTION:** aircraft performing instrument approach will also report while on the procedure turn (or conventional turn). That is: they are aligning the aircraft on the final path for a straight in approach 7 to 10 nm out on the runway axis. You have to consider that you might conflict with them when turning base or final if you are in downwind at the time they make their radio call and therefore consider not turning base until you cross them in their short final approach.

## 2 - Accident and Incident Reporting

### Categories

- **Aviation Occurrence:** Any accident or incident relating to the operation of an aircraft
- **Aviation Accident:** An accident related to the use of an aircraft in which :
  - A person is seriously injured or killed.
  - An aircraft sustains substantial damage which affects its structural strength, performance or flight characteristics or is reported lost or inaccessible.

**Substantial damage:** Any damage which can be repaired locally but which renders the aircraft incapable of flight.

### Aviation Incident

An incident relating to the use of an aircraft during which occurred:

- Engine failure
- Radio failure
- Smoke or fire
- Difficulties controlling the aircraft
- The aircraft departs the intended take-off or landing area
- Flight crew incapable of performing duties
- Depressurization
- Fuel starvation.
- The aircraft is refueled with incorrect or with contaminated fuel.
- A collision or loss of separation occurs between aircraft
- An emergency is declared
- Dangerous goods are spilled within the aircraft or are released from the aircraft.



## **Aviation occurrence reports**

When an accident occurs, it must be reported to the Transportation Safety Board of Canada (TSB). The report must contain the following information regarding the accident:

- the type, model, nationality and registration of the aircraft.
- the name of the owner and if applicable the operator and renter of the aircraft.
- the name of the PIC
- the time and date of the accident.
- the last point of departure and intended destination.
- the actual position of the aircraft (latitude and longitude)
- the number of flight crew on board and the number of deaths.
- a description of the accident
- a detailed description of all dangerous materials on board the aircraft
- the name and address of the writer of the report.

## **Preserving the integrity of an aviation occurrence site, the aircraft, its components and documentation.**

It is forbidden to move or touch anything on the site of an aviation occurrence unless authorized by an investigator except: 1) to save a person; 2) protect evidence from destruction by fire or exposure; 3) security of persons or goods.

## **3 - Transportation Safety Board**

Performs investigations following an aviation accident or incident. The goal of the investigation is to prevent the occurrence of a similar event. The investigation is not intended to lay blame or responsibility. However, keep in mind that some other instances might!

## **4 - Seats, Harness and Safety Belts on Board**

No person shall operate an aircraft other than a balloon unless it is equipped with a seat and safety belt for each person on board the aircraft other than an infant. (2 years or less)

When seats are not provided for passengers or parachutists the pilot must ensure that a restraint system is securely fastened to the main structure of the aircraft.

The pilot-in-command shall ensure that at least one pilot is seated at the flight controls with safety belt fastened during flight time.

If responsible for an infant for whom no child restraint system is provided, the infant shall be held securely in the adult passenger's arms.

## **5 - Use of Oxygen**

Where an aircraft is operated at cabin-pressure-altitudes above 10,000 feet ASL but not exceeding 13,000 feet ASL, each crew member shall wear an oxygen mask and use supplemental oxygen for any part of the flight at those altitudes that is more than 30 minutes in duration. Oxygen must then be available for at least 10% of passenger (at least one) present onboard. Oxygen shall be used at all times and by every personal onboard (crew and passengers) when operating at a cabin-pressure-altitude exceeding 13,000 feet ASL.

## **6 – Distress, Emergency and Safety Calls**

See Chapter 4, Radio Procedure (PO 401).

## 7 - Wake Turbulence

Wake Turbulence caused by wing-tip vortices is a by-product of the creation of lift. The higher pressure below a lift-generating wing moves to the area of lower pressure on the upper surface, turning around the tip of the wing. This “tornado” movement of air is very pronounced at the wingtips. The vortices follow the upper surface of the wing and leave the airfoil as a spiral inclined down and aft. Wake Turbulence is thus composed of two cylindrical vortices rotating in opposite directions, one from each wingtip. Strongest vortices generated by: heavy airplane, low speed, clean configuration.

**To reduce induced drag:** Wingtip vortices, a component of induced drag, can be reduced only during the aircraft design process. A wing with a high aspect ratio will generate less induced drag than a low aspect-ratio wing. This why gliders are designed with long wingspan and short chord.

**To avoid wake turbulence:** Wait at least 2 minutes before landing or taking off behind another aircraft. Before taking off behind a large aircraft, take off before its rotation point and remain above its climb path. When landing, remain above its approach path, note the large aircraft’s touch-down point and land past this point.

**Ground effect:** Reduces induced drag when the aircraft is flying at low speed very close to the ground. Contrary to common belief, this is not because the aircraft is supported by a cushion of air between the wings and ground.

**Responsibility:** Even if ATC has its own requirement regarding wake turbulence, the PIC is ultimately the SOLE responsible for wake turbulence avoidance.

## 8 – Blood Donation, SCUBA Diving and Anesthesia

**Blood Donation:** Generally, active pilots should not donate blood, but if blood has been donated they should not fly for at least 48 hours. (AIR 3.14)

**SCUBA Diving:** After non-decompression dives, flights up to altitudes of 8 000 feet ASL (2432m) should be avoided for 12 hours. Where decompression stops have been required on returning to the surface, the interval should be 24 hours. For actual flights above 8 000 feet ASL the interval is 24 hours, regardless of the type of dive, as even pressurized aircraft may lose cabin pressurization. (air 3.6)

**Anesthesia:** With spinal or general anesthetics, or with serious operations, you should not fly until your doctor says it is safe. After local anesthetic, you should wait 24 hours before flying (AIR 3.13)

## **9 – Signs and Symptoms of Hypoxia**

**Hypoxia:** Hypoxia is a lack of sufficient oxygen for the body to operate normally. Its onset is insidious and may be accompanied by a feeling of well-being, known as euphoria. To avoid hypoxia do not fly above 10 000 feet ASL (3 048 m) without supplemental oxygen or pressurization or above 5000 feet ASL at night. The use of cigarette can result in one feeling hypoxia symptoms at lower altitude.

## **10 - Spatial Disorientation and Flicker Vertigo**

Spatial disorientation refers to loss of directional awareness or confusion regarding actual position or movement relative to the ground.

**Flicker Vertigo** refers to a phenomenon which may occur when a single-engine aircraft is descending directly into the setting sun. The spinning propeller at idle power causes a stroboscopic effect which can cause nausea, mental confusion or, rarely, unconsciousness in certain individuals.

The word “vertigo” is sometimes used to refer to spatial disorientation. Vertigo is a sensation of rotation or turning, a hallucination of movement of the victim or the environment.

## **11 – Consumption of Alcohol and Medication**

**Alcohol:** The legal limit dictated by Transport Canada is 8 hours from the last alcoholic beverage until flight. The ACGP limit is 12 hours, in accordance with CF policy. After excessive consumption (i.e. “getting drunk”) the time limit is 48 hours. Generally speaking pilots should not fly if still under the effects or after-effects of alcoholic consumption, including hangover.

**Medication:** Before it was prohibited to fly when drugs were used. Now, restrictions on flying are based on the medication and the condition being treated. Assuming individuals have not experienced side-effects during the initial period of treatment, some medications are approved for use without flying restrictions. To know the exact list see A-CR-CCP-242/PT-006, chapter 1, section 4 (aeromedical, proficiency and currency standards (physiological restrictions)) points 1, 2, 3 and 4.

## **12 - Aircraft Surface Contamination on the ground**

**Weight:** Accumulation due to snow and ice. Remove even if no flight is planned. Never assume that snow will blow off during take-off; it may even compact into ice during flight. Weight is not the real problem as ice/snow build up will seldom put the aircraft over its total weight limit. The real danger is the change in flight characteristic of the airplane.

Containments will decrease lift and increase drag as well as modify flight characteristics in an unpredictable way that could potentially be disastrous.

**Critical Surfaces:** of an aircraft means the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface on an aircraft and, in the case of an aircraft that has.

**Water:** Accumulated water in the static and pitot ports, ventilation port, and air intakes may freeze, causing malfunctions.

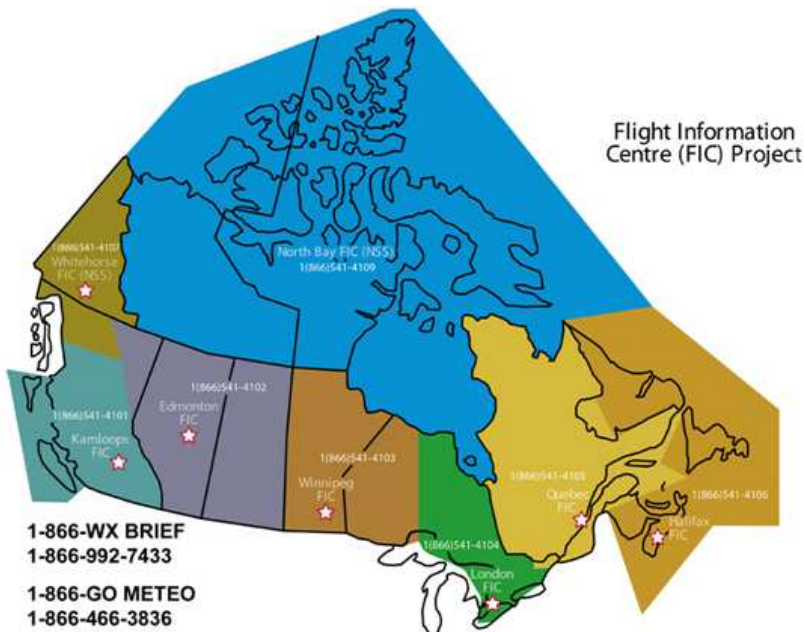
**Pre-flight Inspection:** Do not let cold temperatures prevent you from performing a thorough inspections; indeed extra vigilance is required.

## 12 - FIC: Flight information center

NAV CANADA's flight information services were initially provided by a network of Flight Service Stations. These stations were designed to provide a full range of flight information services - from local airport advisories, vehicle control and aviation weather observations to pre-flight briefings, flight planning, and alerting and enroute radio communications services.

As the aviation industry evolved, significant improvements to the provision of flight information services were required. In 1998, NAV CANADA commissioned a study to evaluate and improve flight information services for the aviation community. Based on the study's findings and feedback from an extensive national consultation, NAV CANADA developed the Flight Information Centre Project to consolidate flight information services.

One common toll-free phone number - 1-866-WXBRIEF (1-866-992-7433) in English and 1-866-GOMETEO (1-866-466-3836) in French - automatically directs you to a FIC in the service area from which the call originates (1-866-GOMETEO routes to the Québec FIC for French service across Canada).



## REVIEW QUESTIONS:

1. When two aircraft are converging at approximately the same altitude,
  - (1) Both aircraft must change heading to the left.
  - (2) The aircraft on the right must descend to avoid the other.
  - (3) The aircraft which has the other on the right must cede the right-of-way
  - (4) The aircraft which has the other on the left must cede the right-of-way.
  
2. In order to pass an aircraft at your 12 o'clock and at the same altitude, you must
  - (1) Climb.
  - (2) Descend.
  - (3) Change heading to the right.
  - (4) Change heading to the left.
  
3. A series of flashing green lights directed at an aircraft signifies respectively:

in flight	on the ground
(1) you are cleared to land;	you are cleared to taxi;
(2) return for landing;	you are cleared for take-off;
(3) return for landing	You are cleared to taxi;
(4) you are cleared for landing;	you are cleared for take-off
  
4. A series of flashing white lights directed at an aircraft in the maneuvering area of an airport signifies:
  - (1) stop.
  - (2) return to your point of departure on the airport.
  - (3) you are cleared to taxi.
  - (4) clear the landing area in use.

5. An airport is an aerodrome:
  - (1) with paved runways.
  - (2) with a control tower.
  - (3) registered
  - (4) certified.
  
6. All runways and taxiways or parts there-of which are closed to aircraft are marked with:
  - (1) red flags;
  - (2) Square red panels marked with yellow diagonals;
  - (3) A white or yellow X;
  - (4) white chevrons.
  
7. An ATC instruction:
  - (1) must be complied with once received by the pilot, so long as the instruction does not compromise the security of the aircraft;
  - (2) must be “read back” to the controller and confirmed before coming into force;
  - (3) is actually a recommendation given by ATC, and the receiving pilot is not obliged to comply nor to acknowledge reception;
  - (4) Is the same thing as an ATC clearance.
  
8. If, after acknowledging a clearance, the pilot realizes that he cannot comply with it, he must:
  - (1) take the actions required by his immediate situation and advise ATC when possible;
  - (2) comply as closely as possible to the clearance and say nothing to ATC;
  - (3) Disregard the clearance;
  - (4) Comply with the parts of the clearance which are acceptable.



9. The main goal of a Flight Safety investigation, following an aviation accident or incident, is to:

- (1) determine fault and responsibility;
- (2) determine the applicability of insurance laws;
- (3) enforce the law;
- (4) prevent a recurrence of the incident.

10. After an aviation accident, the pilot or operator of the aircraft in question must transmit the details of the accident to the TSB:

- (1) within seven days by registered mail;
- (2) within 24 hours by telephone;
- (3) within 48 hours by fax;
- (4) as soon as possible by the fastest communication medium.

11. As part of initial contact with a Canadian ATC unit, the pilot of the aircraft C-GFLU should transmit the aircraft registration as:

- (1) "Lima Uniform, over."
- (2) "Foxtrot Lima Uniform, over."
- (3) "Golf Foxtrot Lima Uniform, over."
- (4) "Charlie Golf Foxtrot Lima Uniform, over."

12. ATIS is usually provided:

- (1) to replace the FSS;
- (2) to reduce congestion on the radio frequencies.
- (3) for rapid updates on weather forecasts.
- (4) only when VMC conditions prevail at the airport.

13. The pilot of an aircraft in flight should if possible maintain a listening watch for distress signals on:

- (1) the ELT in "Receive" mode.
- (2) VHF frequency 121.5 on the onboard radio.
- (3) VHF frequency 121.5 during the first 5 minutes of every hour.
- (4) the IDENT frequency of the radio navigation aid being used.

14. Unless oxygen and oxygen masks are available, as specified in the CARs, no person shall pilot a non-pressurized aircraft above:

- (1) 9 500 feet ASL.
- (2) 10 000 feet ASL.
- (3) 12 500 feet ASL.
- (4) 13 000 feet ASL.

15. The CARs identify an "infant" as a person:

- (1) weighing less than 30 lbs;
- (2) under 3 years of age;
- (3) weighing less than 50 lbs and under 5 years of age;
- (4) under 2 years of age.

16. Once the PIC has instructed that seat belts be fastened, all infants for whom a child restraint system is not provided must be:

- (1) securely belted into a seat using the seat belt;
- (2) held securely in the arms of an adult who has their seat belt fastened;
- (3) held securely in the arms of an adult with the seat belt around the adult and infant;
- (4) secured by any of the above methods.

17. When the ceiling is reported at 1000 feet and visibility is reported at 3 miles, in order to maintain VFR flight, an aircraft cleared to enter the circuit must:
- (1) fly as high as possible without entering the clouds;
  - (2) fly 500 below the base of the clouds;
  - (3) fly at 700 feet AGL;
  - (4) conform to Special VFR limits.
18. Pilots shall activate the “IDENT” control on their transponder:
- (1) prior to entering the control zone;
  - (2) only when instructed to do so by ATC;
  - (3) before each change of altitude;
  - (4) after each change of transponder code.
19. The holder of a student pilot permit may, for the sole purpose of flight training, act as PIC of an aircraft;
- (1) only while accompanied by a flight instructor;
  - (2) during the day and night;
  - (3) only during the day;
  - (4) and carry passengers.
20. To avoid wake turbulence, when taking off behind a heavier aircraft, a pilot should:
- (1) remain in ground effect until after the point of rotation of the larger aircraft;
  - (2) take off in the calm air between the vortices;
  - (3) taxi to beyond the rotation point of the large aircraft, then take off remaining below the climb path of the large aircraft;
  - (4) take off before the rotation point of the large aircraft and climb to remain above its climb path, or request a turn to avoid its trajectory.

# 403 – Aerial Navigation

## 403.01 - Navigation Basics

### 1 - The Earth

The Earth is a sphere, or rather an « oblate spheroid »: a sphere flattened at the top and bottom. The surface of the globe is divided by convention into a geometrical pattern of intersecting circles called the **graticule**. The Earth turns on its axis from west to east. It's axis meets the surface at the North and South true poles.

#### **Magnetism**

The Earth is a magnet, with a North and South magnetic pole. Invisible lines of force link the two poles, creating a magnetic field which encircles the planet. The lines of force emanate from the North Pole and return to the core via the South Pole. The lines they follow are called Magnetic Meridians. The lines of force are horizontal, parallel with the Earth's surface, at the Equator; they become gradually more vertical as they approach the poles. This is magnetic dip and will induce some errors in compass indications. Magnetic North and South poles are not located at the same position as the true North and South poles. Furthermore, the position of the Magnetic Pole changes very slightly from year to year.

### 2 - Definitions

**Heading:** The direction in which the longitudinal axis of an aircraft is pointed, usually expressed in degrees clockwise from North (True, Magnetic or Compass Heading).

**True Heading:** is heading measured in relation with a true meridian.

**Magnetic Heading:** is the heading in relation with a magnetic meridian. Variation is used to convert heading or bearing from true to magnetic or vice versa.

**Compass Heading:** Magnetic Heading corrected for deviation errors of the compass. Heading indication directly read on the magnetic compass.

**Variation:** The angle between the true meridian and magnetic meridian to which the compass is aligned at a given point on the Earth's surface. Most maps are designed and oriented with respect to true poles and meridians. A pilot must convert directions he gets from those map to use it with a magnetic compass. At any given point on the earth, there is an angular difference between true and magnetic north. Also known as magnetic variation.

**Deviation:** The angle formed between the needle of a compass and the magnetic meridian. (A form of compass error). Caused by local magnetic fields created by the metal in the aircraft structure, engine and electronic equipment.

**True and Magnetic Direction:** Direction measured in degrees true when read directly from a map or in magnetic degrees when variation is considered.

**Great Circle:** Circle on the surface of a sphere whose plane passes through the centre of the sphere and which therefore cuts the sphere into to equal parts. An arc of this circle represents the shortest distance between two points. When flying a great circle line, the heading will not stay constant along the path because the earth is an oblate sphere. All meridians are arc of a great circles and the Equator is also a Great Circle

**Magnetic Dip:** Angle between the horizontal plane and the plane of the magnet (or compass) under the influence of a non-horizontal magnetic line of force. This will cause the compass to malfunction at high latitude and will also induce the acceleration / turns errors in the compass.

**Agonic lines (0° variation isogonic line):** Lines shown on a map joining points of zero magnetic variation. That is where the north and magnetic poles are in transit (lie in a straight line) There are two agonic lines, one in north America and the other in on the other face of the Earth.

**Isogonic lines:** Lines on a map joining points of equal magnetic variation. Isogonic lines are labeled « East » or « West » according to their position with regards to True North. They also provide a number which represent the angular correction to convert true degrees to magnetic. You shall add west variation and subtract east variation to convert true to magnetic (“West is best (+), East is least (-)”) or the reverse to convert magnetic to true.

Isogonic lines (as well as agonic lines) are not straight lines, but rather bend and twist due to the influence of local perturbations in the local magnetic field due to magnetic bodies below the Earth’s surface.

**Rhumb line:** Curved line on the Earth’s surface which intercepts all meridians at the same angle. A straight line drawn on a Mercator projection. All parallels of latitude are Rhumb lines. The Equator has the property of being the only line on the surface of the Earth to be both a Rhumb line and a Great Circle at the same time!

**Direction:** Direction is measured in degrees, numbers clockwise from North. North = 0° or 360°; East = 90°; South = 180°; West = 270°.

**Arc of a Great Circle:** A straight line drawn on a Lambert Conformal Conic Projection is an arc of a Great Circle. All meridians are Arcs of a Great Circle.

**Magnetic North Pole:** The Earth is a magnet. The magnetic field of the planet converges on the two poles, the North and South magnetic poles.

**Bearing:** The angular position of an object in relation to the longitude overflown by your aircraft; also called Azimuth. Measured in the same fashion as direction. Bearing bears no relation to the heading of an aircraft.

### **3 - Characteristics of the Parallels and Meridians; Geographic coordinates**

#### **Meridians of Longitude**

Half-Great Circles joining the geographic poles of the earth (True Meridians) Measured 0° to 180° East and West of the Prime Meridian. (which passes through Greenwich, UK.) The 180th Meridian corresponds along most of its length to the International Date Line.

The Earth is divided into 24 time zones, each 15° of longitude in width. ( $360 / 24 = 15$ ) Longitude is measured in degrees (°), minutes (′) and seconds (″). On some maps, decimals are used instead of seconds.

#### **Parallels of Latitude**

Imaginary circles on the Earth's surface whose planes lie parallel to the Equator. The Equator is a Great Circle, situated equidistant from both Poles. Parallels are measured from 0° to 90° North and South, measured from the Equator. Latitude is measured in degrees (°), minutes (′) and seconds (″). On some maps, decimals are used instead of seconds. **Each minute of Latitude represent 1 NM in length.**

## **How to Use Geographic Coordinates**

The intersection of lines of latitude and longitude identify a position on a map. It is used to precisely identify any location on the terrestrial surface. The distance between any point and another point can be determined from the change in latitude and change in longitude between the two points through some trigonometric calculations which you will not learn here! The process used to determine geographic coordinates will be explained in class. The following is an introductory explanation and exercise.

Here is a geographic coordinate, which describes a precise location (within 100 feet):

49°46'55''N 77°48'20''W

° represents degrees, ' minutes and '' seconds

There are 60 minutes in a degree and 60 seconds in a minute.

**49°46'55'' N** is latitude coordinate; N indicates that the coordinate is north of the Equator

**77°48'20''W** is a longitude coordinate. W indicates that the coordinate is West of the Prime Meridian. Latitude number increase when going toward the North Pole for north latitudes and going toward the South Pole for south latitudes. Same principle applies to meridians. They increase toward west for west longitudes and toward east for east longitudes

### **Example:**

1. Open the map in the back pages of your copy of FTGU and find the airport in Trenton ON (On the North shore of Lake Ontario, about in the middle of the lake). When the map is positioned so you can read the text, the top of the map is North, the Bottom is South, the left margin is West and the right margin is East.
2. Note the graduated black lines running horizontally and vertically across the map. These are meridians of longitude and parallels of latitude.



3. Each meridian and parallel represented bears a number in bold text. Trenton is located between  $78^{\circ}00'W$  and  $77^{\circ}30'W$ , and between  $44^{\circ}N$  and  $44^{\circ}30'N$ . ( $44^{\circ}30'$  is not inscribed on the map; only whole degrees are identified.)

4. To calculate the longitude with more precision, use the graduations drawn on the meridians. Place a ruler oriented vertically on the map and count the minutes from the nearest degree line. Trenton's longitude is  $78^{\circ}32'W$ .

5. To calculate the latitude with more precision, use the graduations drawn on the parallels. Place a ruler oriented horizontally on the map and count the minutes from the nearest degree line. Trenton's latitude is  $44^{\circ}07'N$ .

6. The geographic coordinates of the Trenton Airport are:  $44^{\circ}07'N$   $78^{\circ}32'W$

**Exercise:** Find the coordinates of the Oshawa Airport, located East of the major city of Toronto. The correct answer is found at the end of the chapter.

## 403.02 - Aeronautical Charts

### 1 - Units of Distance

#### Distance

- Statute Mile: 5280 feet.
- Nautical Mile : The average length of a minute of latitude : 6080 feet  
1NM = 1,85 Km  
1NM = 1,15 SM
- Kilometer : 3280 feet

It may also be useful to know that 66 nautical miles = 76 statute miles = 122 kilometers

Example: Convert 250 kilometers into Nautical Miles

$$122 \text{ km} \rightarrow 66 \text{ NM}$$

$$250 \text{ km} \rightarrow x = 135 \text{ NM}$$

Example: Convert 14 Statute Miles into Nautical Miles

$$76 \text{ SM} \rightarrow 66 \text{ NM}$$

$$14 \text{ SM} \rightarrow x = 12 \text{ NM}$$

It may also be helpful to know that, when using a VNC chart (which has a scale of 1: 500 000), 1 inch represents a distance of about 8 Statute Miles.

The best way to determine distance between two points is the paper method. Put a white piece of paper over the map, and put a mark on the edge of the sheet in front of your two points. Then, take your sheet and place it beside the distance scale of the map or simply measure over minutes of LATITUDE what the distances between the two points is. Remember, one minute of latitude measured along a meridian equals one nautical mile.

## 2 - Units of Speed

### Measurements of Speed

**Speed:** the rate of change of position over time compared to an object at rest.

**Miles per hour (mph):** Speed in Statute Miles per hour

**Knots(kts):** speed in Nautical miles per hour

**Kilometers per hour (km/h):** speed in kilometres per hour

**Indicated Airspeed (IAS):** airspeed as shown on the airspeed indicator.

**True Airspeed (TAS):** Actual speed of the aircraft through the air mass. True airspeed is calibrated airspeed corrected for density and temperature errors.

The relationship between Speed, Time and Distance is described by the equation

$$Speed = \frac{Distance}{Time}$$

If you have two of the above variables you can determine the third by manipulating the equation to give those two other results:

$$Time = \frac{Distance}{Speed}$$

$$Distance = Speed \times Time$$

## 3 - Calculations of speed, distance and time

$$D = S \times T$$

Convert minutes to hours.

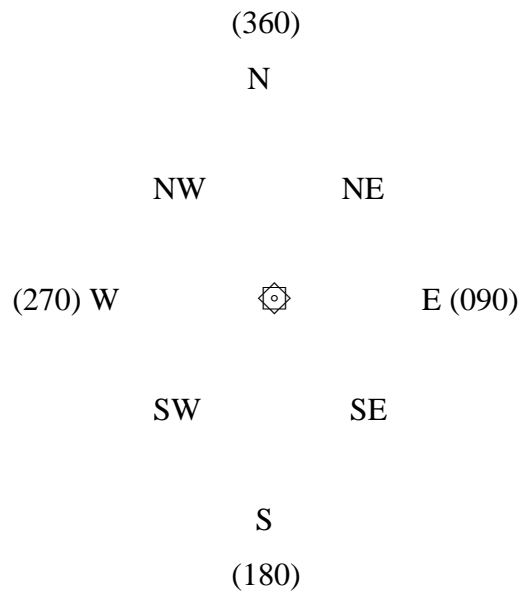
Example: 15 minutes  $15 / 60 = 0.25$  hours

**Examples:**

1. Calculate the distance covered by an aircraft flying at 100 kts for 30 minutes:  
 $D = 100 \text{ kts} \times 0.5 \text{ hours} = 50 \text{ NM}$
2. Calculate the speed of an aircraft which has covered 100 NM in 45 minutes:  
 $V = 100 \text{ NM} / 0.75 \text{ hours} = 133 \text{ kts}$
3. Calculate the flight time of an aircraft which has covered 60 NM at a speed of 70 kts:  
 $T = 60 \text{ NM} / 70 \text{ kts} = 0.86 \text{ hours} = 51 \text{ minutes}$

**4 - Cardinal Points**

Cardinal Points: the Compass Rose



## 5 - Measuring True Track on a Chart

Here is a quick process which will allow the calculation of true track on a chart. You will need a ruler and a Douglas Protractor.

**Example:** Determine the true track for a flight departing Trenton for Oshawa.

1. Find the Trenton Airport and the Oshawa Airport on the chart at the back of your From The Ground Up.
2. Place a point in the centre of each airport diagram.
3. Draw a straight line joining the two points.
4. Take your Douglas Protractor. Place the centre of the protractor on the track, preferably near the midpoint. That is because you just draw an arc of a great circle on your map (a straight line on a VNC is an arc of a great circle) and therefore the heading which is required to follow the track will change along the route. By taking the heading measurement midtrack, you take a mean heading that will take you to your destination. You will find yourself not exactly following your track but on short trip, this error is very small (except if the track is thousands of miles long. Check that the protractor is oriented properly (i.e. North is up, West is left etc)
5. The protractor is graduated so it can be easily aligned with meridians and parallels. Keeping the centre of the protractor on the track line, align one of the meridian lines on the protractor with a corresponding meridian on the map. This will allow a precise reading.
6. Look at where the track lines cross the edge of the protractor. The measure indicated there is the true track for the flight. Thus, the true track from Trenton to Oshawa is 258 degrees. For the return trip the track is 078 degrees. Make sure that you take the reading in the direction you intend to fly to.

**Exercise:** Find the true track for a flight between the Lindsay Airport and Peterborough Airport. \_\_\_\_\_ Both airports are located North of Oshawa. (The correct answer is found at the end of this chapter.)

## **6 - Determine the Variation from a Chart**

Isogonic lines giving the measure of magnetic variation are oblique dashed lines drawn at regular intervals on the map. They represent the angle between true North and magnetic North.

### **Example:**

Find the magnetic variation for the Trenton (Ontario) Airport

1. Open the map found at the end of your From the Ground Up and find the Trenton Airport.
2. Note the oblique line passing just West of the airport. This line is labeled  $11^{\circ}$  W, and tells us that the angle between the positions of the true and magnetic poles is  $11^{\circ}$  wide, with the Magnetic pole appearing to the West of the geographic pole.

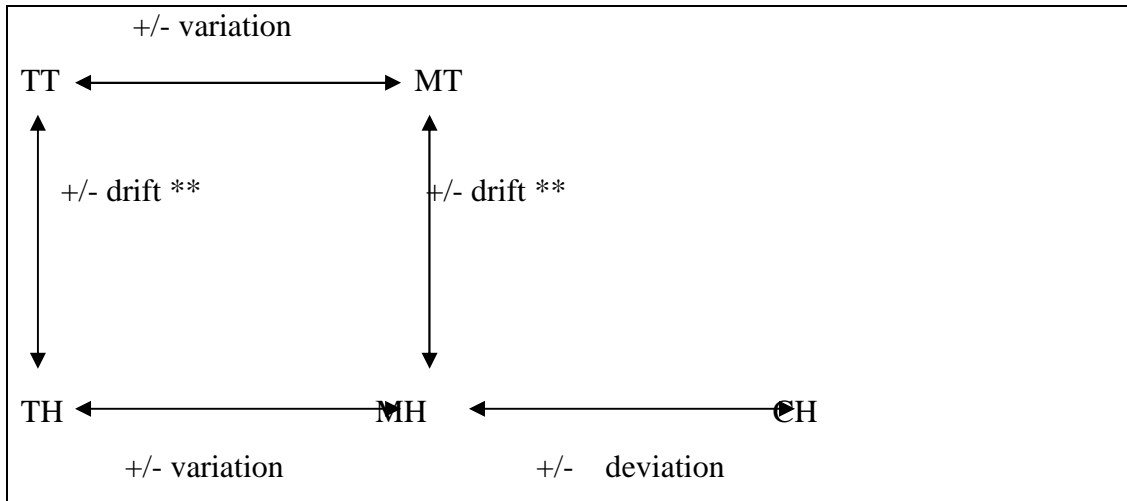
To find the applicable variation for a given flight (ex. Oshawa to Trenton) take the average of the nearby variations. In this case, the route passes over the  $10^{\circ}$ W and  $11^{\circ}$ W isogons; the variation applied is therefore  $10.5^{\circ}$ .

The applicable variation for an airport can also be found in the CFS.

## **7 - Calculation of Magnetic and Compass Headings**

### **Heading conversions**

To convert a true heading to, remember the mnemonic WEST IS BEST, EAST IS LEAST. The reverse is to be applied when converting from magnetic to true. This phrase means to ADD West variation, and SUBTRACT East variation. Here is the formula:



TT: True Track MT: Magnetic Track TH = True Heading: MH: Magnetic Heading  
 CH: Compass Heading

\*\* There is two way around to convert true to magnetic. Either start by considering wind then variation to get to magnetic or start with variation then consider wind. Both methods will lead to the same results. ATTENTION: One must use wind information in true or magnetic depending in which order they are processing their conversion.

Drift is the correction which must be applied to the route to compensate for the winds. Once this correction has been applied true track or magnetic track becomes true heading or magnetic heading.

Deviation is the correction which must be applied to magnetic heading to compensate for compass errors caused by the magnetic properties of the aircraft structure and systems. Once this correction is applied the magnetic heading becomes compass heading. Compass heading is what is used to fly from point to point.

**Exercise:**

TT = 100 degrees

Variation = 10°W

Drift = 5°E

Deviation = 3°W

Magnetic Heading \_\_\_\_\_ Compass Heading \_\_\_\_\_

(The correct answers are found at the end of this chapter.)

## 8 - Scale and Measuring Distance

**Scale:** Relationship between units of distance on the chart to the real distance on the Earth. Two methods of expressing scale are used:

**Representative Fraction:**

The most common expression of scale on charts. Expresses the ratio between a unit of distance on the chart to the corresponding number of units on the Earth. (Ex. 1:500 000 means 1 meter on the chart represents 500 000 meters of distance on the ground.)

**Graduated Scale:**

Simply a line printed on the border of the chart which is graduated to show visually the length of a mile on the chart.

**Measuring Distance**

The scale of the chart is indicated at the bottom of the sheet and permits the measurement of distances on the chart. A navigation ruler has also been printed, graduated in the various scales used on aviation charts such as the VNC, VTA, and WAC, in order to facilitate the pilot's task.

Scale of different charts:      WAC 1 : 1 000 000    or 16 miles to the inch  
   VNC 1 : 500 000      or 8 miles to the inch  
   VTA 1 : 250 000     or 4 miles to the inch.



**Exercise:** Measure the distance in Nautical Miles between the Trenton and Oshawa Airports. \_\_\_\_\_ These airports are found on the map at the end of your copy of From the Ground Up. The correct answer is found at the end of the current chapter.

## **9 – Lambert Conformal Conic Projection**

### **Maps**

A map is a small-scale representation of a section of the terrestrial surface. The Earth is a sphere; the surface can therefore not be precisely reproduced on a 2-dimensional surface. Maps are constructed using four basic elements:

- Areas
- Shapes
- Bearings
- Distances

The mathematical principle on which maps are created is called projection. The projection method is stated on every map.

### **Lambert Conformal Conic Projection**

The Lambert Conformal Conic Projection (LCCP) is based on the geometric model of a sphere projected onto the surface of a cone. The open face of the cone is tangent to the equator, and the point of the cone is vertical of the North Pole. In this projection:

- the meridians converge towards the poles;
- the parallels of latitude are curved and concave towards the nearest pole;
- the scale of distance is essentially uniform;
- a straight line drawn on a map based on the LCCP represents an arc of a Great Circle, and;
- VNC, WAC and Hi / Lo enroute maps are based on this principle.

## **10 - The Mercator and Transverse Mercator Projections**

### **Mercator Projection**

The Mercator Projection is based on a model of a sphere inside a cylinder, where the equator is tangent to the sides of the cylinder. To visualize the model on which this projection is based, imagine a light source inside a glass globe shining outwards, projecting the meridians and parallels onto the surface of a surrounding cylinder (See the diagram in the From The Ground Up page 185). This projection has the following characteristics:

- meridians are straight and parallel lines;
- parallels are straight and parallel lines;
- the scale of distance is not constant;
- a straight line drawn between two points on the map is a Rhumb Line;
- this projection experiences considerable distortion in longitude in the Northern Regions;
- this projection is relatively accurate in the representation of distance in the equatorial regions, and;
- world map is normally based on this principle.

### **Transverse Mercator Projection**

The Mercator projection is used, but in the model the cylinder is rotated 90° around the sphere, so the cylinder walls are tangent with a particular meridian rather than the equator. It is normally used to cover very small area. In this projection the map is entirely accurate only along one meridian. The properties of the Transverse Mercator are similar to those of the Mercator, except:

- scale is precise regardless of latitude;
- Longitude and Latitude will appear curved if the area covered is wide enough;
- distance is precise along the central meridian. And would normally be constant everywhere on the map considering that the area covered is normally very small;
- there is some distortion towards the East and West margins of the map, and;
- VTA map is based on this method.

## 11 - Relief

Representation of the height of terrain above sea level on aeronautical charts. There are three ways to show relief on a chart:

### Layer tinting

The map is colored to represent different levels of elevation. On the white border of every map, an elevation legend is printed indicating the colors used for each elevation.

### Contour Lines

Lines joining points of equal elevation above sea level. The closer the lines, the steeper and more abrupt the terrain slope. The gradient (steepness) of a slope is indicated by the horizontal distance between lines.

### Spot Heights

Particularly high points are indicated on the map, along with the height of the point above sea level. The highest elevation on the chart is identified by bold numbers.

### Known obstacles or groups of obstacles

Elevations are indicated in ASL and in AGL in parentheses.

## 12 - Highest Elevation in a Region of a Chart

**Maximum Elevation Figure (MEF):** A large number is found at the centre of each section formed by lines of longitude and latitude. This number represents the highest terrain altitude within that section + 328 ft (100 m), or the altitude of the highest obstacle known, (Whichever is higher) then rounded up to the next hundred of feet.

**Example:** 3<sub>8</sub> represent the height above sea level in thousands and hundreds of feet. Thus the elevation of the highest terrain or obstacle is considered to be 3 800 ft.

**Highest Elevation on a Chart:** The position and elevation of the highest point on the chart is found in the border over the layer tinting scale, which is found in the legend of the chart.

## **13 - Types of Charts**

### **VFR Navigation Chart ( VNC series)**

These charts are intended for visual navigation. The chart is printed on both sides : the northern half of the map area is drawn on one side and the southern half on the other. Each chart is designated by the name of its major feature (ex.: Toronto, Winnipeg, Montreal...) The scale is 1:500 000, which means 1 inch is equivalent to around 8 miles. VNCs are based on the Lambert Conformal Conic Projection and have the same characteristics as all maps of this projection.

### **World Aeronautical Charts (WAC series)**

These charts are also intended for visual navigation. They are used above all for flight at high altitudes and airspeeds and over long distances. WAC charts are based on the Lambert Conformal Conic Projection and conform to the characteristics of this projection. The scale is 1: 1000 000, or about 16 miles to the inch.

### **VFR Terminal Area charts (VTA series)**

VFR Terminal Area charts are large-scale 1:250 000 published many Canadian airports which have designated Terminal Control Areas and a high traffic volume. VTA border are drawn on VNC map to help the pilot identify where they are located and when he need to refer to them. VTA map contain calling in points and VFR standard procedure inside its boundary. VFR Terminal Area charts are based on the Transverse Mercator projection and conform to all characteristics of this projection.

### **Hi / Lo Enroute Chart**

These charts provide necessary information for radio-navigation using the established airways. Main purpose : IFR flights. These charts do not show cities, towns or geographic features (except major ones); rather they show radio-navigation aids, IFR checkpoints, radio frequencies, etc.

## **Canada Flight Supplement**

The Canada Flight Supplement lists all aerodromes which are found on VNC, VTA and WAC aeronautical charts, for both the northern and southern regions of Canada. Intended for use alongside the aeronautical charts, this book must be carried by all pilots undertaking a long cross-country flight. Within this book is found a diagram of the aerodrome, the layout of the runways, placement of buildings and control towers, alphanumeric code of the aerodrome, geographic coordinates, magnetic variation, local time conversion, elevation of aerodrome, radio frequencies, the services offered and various other information.

Also, a pilot will find on which map is the airport represented and will find a list of up to date maps to ensure that his own maps are still valid. Some VFR standard procedures will also be listed where no VTA map exists for a particular airport.

## **14 - Topographic symbols**

Almost every symbols depicted on an aeronautical map are represented and explained in the legend. Make sure to refer to it for any question about a map. 99% of the time the answer to your question is waiting there for you to find.

### **Isogonic Lines**

These lines (Which join areas of equal magnetic variation) are shown on the map by dashed lines.

The value of variation is printed at regular intervals on the line.

### **Settlements, Roads, Railways**

Towns and villages are represented by yellow squares. Cities and large towns are represented by a yellow area with a black border, which corresponds to the real shape and size of the settlement. Highways are represented by a red or brown line, and divided highways by double lines. Railways are represented by black lines.

## **Aerodromes**

Small aerodromes are represented by a circle. Larger aerodromes with paved runways are represented in their precise location on the chart by a diagram of their runway layout.

## **Restricted Airspace**

Areas in which flight is restricted are identified on aeronautical charts and information regarding the area is printed on the chart. These areas include alert zones, danger areas, restricted airspace, advisory airspace, altitude reservations and military operations areas.

## **Compass Rose**

A circle divided into 360 degrees printed on the chart centered on radio navigation aids (VOR and TACAN) and can be used for measuring directions. Oriented to Magnetic North on charts within the Southern Domestic Airspace and to true North when within the northern domestic airspace. On a VNC, (scale 1 : 500 000), the diameter of the compass rose is about 19 NM.

## **Aeronautical Data**

The aeronautical data legend, explaining all symbols and information found on the chart, is always printed somewhere on the sheet. This legend contains information on the aerodromes, radio installations, airspace, etc.

## **Aerodrome Data**

Next to an aerodrome symbol, there is a line leading to a dashed lined box containing the name of the aerodrome. Under it is written information about elevation of the field, presence of lighting equipment, longest runway length and information about the type of zone and the proper frequency to use at that aerodrome.

## **Radio Aids to Navigation Box and Air/ Ground Communication Box**

(See the legend on the VNC for more information)

## **Obstructions**

Identified by a symbol; usually a tower symbol. Beneath the symbol, the elevation in feet ASL and in feet AGL (in parentheses) is printed.

# **403.03 - Map-reading**

## **1 - Cartographic Analysis**

Mental Route Image From Cartographic Analysis

The route of a cross-country flight generally passes over many potential visual reference points which can be used for navigation. An acceptable reference might be a village, a highway, a golf club or a waterway, etc. It is important that the reference be easily identifiable; as an example, a pilot would not use a small lake as a reference when the terrain is dotted with similar small lakes. At St-Jean-sur-Richelieu, the mountains to the North-East (Mont St. Hilaire, Mt. St. Gregoire, Mt. St.-Bruno, Mont Yamaska etc) can be used as easy reference points as they have distinct and easily recognizable shapes. A pilot using reliable reference points which can be checked against the map will be able to confirm his position and thereby ensure not to deviate from the planned route.

## **2 – How to Orient a Chart**

When following a path marked on a chart, it is recommended to orient the chart to the direction of flight, even if this makes it difficult to read the text because it is sideways or upside-down. This way, visual references will be displayed the same way real points are relatively to the cockpit.

## **3 – Folding a Chart**

A chart should be folded into segments 11 or 12 inches across so the route is about in the centre.

A chart is folded in « accordion » so successive portions of the route can be located in flight by flipping a sheet. If multiple charts are required, each should be numbered and placed in the order of use.

## **4 – Legend**

(See VNC / WAC / VTA chart) Again! 99% of the answers about map you are seeking are waiting for you in that legend.

## **403.04 - Flight Planning**

### **1 – Effect of Wind**

Wind effect in flight has to be considered for navigational purposes. Wind will increase or decrease your flight time required to get to destination and/ or will take you off track. A headwind decreases groundspeed; a tailwind increases groundspeed (Neither has any effect on true airspeed). A pilot who wants to save time and fuel would like to have a tailwind component for the flight. Wind across the track (a crosswind) will cause the airplane to drift. The pilot must therefore calculate the drift angle in order to fly the correct heading to stay on track.

### **2 – Track, True Track, Track Made Good, Groundspeed, Heading, Track Error**

**Track:** The path over the ground the pilot intends to follow. The track can be represented by a straight line drawn on a map. The direction of the flight is the angle this line forms with a meridian, measured clockwise from North (360°). The track can be calculated using True, Magnetic or Compass North (therefore True Track, Magnetic Track or Compass Track).

**Track Make Good:** Is the actual track that the airplane is following over the ground

**Track Error:** Angle between the Track and Track Made Good. Measured in degrees Right or Left of the Track.



**Groundspeed:** The speed of the aircraft over the ground, regardless of its speed through the air mass. The aircraft's groundspeed is equal to the sum of its airspeed and the headwind or tailwind component. If the headwind component is positive (i.e., 10 knots headwind) the groundspeed will be reduced; if the headwind component is negative (i.e. 10 kts tailwind) the groundspeed will be increased.

### **3 – 10-Degree Drift Lines, Opening and Closing Angles**

#### **10-Degree Drift Lines**

These are lines drawn on a map emanating from the point of departure and the destination. The lines emanating from the point of departure have an opening angle; the lines from the destination have a closing angle. Each of these lines forms an angle of  $10^\circ$  with the track line. They are generally drawn with a different color than the track line so as not to confuse them. 10-Degree drift lines help the pilot estimate track error and determine the appropriate correction to apply to the heading.

#### **Opening and Closing Angles**

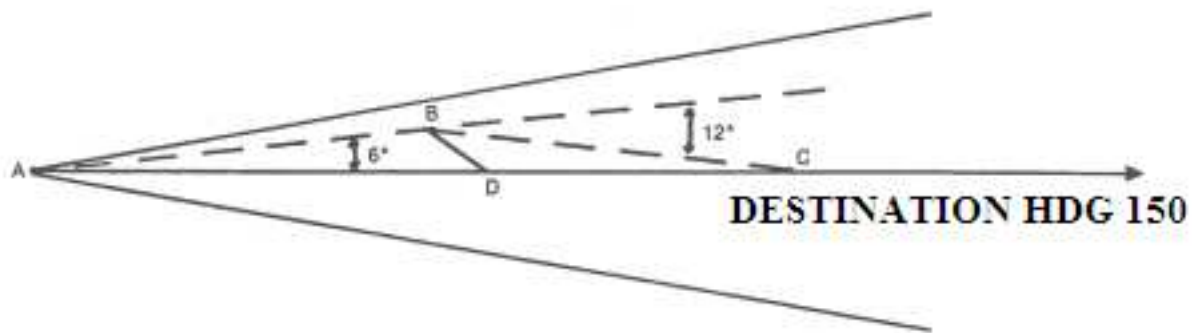
**Opening Angle:** angle between the Track and Track Made Good. Measured in degrees left or right of the Track.

**Closing Angle:** angle between the old Track and the new Track which will bring the aircraft to the destination.

#### **Track Error Correction: Double Track Error Method**

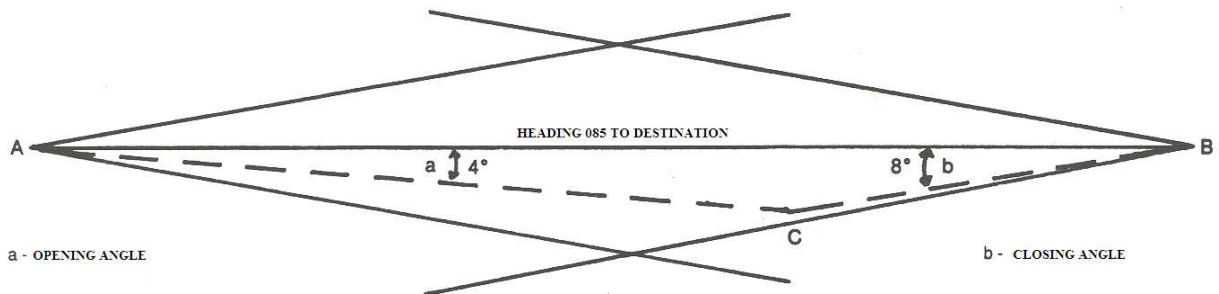
Must be used before passing the halfway point of the leg. While in flight, the pilot determines that he is off the required track. The pilot determines how many degrees the aircraft has deviated to the left or right of the track, using the 10-degree drift lines. The track error is doubled and added or subtracted to the heading in order to intercept the required track. If the drift is to the right, subtract the correction; if the drift is to the left, add the correction. When the aircraft

intercepts the route, half the correction is removed in order to fly the corrected heading to the destination.



### Track Error Correction: Opening and Closing Angles Method

Can be used to correct heading after the half-way point of the leg. While in flight, the pilot determines if the aircraft is off the desired Track. The pilot determines how many degrees the aircraft has deviated to the left or right of the track, using the 10-degree drift lines. To arrive at the destination, the pilot adds the opening and closing angles and modifies the heading by that number of degrees (left or right depending on which side of the track the error occurred) i.e. toward the destination. If the drift is to the right, subtract the correction; if the drift is to the left, add the correction.



### Track Error Correction: Visual Alteration Method

If it is possible to visually identify a landmark found precisely on the track, you can use the landmark to return to the track. You calculate the heading which will place you on a track parallel to your desired track and when you arrive at your landmark on the required track, you fly this heading.

## 4 - One-in-Sixty Rule

A track error of  $1^\circ$  will result in an error of position of about 1 mile sideways after a distance of 60 miles. A pilot on a cross-country flight can tell easily how far he has drifted from his track, but may have difficulty estimating by how many degrees he has been set off course. This rule provides an easy estimation for that.

**Example:** A pilot notices that he has drifted 2 miles right of his route after flying 60 miles, which is halfway to his destination. If he was flying a heading of 090, what is the new heading he must fly to reach his destination? According to the One-in-Sixty Rule, the pilot has drifted 2 degrees to the right of his required route. To correct the error, he must subtract two degrees from his heading to bring the aircraft parallel to his required track (Hdg 088), and then subtract another 2 degrees to bring the aircraft to the destination since he is halfway enroute. Note that opening and closing angle method could have been used as well.

## 5 - Flight Planning Exercise

Preparing a route is the process of assembling all the information necessary for a cross-country flight and noting them on a map for easy reference in flight. For cross-country flights, the most important thing is to understand the weather you will encounter, make sure your map is prepared, have a good idea of the landmarks you will be using and know how to determine your position

No Flight Planning exercise is planned in this chapter. However, the subject is introduced with special attention to the elements to be covered in class.

### Weather

Adequate weather information is required in order for the pilot to make important decisions for the cross-country flight. The best way to get weather information is to obtain a briefing from a Flight Information Specialist at an FSS, or from the Environment Canada Weather service, in person or by telephone. The [NavCanada internet site](http://www.navcanada.ca) (www.navcanada.ca) also provides detailed weather information intended for aviation use.

Once the necessary information has been collected, you can make the decision whether to fly or not. As well, you can prepare for what you will encounter on your path if you do decide to fly. You will learn how to find and apply the pertinent weather information in your upcoming Weather and Navigation courses.

### **Planning the Route**

The planning stage of a flight begins the moment you decide to fly somewhere. Deciding where you are going and where you will begin your flight implies important decisions regarding your route. Straight lines are the fastest routes, but there are other factors to take into account including but not limited to:

- Terrain
- Airspace
- Acceptable off-field landing areas
- Range of the aircraft
- Weather

### **Preparing the Map**

Before drawing anything, be sure to have lead pencils and markers ; to use the correct scale ; and to have at hand your CR-3 flight computer, Douglas Protractor, navigation ruler and the proper maps.

**The track** is the first line to draw on the map. This line should be thick, dark and precise; easily recognizable compared to the other lines on the map.

**10-degree drift lines** are drawn emanating from both extremities of the flight,  $10^{\circ}$  off the track.

**Ten mile marks** are small marks drawn across the track each 10 miles, which will be useful in evaluating your progress. They are drawn starting from the destination back to the departure airfield. Depending on the track length, other values could be chosen. Fractional distance marks divide each interval into equal segments of halves and quarters, simplifying time-enroute calculations.

**A Douglas protractor** is used to find the True Track. Make measurement around mid-track because you remember that your track is an arc of a great circle and therefore heading is not constant along the route.

**Check the isogonic** lines the route crosses (or is the nearest). Use the magnetic variation to calculate the magnetic track.

**Chose a cruising altitude**, based on the magnetic track (if over 3000' AGL), based on the obstructions along the route, the wind direction and speed etc.

**Measure** the distance of the route.

**Using the flight computer** or a triangle of velocities, calculate the drift caused by the forecast winds (true heading and magnetic heading) and your expected groundspeed. You will need to know your true airspeed and the speed and direction of the winds at your chosen cruising altitude.

The triangle of velocities will be discussed in more detail later in this document.

**The deviation** must be determined using the For-Steer card of the aircraft. The result is the compass heading. This is what will be used to actually fly the route. Refer to lesson 403.02 (7) for conversion from True Track to Compass heading procedure.

**The time enroute** and fuel consumption can be calculated from the distance, groundspeed, and the intended cruise power setting respectively. Make sure you have enough fuel including the required reserve

## **Triangle of Velocities (OPTIONAL TOPIC)**

The solution to drift calculation problems is based on the principle of the Triangle of Velocities. The heading and true airspeed of the aircraft are represented by one side of the triangle. The wind speed and direction, drawn on the same scale as the heading and airspeed, are a second side of

the triangle. Don't forget that the wind is reported originating from a direction; thus the vector of wind reported as "270°" points toward 090.

The track and groundspeed are represented by the third side of the triangle. As long as you know four of the six elements (two of the triangle sides), you can complete the triangle and find the missing data.

It is essential that all the units of speed and distance be compatible.

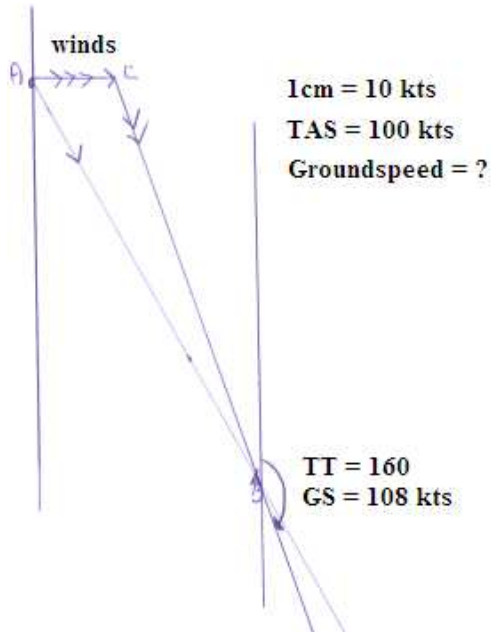
(ex. Distance = NM, speed = kts)

**Example:** Winds from 270°T at 20 kts; true airspeed (TAS) 100 kts and True Track (TT) of 150°T. To find required heading and ground speed, follow these steps:

1. On a blank sheet of paper, draw a vertical line representing a true meridian.
2. In the corner of the sheet, inscribe the scale which will be used to represent the speed and distances. Ex. 1 cm = 10 kts.
3. Place a point A on the vertical line drawn in Step 1.
4. From point A draw a line A-B to represent the true track. Use the Douglas protractor and a ruler to draw the line oriented according to planned true track. A single arrow identifies the Track vector. Its length, representing groundspeed, is yet to be determined so draw it long enough.
5. From point A, draw a line A-C to represent the speed and direction of the wind. The angle between the meridian and line A-C = wind direction; the length of line A-C = wind speed. Don't forget that the wind ORIGINATES from the reported direction. A wind reported as 270 is shown as a line pulling towards 090. A triple arrow identifies the wind vector.
6. From point C, draw a line C-B which intersects line A-B. Line C-B is to be of a length equal to the true airspeed of the aircraft. A double arrow identifies the heading vector.
7. The length of line A-B will be the groundspeed of the aircraft.
8. At point B, draw a second true meridian parallel with the first. The angle between North indicated by this second meridian and line C-B at point C gives the True heading required to maintain true track.

**Answer:** TH = 160° GS = 108 kts

The answer may vary slightly depending on the precision of the drawing.



The lengths of the lines in this triangle are not to scale; it is only an example.

One can see the velocity triangle as a chess game which consists of staying on the true track. Wind play first, then heading / true airspeed plays next (the pilot). The player (pilot) needs to orient his line of the length (to scale) equal to its true airspeed so that it end up exactly on track from where the wind left him (point C). In math languages, what you are doing is adding vectors together to end up with a resultant which is the track make good (which is if your triangle is correct equal to true track) and ground speed.

### Checkpoints

Distinctive points of reference all along the route at varying intervals. They are identified on the map so the pilot can use them to determine the track error, if necessary.

## **Finding Position**

Determination of position is performed while flying. The pilot must compare the reference points outside to the ones he sees on his map. Reference points are used in order to precisely identify a location. Often it is useful to write the time these check points were reached for future reference, ground speed determination and estimated time of arrival appraisal.

## **Landmarks**

A good landmark is a feature which is easily visible from the air and which is pre-eminent in the region where it is found. The most common: Waterways, heights of land, roads, railway lines, towns, golf courses and racetracks.

## **Using the FLIGHT COMPUTER**

### **Find Groundspeed:**

The following information is given:

True Airspeed (TAS):

True Track (TT)

Wind Speed and Direction (Winds)

1. Adjust the computer so the arrow over "TAS" is pointing to the true airspeed.
2. Adjust the disc marked with green writing until the True Track value is over the black TC arrow. (Keep the true airspeed in place).
3. On the disc marked in green, draw a line from the wind direction to the centre of the computer. (red line).
4. In this quarter of the grid, draw an arc joining the wind speed on the horizontal and vertical axes, following the curve of the green concentric circles. (blue line).



5. Where the red and blue lines intersect, draw a horizontal line to cut the vertical axis squarely. (horizontal green arrow)

6. Using the same scale as with the wind speed previously, read the value on the vertical axis where it is cut by the green arrow. Add or subtract this number to the true airspeed on the computer, which will give you the groundspeed.

Head wind (-) : Subtract

Tail wind (+) : Add

### **Find the True Heading**

Same as above for steps 1 to 5.

1. Where the red and blue lines intersect, draw a vertical line to cut the horizontal axis squarely. (vertical green line)

2. Using the same scale as before with the wind speed, take the value on the horizontal axis at the point where the line crosses, and find this value on the outer numbered circle.

3. Look at which degree on the “for crosswind” disc the value is closest to, then add or subtract this degree from the true track of the airplane, following the notation on the axis of the computer; this will give the true heading.

Left crosswind (-): Subtract

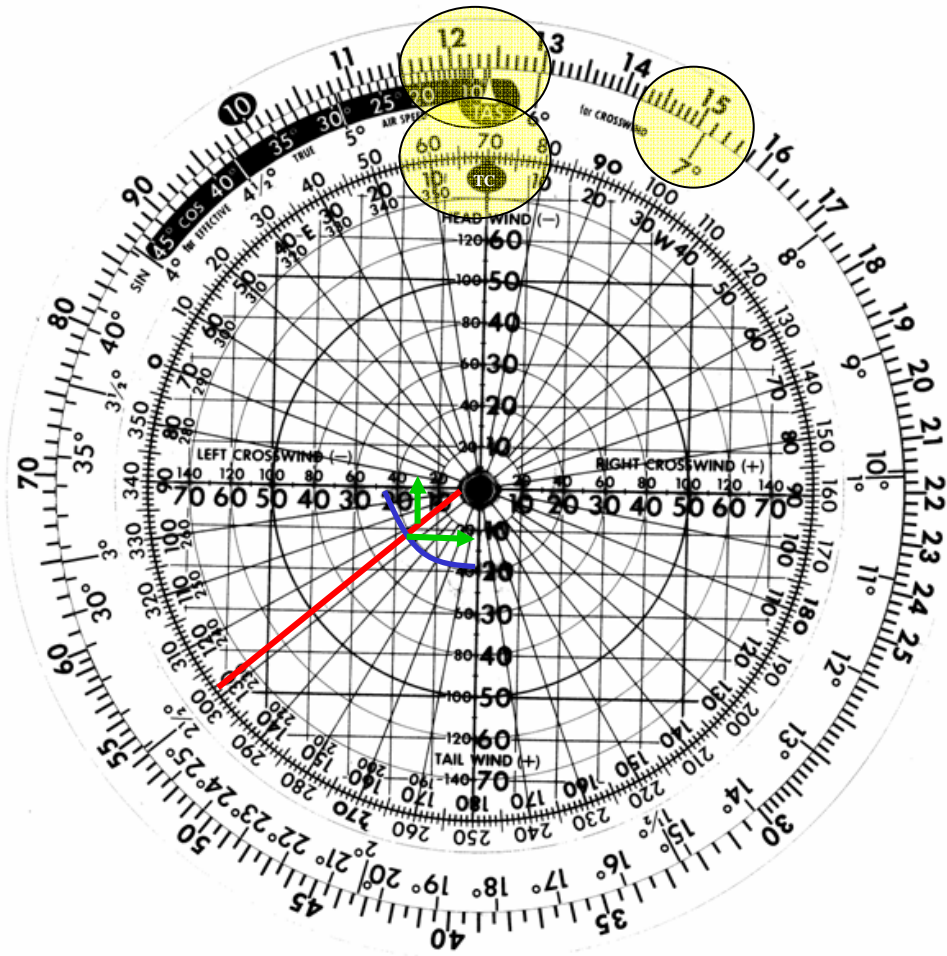
Right crosswind (+): Add

### **Example:**

TAS: 124 kts

TT: 070°

Winds: 300° at 20 kts



### **Find the Groundspeed**

Winds in-axis: 14 kts

(Tail wind)  $124 \text{ kts} + 14 \text{ kts} = 138 \text{ kts}$

Groundspeed: 138 kts

### **Find the True Heading**

Crosswind: 15 kts

Drift:  $7^\circ$

(Left crosswind)  $070^\circ - 7^\circ = 063^\circ$

True Heading:  $063^\circ$

In some case you will find that the appropriate heading correction for drift is more than  $10^\circ$ . In that case, you will need to apply a correction to True Airspeed as a significant amount of your forward momentum is now used to fight wind drift. Look up next to TAS arrow there is a black stripe. On this stripe there are white digits (degrees) corresponding to the correction you found. Aligned with it is now the True airspeed you should use for ground speed determination

From the problem above, suppose that you need to apply  $15^\circ$  to correct drift. You now go on the black stripe and find that your corrected TAS is now 120 kts... a 4 kts correction. Not a big deal but for precision matter it needs to be considered. You would now use 120 kts to calculate your ground speed with the headwind / tailwind component.

### **LOST procedures**

Even the best of the best plan does not always go well. Getting lost however, does not mean you have no mean of getting back on track. Here are some procedure you should follow to avoid getting lost and when lost, should help you getting back on track or straight to destination or even straight to an alternate airport.

1. Make sure you made a detailed navigation plan
2. Be familiar with the region you will be flying over. In case you are not, study maps that are available, do not hesitate to use tools such as Google Earth to make a pre-flight reconnaissance.
3. Be certain once in flight to do a proper follow up of your drift and ground speed along with time of passage. This will become critical in the analysis of your probable position if you know roughly how far you potentially went from your last known position.
4. Consider turning back. You might be flying from a well-known to a much less known region. Never forget in this case that the well-known region is stationary, waiting for your return behind. Also, most likely your last known position is still behind your back.
5. If you can't readily find your position after a while ( which is not two and a half hours after getting lost !!! ), slow the aircraft down to save fuel. This should be done not more than 15 minutes after your last known position. Not only will you save fuel, but also you will not find yourself screaming down full speed over an unknown landscape. Try to stay over the same spot while reassessing your position.
6. Estimate the amount of fuel still in your tank and get an estimate of flight time and range available.
7. Try using radio navigation equipment if any available to determine your position.
8. If in controlled airspace, ask for radar assistance and or vectors from ATC.

9. If in uncontrolled airspace, try reaching an FSS on 126.700 MHz. They can provide assistance in the form of advice but also they can provide VDF vectoring (see Lesson 404.02 section 4 about VHF direction finding).
10. Try contacting other aircraft on 126.700 MHz or even over an uncontrolled airport frequency along your planned route. You could eventually ask their position, plot it on your map and draw circles on the predicted range of their radio according to their altitude added of yours. If you have 3 aircraft therefore 3 circles, you are most likely inside the overlapping zone ! Use this formula:  

$$VHF\_Range = 1.23(\sqrt{Their\_Altitude} + \sqrt{Yours})$$
The range is in Nautical miles, and the altitude is entered in feet AGL. Yes you will need a hand pocket calculator for this! This technique works better for low altitudes flyers to get smaller circles.
11. If nobody ever answers your radio call, try the distress frequency 121.500 MHz, High flying airliners as well as ATC and ATS monitor this frequency permanently.
12. One last resource you have is the triangle pattern. Try flying an equilateral triangular path with turns of 120° and straight length of 2 minutes. This will show on radar and Search and rescue effort will be initiated. Fly a pattern with left-hand turn if your radio is broken.
13. Consider making a precautionary landing when fuel reserve will run low.

### **Answers to the exercises in the preceding chapter:**

- 1) Coordinates of the Oshawa Airport: 43°55' N 78°54' W
- 2) TT between Lindsay and Peterborough: 114 degrees
- 3) Magnetic and Compass Headings: 105 degrees and 108 degrees
- 4) Distance between Oshawa and Trenton: 71 NM
- 5) Identify the object found at 46°05'47"N 70°42'53"O : St.-Georges Airport.

## REVIEW QUESTIONS

1. How is latitude numbered on the Earth? \_\_\_\_\_
2. How is longitude numbered on the Earth? \_\_\_\_\_
3. How many degrees of longitude are in each time zone? (24 time zones)  
\_\_\_\_\_
4. A line across the Earth's surface which cuts across each meridian at an equal angle is called : \_\_\_\_\_
5. Magnetic variation is defined as the angle between the direction of \_\_\_\_\_ and \_\_\_\_\_ anywhere on the Earth.
6. A line joining areas of zero variation is called: \_\_\_\_\_
7. The angle between the needle of an individual compass and a magnetic meridian is called : \_\_\_\_\_
8. What is the track error caused by wind? \_\_\_\_\_
9. You cover a distance of 220 NM in 120 minutes. What is your groundspeed?  
\_\_\_\_\_
10. List the four basic elements of map construction:  
\_\_\_\_\_
11. The mathematical principle on which map construction depends is called:  
\_\_\_\_\_

12. List the four characteristics of the Lambert Conformal Conic Projection.

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13. Identify two differences between a WAC chart and a VTA chart

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14. How are isogonic lines represented on nav charts?

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15. What does the coloration (layer tinting) on a chart signify?

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16. Determine the compass heading if : ( Use “West is best, East is least” backwards when you are inversing the equation. West -, East +) CH = 250°, Variation = 4°W, drift = 7°E, Deviation = 2°E TT = \_\_\_\_\_

17. What are the 4 things to draw on your map before a cross-country flight?

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18. What does the notation “Winds 090° at 30 kts” mean?

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19. Find the Groundspeed (GS) and True Heading (TH) using a triangle of velocities and the following data: TAS = 90 kts, TT = 135°, Winds = 270° at 20 kts.

GS: \_\_\_\_\_ TH: \_\_\_\_\_

20. Before passing the half-way mark on your cross-country flight you notice that you have drifted  $5^\circ$  to the right of your intended track of  $132^\circ$ . What new heading should you take to regain your track and continue to your destination? (Use the Double Track Error Method) \_\_\_\_\_
21. The One-in-Sixty rule states that a deviation of \_\_\_\_\_ degree(s) over a distance of 60 miles will result in an error in position of about \_\_\_\_\_ mile(s).
22. How can you find the highest elevation on a map?  
\_\_\_\_\_
23. Convert 15 nautical miles into Statute Miles and Kilometers.  
\_\_\_\_\_



# 404 - Radio

## 404.01 - Theory of Radio and Standard Phraseology

### Important Information:

- Restricted Radiotelephone Operator's Certificate
- Issued by Industry Canada
- Valid for Life
- To obtain a restricted radiotelephone operator's certificate, one must demonstrate his competence by writing an examination (pass mark 70%)

### Radio Equipment Licence

- Issued by Industry Canada.
- The radio equipment must be approved or declared technically acceptable by Industry Canada to be eligible for a Licence. (Important)
- The equipment must be used on assigned frequencies only.

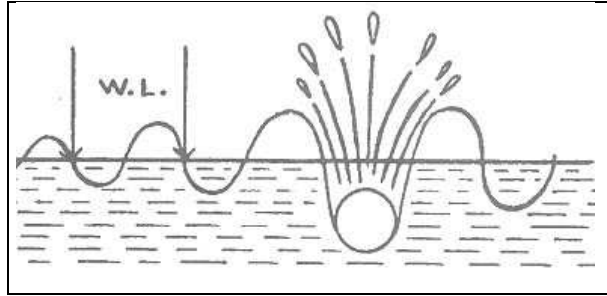
### Radio Station Licence

- Issued by Industry Canada.
- All radio stations in Canada must have one, unless they received an exemption
- The licence generally specifies the call signal of the station, the frequencies to be used for transmitting and any special conditions that apply to the station

## 1 - Wavelength, Crest, Trough, Frequency and Amplitude

**Wavelength:** Actual linear measurement of a wave; one full cycle.

Constant over distance.



**Crest (summit):** The highest part of a wave.

**Trough:** The lowest part of a wave.

**Cycle:** One complete vibration, from summit to summit or from trough to trough.

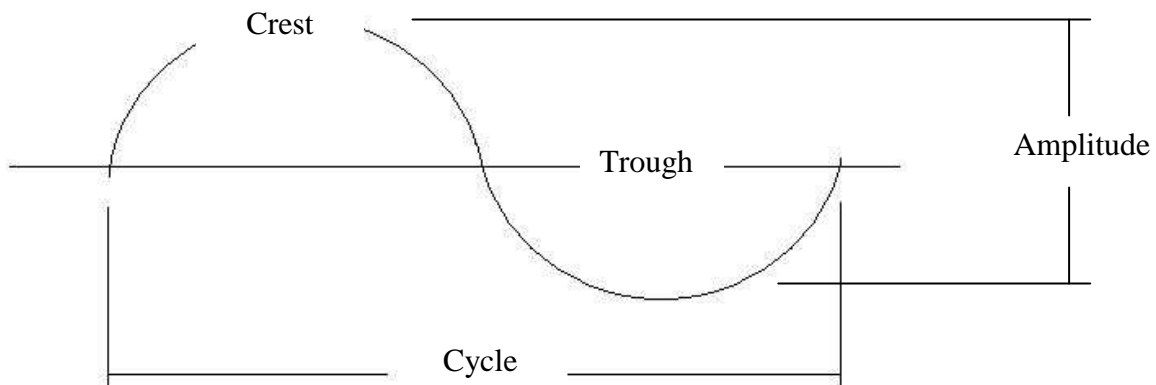
**Amplitude:** Intensity of the wave (height difference between crest and trough).  
Diminishes with distance until the signal fades away.

**Frequency:** Number of cycles per second.

**Hertz:** Unit of measurement used for frequency ; one Hertz is equal to one cycle per second.

Kilohertz (KHz) = a thousand hertz

Megahertz (MHz) = a million hertz



## 2 - Radio Bands

### **Low and Medium Frequency (LF / MF)**

Between 200 and 535 KHz. Used by commercial broadcasting stations and non-directional radio-navigation beacons (NDB).

### **High Frequency (HF)**

Between 3 and 30 MHz.

Excellent choice for air-ground communications in the sparsely-settled areas of Canada.

Used for transatlantic flights.

### **Very High Frequency (VHF)**

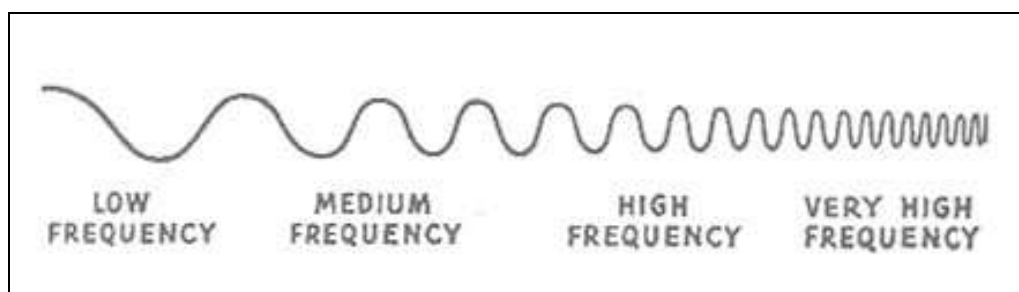
Between 30 and 300 MHz.

Used by commercial and private aircraft.

### **Ultrahigh Frequencies (UHF)**

Between 300 and 3000 MHz.

Used by military aircraft and special government services.



## 3 - Ground Waves, Sky Waves, Skip Zones, Line-Of-Sight

### **Ground Waves:**

- Follow the earth's surface;
- Travel in straight lines;

- However, they bend around obstacles in their path due to surface attenuation and diffraction.

**Sky Waves:**

Travel up into the atmosphere and are reflected back to earth by the ionosphere.

**Skip Zone:**

- Between the point where the ground waves end and the where sky waves strike the ground, there is a « Skip zone ».
- Signals are very erratic or entirely absent.

Ground wave, sky wave and skip zone are typical of HF signals.

**Line-of-Sight:**

VHF / UHF waves are not reflected by the ionosphere, but follow a straight trajectory until rendered imperceptible through attenuation. This is why they can only be captured by aircraft in line-of-sight of the emitting station (that is, for whom the station is not concealed behind the curvature of the Earth).

**Estimating Line-of-Sight Range**

Range in nm of a VHF radio can be calculated as being about the square root of the altitude of the antenna in feet time 1,23.

$$1.23 \times \sqrt{\textit{Altitude}}$$

## 4 - Standard Phraseology

<b>A</b>	<b>Alfa</b>	<b>N</b>	<b>November</b>
<b>B</b>	<b>Bravo</b>	<b>O</b>	<b>Oscar</b>
<b>C</b>	<b>Charlie</b>	<b>P</b>	<b>Papa</b>
<b>D</b>	<b>Delta</b>	<b>Q</b>	<b>Quebec</b>
<b>E</b>	<b>Echo</b>	<b>R</b>	<b>Romeo</b>
<b>F</b>	<b>Foxtrot</b>	<b>S</b>	<b>Sierra</b>
<b>G</b>	<b>Golf</b>	<b>T</b>	<b>Tango</b>
<b>H</b>	<b>Hotel</b>	<b>U</b>	<b>Uniform</b>
<b>I</b>	<b>India</b>	<b>V</b>	<b>Victor</b>
<b>J</b>	<b>Juliet</b>	<b>W</b>	<b>Whiskey</b>
<b>K</b>	<b>Kilo</b>	<b>X</b>	<b>X-ray</b>
<b>L</b>	<b>Lima</b>	<b>Y</b>	<b>Yankee</b>
<b>M</b>	<b>Mike</b>	<b>Z</b>	<b>Zulu</b>

### Numbers, Time, Money, Altitude, Heading.

#### Numbers:

<b>0</b> - ZE-RO	<b>5</b> - FIFE
<b>1</b> - WUN	<b>6</b> - SIX
<b>2</b> - TOO	<b>7</b> - SEV-en
<b>3</b> - TREE	<b>8</b> - AIT
<b>4</b> - FOW-er	<b>9</b> - NIN-er
Decimal - <b>DAY</b> -SEE-MAL	Thousand - <b>TOU</b> -SAND
Hundred - <b>HUN</b> -dred	

All numbers except whole thousands should be transmitted by pronouncing each digit separately. Whole thousands should be transmitted by pronouncing each digit in the number of thousands followed by the word “thousand”.

**Examples:**

- 10 becomes - one zero
- 75 becomes - seven five
- 100 becomes - one zero zero
- 5,800 becomes - five eight zero zero
- 11,000 becomes - one one thousand
- 68,009 becomes - six eight zero zero nine

**Time:**

- The 24-hour coordinated time (Zulu) system is used
- Use of local time is specified
- Examples:   Midnight = 00:00 hrs  
                  2:30 PM Local = 14:30 hrs Local

**Money:**

- Say « dollars » at the beginning of the figure
- Example:    45.32\$ = Dollars - Four – Five – decimal – Three – Two

**ATTENTION:** This norm is different in French as they would pronounce “dollars” at the end.

**Altitude:**

- Given in thousands and hundreds of feet.
- Examples:    1000' = 'Thousand'  
                  2500' = Two 'thousand' five hundred

**Heading:**

- Expressed in three figures, in degrees magnetic unless specified.
- Example:    060o = Heading Zero Six Zero

## Standard Phraseology

<b>Word or Phrase</b>	<b>Meaning</b>
ACKNOWLEDGE	Let me know that you have received and understood this message.
AFFIRMATIVE	Yes, or permission granted.
BREAK	Indicates the separation between portions of the message. (To be used where there is no clear distinction between the text and other portions of the message.)
CHANNEL	Change to channel ... before proceeding.
CLEARED	Authorized to proceed under the conditions specified.
CONFIRM	Have I received the following ... or Did you receive the message?"
CORRECTION	An error has been made in this transmission (or message indicated). The correct version is ....
DISREGARD	Consider this transmission as not sent.
GO AHEAD	Proceed with your message.
HOW DO YOU READ?	What is the readability of my transmission?
I SAY AGAIN	Self-explanatory (use instead of "I REPEAT").
MAYDAY	The spoken word for distress communications.
MAYDAY RELAY	The spoken word for the distress relay signal.
MONITOR	Listen on (frequency).
NEGATIVE	No, or that is not correct, or I do not agree.
OUT	Conversation is ended and no response is expected.
OVER	My transmission is ended and I expect a response from you.
PAN PAN	The spoken word for urgency communications
READ BACK	Repeat all, or the specified part of this message back to me exactly as received (do not use the word "REPEAT").

ROGER	I have received all of your last transmission.
ROGER NUMBER	I have received your message Number _____.
SAY AGAIN	Self-explanatory. (Do not use the word "REPEAT".)
STAND BY	I must pause for a few seconds or minutes, please wait and I will call you.
SEELONCE	International expression to indicate that silence has been imposed on the frequency due to a distress situation.
SEELONCE FEENEE	International expression to indicate that the distress situation has ended.
SEELONCE MAYDAY	An international expression to advise that a distress situation is in progress. The command comes from the station in control of the distress traffic.
THAT IS CORRECT	Self-explanatory.
VERIFY	Check coding, or text and confirm with originator.
WILCO	Your instructions received, understood and will be complied with.
WORDS TWICE	(a) As a request: Communication is difficult, please send each word, or group of words, twice; (b) As information: Since communication is difficult, I will send each word, or group of words, twice.

## **5 - Priority of Communications**

- 1- Distress call
- 2- Urgency call
- 3- Communications relating to radio direction findings. (VDF)
- 4- Flight Safety Communications
- 5- Weather Information communications
- 6- Scheduled broadcasts
- 7- Communications relating to the application of the United Nations charter
- 8- State Communications for which priority rights have been invoked
- 9- All other communications



## **404.02 - Services to Aviation and Emergency Procedures**

### **1 - Message Technique**

A radio transmission is considered strictly confidential.

#### **Parts of a Message**

##### **Example:**

1. Call-Up: “St-Jean Tower, this is glider Foxtrot Delta Whiskey Bravo”
2. Reply: “Glider Delta Whiskey Bravo, St-Jean Tower.”
3. Message: “St-Jean Tower, Delta Whiskey Bravo on left downwind for Grass 29.”  
Twr reply: “Delta Whiskey Bravo, St-Jean Tower. Winds 320 at 10 kts ; cleared to land Grass 29. “
4. Acknowledgement: “Delta Whiskey Bravo.”

The 3 last letters of the glider’s registration is used on initial contact with the St-Jean tower instead of 4 only because gliding operations are frequent and they are very familiar with the glider registrations. In general, the last four letters are used on the initial call-up.

### **2 - Use of the Radio**

#### **Good Radio Technique**

- Pronounce words clearly.
- Use a moderate rate of speech.
- Keep a constant tone of voice.
- Hold the microphone in the correct position - about 1 inch from the lips.
- Avoid “um’s” and “ah’s”.
- Acknowledge receipt of all ATC messages which are sent to you.
- Profanity or offensive language is prohibited.
- Do not use the radio for personal requests (i.e. Transportation, lodging, food)

- Know what you want to say before you begin speaking.
- Listen before you transmit to avoid interrupting a communication in progress.

### 3 - Emergency Radio Procedures

**Distress Call:** Grave and immediate danger requiring immediate assistance. It shall not be sent to a specific station in particular

**Format:**        Mayday (3 times)  
                      THIS IS  
                      CALL SIGN (3 times)  
                      *Distress Message*

**The distress message** shall follow the **distress call** as soon as possible. The distress message should include as many as possible of the following elements:

1. the distress signal "MAYDAY";
2. the call sign of station in distress (once);
3. the nature of the distress condition and kind of assistance required (i.e., what has happened);
4. the intentions of the person in command;
5. the particulars of its position (airspeed, altitude, heading);
6. the number of persons on board and injuries (if applicable);
7. any other information which might facilitate rescue;
8. the call sign of the station in distress.

**Example:**        MAYDAY  
                      PIPER FOXTROT X-RAY QUEBEC QUEBEC  
                      POSITION: 20 MILES EAST OF WINNIPEG  
                      ALTITUDE: 1500 FEET  
                      AIRSPEED: 125 KNOTS

HEADING: 270 T  
STRUCK BY LIGHTNING  
DITCHING AIRCRAFT  
ONE PERSON ON BOARD  
PIPER FOXTROT X-RAY QUEBEC QUEBEC

The first transmission of the distress call and message by an aircraft should be made on the air-ground frequency in use at the time. If the aircraft is unable to establish communications on the frequency in use, the distress call and message should be repeated on the aeronautical emergency frequency (121.5 MHz).

The distress message shall be repeated at intervals by the aircraft in distress until an answer is received or until it is no longer feasible to continue. The intervals between repetitions of the distress message shall be sufficiently long enough to allow time for stations receiving the message to reply.

**Action by other Stations Hearing a Distress Message:**

1. Continue to monitor the frequency on which the distress message was received and, if possible, establish a continuous watch on appropriate distress and emergency frequencies.
2. Notify any station with direction-finding or radar facilities and request assistance unless it is known that this action has been, or will be, taken by the station acknowledging receipt of the distress message.
3. Cease all transmissions which may interfere with the distress traffic.

**Acknowledgment of Receipt of a Distress Message**

The acknowledgment of receipt of a distress message shall be given in the following form:

1. the distress signal “MAYDAY”
2. the call sign of the station in distress (spoken three times);
3. the words “THIS IS”;
4. the call sign of the station acknowledging receipt (spoken three times);
5. the words “RECEIVED MAYDAY”.

**Example:** MAYDAY  
PIPER FOXTROT X-RAY QUEBEC QUEBEC  
PIPER FOXTROT X-RAY QUEBEC QUEBEC  
PIPER FOXTROT X-RAY QUEBEC QUEBEC  
THIS IS  
WINNIPEG TOWER  
WINNIPEG TOWER  
WINNIPEG TOWER  
RECEIVED MAYDAY

### **Relay of a Distress Message**

A distress message repeated by a station other than the station in distress shall transmit a signal comprised of:

1. the signal “MAYDAY RELAY” (spoken three times);
2. the words “THIS IS”;
3. the call sign of the station relaying the message (spoken three times);
4. the distress signal “MAYDAY” (once);
5. the particulars of the station in distress such as its location, nature of distress, number of persons on board, etc.

**Example:** MAYDAY RELAY, MAYDAY RELAY, MAYDAY RELAY  
THIS IS  
CESSNA NOVEMBER JULIETT INDIA  
CESSNA NOVEMBER JULIETT INDIA  
CESSNA NOVEMBER JULIETT INDIA  
MAYDAY  
PIPER FOXTROT X-RAY QUEBEC QUEBEC  
STRUCK BY LIGHTNING  
DITCHING AIRCRAFT  
POSITION: 20 MILES EAST OF WINNIPEG  
ALTITUDE: 1500 FEET  
AIRSPEED: 125 KNOTS  
HEADING: 270 DEGREES  
ONE PERSON ON BOARD  
PIPER FOXTROT X-RAY QUEBEC QUEBEC

### **Cancellation of Distress**

When a station is no longer in distress, or when it is no longer necessary to observe radio silence (i.e. the rescue operation has concluded), the station that controlled the distress traffic shall transmit a message addressed to “ALL STATIONS” on the distress frequency(ies) used, advising that normal working may resume. The proper procedure for cancelling a distress message is:

1. the distress signal “MAYDAY” (once);
2. the words “HELLO ALL STATIONS” (three times);
3. the words “THIS IS”;
4. the call sign of the station transmitting the message;
5. the filing time of the message;
6. the call sign of the station in distress (once);
7. the words “SEELONCE FEENEE”;

**Example:** MAYDAY  
HELLO ALL STATIONS, HELLO ALL STATIONS, HELLO ALL STATIONS  
THIS IS  
WINNIPEG TOWER  
IME 1630 ZULU  
PIPER FOXTROT X-RAY QUEBEC QUEBEC  
SEELONCE FEENEE  
OUT

The procedure outlined above is mainly for the benefit of other stations so they can resume regular service. To ensure that search and rescue stations are advised that a station is no longer in distress, a normal call to the nearest aeronautical station detailing the reasons for cancelling the distress call **MUST** be made.

**False distress calls:**

A fine of over \$5000 and imprisonment for up to 12 months

**Urgency Call:** Situation concerning the safety of the aircraft or of a person on board or in sight.

**Transmission:** The message may be directed to a specific station.

**Urgency Message**

The urgency message should contain as many of the following elements as required, spoken distinctly and, if possible, in the following order:

1. the urgency signal “PAN PAN” (three times);
2. the name of the station addressed or the words “ALL STATIONS” (three times);
3. the words “THIS IS”;

4. the identification of the aircraft;
5. the nature of the urgency condition;
6. the intentions of the person in command;
7. the present position, flight level or altitude and the heading;
8. any other useful information.

**Example:** PAN PAN, PAN PAN, PAN PAN  
ALL STATIONS, ALL STATIONS, ALL STATIONS  
THIS IS  
CESSNA FOXTROT NOVEMBER JULIETT INDIA  
LOST, REQUEST RADAR CHECK  
POSITION: UNKNOWN  
AIRSPEED: 112 KNOTS  
ALTITUDE: 1050 FEET  
CESSNA FOXTROT NOVEMBER JULIETT INDIA  
OVER

**Example of reply:**

PAN PAN  
CESSNA FOXTROT NOVEMBER JULIETT INDIA  
THIS IS WINNIPEG TOWER  
YOUR POSITION IS 20 MILES SOUTH OF WINNIPEG  
WINNIPEG TOWER  
STANDING BY

**Cancellation of Urgency Message**

When the urgency message which calls for action by the stations receiving the message has been transmitted, the station responsible for its transmission shall cancel it as soon as it knows that

action is no longer necessary. The cancellation message shall be addressed to “ALL STATIONS”.

**Example:** PAN PAN  
ALL STATIONS, ALL STATIONS, ALL STATIONS  
THIS IS  
CESSNA FOXTROT NOVEMBER JULIETT INDIA  
CESSNA FOXTROT NOVEMBER JULIETT INDIA HAS BEEN POSITIONED  
AT 20 MILES SOUTH OF WINNIPEG AIRPORT PROCEEDING NORMALLY  
CESSNA FOXTROT NOVEMBER JULIETT INDIA  
OUT



## **4 - Services offered by ATC and FSS**

The following are some of the services offered:

(for more information see lesson 401.04 and 401.05)

### **Control Tower (ATC):**

- Controls all aircraft landing and taking off as well as all VFR traffic operating in the control zone surrounding the airport.
- Situated inside a control zone.
- Permits the safe and rapid circulation of air traffic.

### **Ground Control:**

- Most controlled airports have ground control.
- Controls the movements of aircrafts, vehicles and pedestrians on the airport surface.

### **Flight Service Station (FSS) and Flight Information Centre (FIC):**

- Gives information such as weather, winds, altimeter setting, NOTAMs.
- Operated by NavCanada.
- Will accept flight plan/itinerary
- Will provide advisory services at uncontrolled airport and control pedestrian / vehicles at that airport.
- Will provide advisory services at remote uncontrolled airport through RCO
- They don't have authority to give instructions to aircrafts.

### **UNICOM:**

- Over uncontrolled airport.
- Not a control unit.
- Gives traffic information about the airfield when in operation. Wind, preferred runway, traffic, altimeter setting, etc...
- They don't have authority to give instructions.

## **VHF Direction Finding**

Provide the pilot with a heading to follow, or a bearing from the VDF station. This service will be provided at the request of the pilot or at the suggestion of ATC. The pilot must provide the following information: position (if known), heading, altitude. ATC or FSS will give a heading to follow for homing in on the VDF station and ask the pilot to transmit at regular intervals to home in on the station.

## **5 - Radio Checks**

1. Call another station using its call sign.
2. Transmit the standard message stating frequency: "Signal Check on 1-2-2 decimal 3, how do you read?"
3. A radio check should not last more than 10 seconds.
4. Readability Scale:
  - 1: Bad (Unreadable)
  - 2: Poor (occasionally readable)
  - 3: Fair (readable with difficulty)
  - 4: Good (readable)
  - 5: Excellent (perfectly readable)

## **RADIO COMMUNICATIONS**

The following provides examples of most radio communications taking place during the summer season between a glider, a towplane and St-Jean tower.

### **SCENARIO # 1**

A glider (C-GVQM) will fly to 3000 ft (or another altitude), towed by a tow plane (C-FTGE):

1. TGE: St-Jean Tower, Super dog 50 plus Victor Quebec Mike, ready for 3000 feet.
2. Twr: Super dog 50, St-Jean tower. Winds 290 at 10 kts. Take off your discretion grass 29.
3. TGE: Super Dog 50.

**After the glider releases, the tow plane continues as follows:**

4. TGE: St-Jean Tower, Super dog 50. Glider released, 3000 feet.
5. Twr: Super dog 50, St-Jean Tower. Call left base runway 29.
6. TGE: Super Dog 50.
7. TGE: St-Jean Tower, Birddog 03, left base runway 29.
8. Twr: Super dog 50, St-JEAN Tower, cleared to land runway 29.
9. TGE: Super dog 50.

**A few minutes later the glider enters the circuit:**

10. VQM: St-Jean tower, glider Victor Quebec Mike, on downwind for the field.
11. Twr: Victor Quebec Mike, St-Jean Tower. Winds 290 at 10 kts; land at your discretion, grass 29.
12. VQM: Victor Québec Mike.

## **SCENARIO # 2**

Glider (C-GVQM) flight with a simulated rope break planned for 800', towed by a tow plane (C-FTGE):

The same communications are used as in Scenario #1 except the following:

1. TGE: St-Jean tower, Super dog 50 plus Victor Quebec Mike, ready for take-off for a simulated rope break, modified circuit.
2. TGE: St-Jean tower, Super dog 50, glider released at 800 feet.

## REVIEW QUESTIONS:

1. Match each term to the definition:

Period	a - constant with distance
Amplitude	b -time to complete one cycle
Wavelength	c -number of cycles per second
Frequency	d -the intensity of the radio wave

2. What band of frequencies is used by civil aviation?

\_\_\_\_\_

3. What frequency band is used primarily by special government services (i.e. military) \_\_\_\_\_

4. What kind(s) of radio waves travel in a straight line? \_\_\_\_\_

5. What is a skip zone? \_\_\_\_\_

6. Precipitation can create static in communication radios because it creates electric charges.  
True or False

7. List two advantages to satellite communications.

\_\_\_\_\_

8. What is the correct pronunciation of the word PILOT in the Phonetic Alphabet?

\_\_\_\_\_

9. What is the emergency frequency used by aviation? \_\_\_\_\_

10. What kind of message has absolute priority over all others? \_\_\_\_\_
11. Which of the listed terms means? “Let me know you have received and understood the message.”
- a) Wilco
  - b) Roger
  - c) Acknowledge
  - d) Out
12. In terms of radiotelephony, what do the following terms mean?
- Ronly: \_\_\_\_\_
- Nordo: \_\_\_\_\_
13. Match the type of call with the first words of the transmission:
- i. Urgency      a) SECURITY
  - ii. Distress    b) MAY DAY
  - iii. Security    d) PAN PAN
14. The first distress call made by an aircraft should be on the following frequency :  
\_\_\_\_\_
15. An Urgency call is:  
\_\_\_\_\_
16. List the steps of an urgency message  
\_\_\_\_\_
17. Spell the word “glider” in phonetic alphabet: \_\_\_\_\_
18. What is a VDF bearing? \_\_\_\_\_

19. List three services provided by ATC: \_\_\_\_\_

20. What are the 4 steps of message transmission procedure? \_\_\_\_\_

\_\_\_\_\_

21. A radio transmission must be \_\_\_\_\_ and \_\_\_\_\_.

# **405 – METEOROLOGY (Objective 1 - Theory)**

## **405.01 - The Atmosphere and Atmospheric pressure**

### **1 - Composition and Properties of the Atmosphere**

#### **Composition of the Atmosphere**

The atmosphere is a mix of invisible gases. The main gases present are:

- Nitrogen 78%
- Oxygen 21%
- Others 1% (argon, carbon dioxide, water vapor, etc.)

From the viewpoint of weather, water vapor is the most important component of the air.

**Condensation Nuclei:** Microscopic particles such as dust, smoke, sea salt, seeds, pollen, etc present in suspension in the atmosphere upon which water vapor condenses to liquid water droplets..

### **2 – Vertical Structure of the Atmosphere**

#### **Divisions of the Atmosphere**

The divisions are based largely on the temperature of each layer.

#### **Troposphere:**

- The lowest layer of the atmosphere
- Most weather takes place in the troposphere.



- Height varies between 28 000 feet ASL at the poles and 54 000 feet ASL over the equator.
- Pressure and density diminish rapidly with height.
- Temperature diminishes rapidly with height until it reaches  $-56^{\circ}\text{C}$ .
- The upper limits of the layer are called the tropopause (temperature constant at  $-56^{\circ}\text{C}$ )

### **Stratosphere:**

- The second layer of the atmosphere.
- Extends upwards from the tropopause to about 160 000 feet ASL.
- Pressure and density continue to diminish.
- Temperature is pretty much constant at  $-56^{\circ}\text{C}$ . for the first 30 000 feet or so in the stratosphere then slowly rise up to about  $10^{\circ}$  due to the ozone layer.
- Ozone layer is located at around 80 000 feet.
- Water vapor and air currents are practically non-existent.
- The upper limit of this layer is called the stratopause.

### **Mesosphere:**

- The third layer of the atmosphere.
- Temperature start to drop from about  $10^{\circ}\text{C}$  to  $-100^{\circ}\text{C}$
- The upper limit of this layer is called the mesopause at around 275 000 feet.
- Ionosphere starts in the lower mesosphere and extends upward through the thermosphere.

### **Thermosphere:**

- The highest level of the atmosphere proper.
- The temperature increases to  $3\ 000^{\circ}\text{C}$  at 40 miles above the surface.

### **Ionosphere:**

- Reflects low and medium and high frequency waves back to earth, affecting radio communications.

**Exosphere:**

A layer so sparse that atmospheric pressure decreases almost to the point of total vacuum. Molecules escape the atmosphere with relative ease making precise measurement of the top of this layer difficult. The threshold of space is generally considered to be between 90 and 100 miles above the surface.

### **3 – Standard Atmosphere**

The ICAO standard atmosphere has the following characteristics:

- Average sea level pressure is 29.92”Hg or 14,7 lbs per square inch
- Average sea level temperature is 15°C.
- Air is considered to be a perfectly dry gas.
- The vertical lapse rate (describing the rate of decrease of temperature with altitude) is 1.98°C/1000 feet. It is often averaged to 2°C/1000 feet.

### **4 – Pressure and Density**

**Atmospheric Density**

Density is a measure of a unit of air’s mass in relation to its volume. Cold air is dense because the molecules of which it is composed move relatively slowly and are therefore closer to each other.

Warm air is less dense because the molecules of which it is composed move more rapidly and therefore take up more space. In consequence, there are fewer molecules in a given volume and thus less mass and less density.

**Pressure and density relationship:**

Vary in direct proportion: when pressure increases, density increases.

## 5 – The Three Properties of the Atmosphere

**Mobility:** The capacity of air for motion.

**Capacity for Compression:** When a parcel of air decreases in volume as a result of compression, its temperature increases.

**Capacity for expansion:** Warm air takes up more space (volume) than cold air. It is less dense. The Capacity for Expansion is the most important property of the atmosphere. When for any reason a gas expands, it cool itself by a process said to be adiabatic. This means it cools itself without giving its heat away to another gas or body! The reason why it is cooling (even though no heat is exchanged) is because of expansion, air becomes less dense and therefore molecules are farther away to each other and there is less collisions between them producing less heat.

## 6 – Units and Measures of Pressure

### Atmospheric pressure

The pressure exerted by the atmosphere at a given place is caused by the weight of the air which extends above it. It is the weight of a column of air which originates at the measuring station and extends upwards to the limits of the atmosphere.

### Units of Measurement

- Inches of Mercury (“ Hg) :  $29,92\text{“ Hg} = 1013,2\text{ hPa}$
- Millibars (mb) :  $1\text{mb} = 1\text{hPa}$
- Hectopascal (hPa):  $1\text{hPa} = 1\text{mb} = 0.1\text{kPa}$
- Kilopascal (kPa) :  $1\text{kPa} = 10\text{ hPa}$

## **Definitions**

**Station Pressure:** Actual atmospheric pressure measured at the elevation of the observing station.

**Mean Sea Level Pressure:** A common standard of different station pressures, used to obtain a consistent record of pressure distribution. This calculation is made by adding the weight of the station pressure to an imaginary column of air extending from station altitude down to mean sea level.

**Altimeter setting:** To ensure that the altimeter indicates the real height of the aircraft above sea level, it must be calibrated to a standard atmospheric pressure setting; this is called the “altimeter setting”. This setting differ slightly from Mean Sea Level pressure; the difference coming from the fact that the station providing this setting is most of the time not at sea level and as to mathematically compensate for the difference in height. Altimeter setting is measured in inches of mercury and gives the precise level over mean sea level.

## **7 – Pressure Systems**

### **High pressure area**

- winds flow clockwise and outwards around a High.
- the pressure is highest at the centre.
- also known as an « anticyclone ».

### **Low pressure area**

- winds flock counter-clockwise and inwards around a Low.
- pressure is lowest at the centre, and
- also known as a cyclone or depression.

## **Secondary Depression**

- Small cyclonic disturbance associated with a larger low pressure system.
- Develops within a region dominated by a major low pressure system (the primary low).
- Rotates counter-clockwise around the primary low.
- Generally associated with thunderstorms in summer and strong precipitation or winds in winter.

## **8 – Troughs, Ridges and Cols**

**Trough:** U-shaped region of lower pressure, surrounded on either side by relatively higher pressure.

**Ridge:** The extension of a high pressure area, bordered on either side by areas of relatively lower pressure

**Col:** A region of neutral pressure between two highs and two lows.

## **9 – Isobars**

**Isobar:** Curved line on a weather map joining areas of equal barometric pressure. Isobars are drawn at intervals of 4 hPa, for pressure observations below 1000 hPa.

## **10 – Horizontal Pressure Differences**

### **Pressure Gradient:**

Defined as the rate of change of pressure for a given distance; measured at right angles to the isobars. Isobars close together on a weather map indicate a strong pressure gradient. The pressure gradient determines the strength of the wind. The closer the isobars, the stronger the winds.

## **405.02 – Pressure, The Altimeter and Winds**

### **1 – Pressure Altitude and Density Altitude**

**Pressure Altitude:** Altitude indicated when the altimeter is calibrated to the ICAO standard (29.92”Hg)

**Density Altitude:** Pressure Altitude corrected for temperature being different from 15°C. One calculates the density altitude to know at what ICAO altitude would prevail the same atmospheric condition that is found at a particular altitude when non ICAO pressure and temperature prevails. For example, being at St Jean airport at 136 feet ASL with a pressure of 27,92” Hg and 30°C is equivalent of being at 4000 feet in ICAO conditions. Aircraft manufacturer will often publish performance data in ICAO atmosphere. In that example you would look at 4000 feet ICAO data to know how your aircraft would perform at 136 feet ASL in St-Jean that day. This prevents the manufacturer from having to publish thousands of pages containing data about every possible combination of pressure and temperatures.

### **2 – Effect on the Altimeter of Flight across Different Pressure Regions**

**Axiom :** From a high to a low watch out below, from a low to a high watch the sky

When flying from a region of high pressure to a region of lower pressure, the altimeter will read high: it will indicate an altitude higher than reality.

When flying from a region of low pressure to a region of higher pressure, the altimeter will read low: it will indicate an altitude lower than reality.

**The source of these errors:** if the altimeter setting is not changed, the altimeter will read according to the initial calibration regardless of the actual surrounding conditions.

**The solution:** pilots must receive updates from stations along their route of flight and re-calibrate the altimeter as they proceed.

The altimeter is a bit dumb! It is in fact associating pressure changes with an altitude change. In standard atmosphere, pressure in the lower levels tends to drop at a rate of 1 inches of mercury per thousand of feet. The trick is that the altimeter cannot make the difference between a pressure change due to an actual change in altitude and a pressure change due to a horizontal displacement of the aircraft to an area of lower or higher pressure. Therefore, the altimeter records any kind of pressure change as a climb or a descent accordingly.

### **3 - Low-Level and Surface Winds**

#### **Wind Formation**

Wind is a phenomenon which originates in pressure differences in the horizontal. At low levels, wind is the result of a flow of air from a high pressure area to a low pressure area. At higher altitudes, wind is the result of differences in densities. Colder air is denser than warm air and therefore pressure drops more rapidly with altitude in cold air. So in higher altitude, for the same level, pressure will be lower in cold air than in warm air creating a pressure gradient due to unequal density. This phenomenon will be best seen at larger scale. In example, air is colder at the pole than the equator.

#### **Wind Speed and Direction**

**Wind Speed:** Reported in knots for the purposes of aviation.

**Wind direction:** Defined by the direction FROM which the wind blows.

**Example:** A North wind therefore is blowing from the north to the south.

Wind is reported in degrees true in weather report and in magnetic by the tower or ATIS messages.

## **Surface Winds and Topography**

Surface winds extend up to around 2000 ft. Topography has a significant influence on surface winds due to surface friction.

## **4 - Surface Friction and Wind Gradient**

**Surface Friction:**

Friction between the ground and the lower atmosphere tends to slow the movement of the air, therefore slowing the wind. This works against the Coriolis force; thus air moving from a high to a low tends to cross the isobars at a small angle instead of remaining parallel. The effect of surface friction extends up to about 2000 feet AGL; at 3000 feet, the wind blows parallel to the isobars at a speed proportionate to the pressure gradient.

**Mechanical Turbulence:**

Friction between the moving air mass and terrain features (hills, mountains, valleys, trees, structures, etc.) is responsible for the whirling vortices of air commonly called eddies. It is generally confined to below 3000 feet.

**Orographic Wave:**

Air flowing across a mountain range usually rises relatively smoothly up the slope of the range but, once over the top, it pours down the other side with considerable force. The air bounces up and down, creating eddies and turbulence. If the air mass has a high moisture content, clouds of very distinctive appearance will develop:

**Cap cloud:** Cloud formation on the summit of the mountain range.

**Lenticular (Lens shaped) cloud:** Form on the wave crests aloft and lie in bands that may extend well above 40 000 feet.

**Rotor clouds:** Form in the rotating eddies downstream of the mountain range.



## 5 – Veering and Backing

### Veering

- The wind veers when it changes direction clockwise.
- Wind veers and increases in intensity with increase in altitude until it gets parallel to the isobars.

### Backing

- The wind backs when it changes direction counter-clockwise.
- The wind backs and decreases in intensity with decrease in altitude until it crosses the isobar at a small angle in direction of the low pressure system..

## 6 – Gusts and Squalls

### Gusts:

- A rapid and irregular fluctuation in the strength of the wind.
- Generally associated with a rapid change in wind direction.
- Caused by mechanical turbulence and by the unequal heating of the Earth's surface.

**Definition from FTGU:** A gust is a rapid and irregular fluctuation of varying intensity in the upward and downward movement of air currents. It may be associated with a rapid change in wind direction.

### Squall:

- A sudden increase in the strength of the wind of longer duration (minimum 2 minutes)
- May be accompanied by a rapid change in wind direction.
- May be caused by the passage of a fast-moving cold front or a thunderstorm.

## 7 – Diurnal Variation

**Diurnal Variation:** Changes in the wind during the course of the day caused by heating of the earth which creates a strong, gusty surface wind. The wind veers and increases in strength during the day. This is caused by the heating of the surface by the sun over the course of the day, which creates vertical currents and turbulence. The turbulence mixes low-level air with the air above which flows parallel to the isobars and which is not slowed by surface friction. This mix causes the winds to veer and adds energy (i.e. Speed).

The wind backs and decreases in intensity during the night. This is caused by the cooling of the surface: turbulence ceases and the air is no longer mixed with upper level winds.

## **8 – Forces acting on the Atmosphere**

### **Coriolis force**

Affects the movement of air because the Earth turns beneath the atmosphere. Looking down at the planet from above the North Pole, an observer would remark that the air is deviated to the right in the Northern Hemisphere and then flows parallel to the isobars. (The Earth turns Counter-clockwise, seen from the same vantage point.)

The air flowing from a high pressure area therefore does not move directly towards the centre of the low pressure area but is deflected to the right and flows parallel to the isobars.

### **Centrifugal Force:**

Tends to increase wind speed in high pressure areas and decrease wind speed in low pressure areas. That is, for the exact same pressure gradient, wind will be a little stronger in a high pressure area than it would have been in a low pressure area.

### **Buys Ballot's Law:**

If you stand with your back to the wind [in the Northern Hemisphere], the Low is on your left. i.e pressure is decreasing on your left side.

## **9 – Land and Sea Breezes**

### **Land Breeze:**

Arises at night. Earth cools more rapidly than water, thereby creating a high pressure area over the earth by subsidence. Relatively warm air over the water, less dense than the cool air over the ground, rises and creates a low pressure area. The cool air flows towards the lower pressure over the water. The wind flows from the shore to the sea.

### **Sea Breeze:**

Arises during the day. The shore heats more rapidly than the water, thereby creating a low pressure area over the ground as the air starts to rise. The warm air over the ground, less dense than the cool air over the sea, rises and creates a low-pressure area. The cool air over water subsides rising the ground level pressure and flows towards the area of lower pressure. The wind blows from the sea to the shore.

## **10 – Anabatic and Katabatic Winds**

**Anabatic Winds:** Bare mountain slopes are heated by solar radiation during the day. With contact the air becomes warmer and less dense, therefore rising up the mountain slope.

**Katabatic Winds:** During the night the mountain slopes cool. The air in contact with the slope is cooled by radiation and becomes denser, causing it to flow down the slopes towards the valleys. This phenomenon also arises during the day on snow-covered slopes.

# 405.03 - Temperature and Humidity

## 1 – The Celsius and Fahrenheit Scales

The freezing point is the temperature at which water droplets transform into ice crystals. The boiling point is the temperature at which water droplets transform into water vapor.

### Temperature Scales

- The Celsius scale designates the freezing point as 0° and the boiling point as 100°.
- The Fahrenheit scale designates the freezing point as 32° and the boiling point as 212°.
- The Absolute (Kelvin) scale assumes an absolute zero of -273°C. Absolute temperature is thus the temperature in Celsius plus 273.

### Conversion:

$$\begin{aligned} \text{Fahrenheit to degrees Celsius} &= (\text{Fahrenheit} - 32) \times 5 / 9 \\ \text{Celsius degrees to Fahrenheit} &= 9 / 5 \times \text{Celsius} + 32 \end{aligned}$$

## 2 - Atmospheric Heating

The **lower levels** of the atmosphere are heated by:

**Radiation:** The heat of the sun reaches the Earth in the form of short-wave radiation, the energy of which is absorbed by the terrestrial surface resulting in an increase in temperature which heats the lower levels of the atmosphere. The atmosphere is heated from below.

**Conduction:** Heat spreads gradually through an object, passing from warm areas to cold areas. Conduction plays a minor role in atmospheric heating.

The **upper levels** of the atmosphere are heated by:

**Convection:** Air over a very warm surface becomes buoyant and rises rapidly through the atmosphere

**Advection:** A flow of air that moves from a cold area over a warm area will be heated in its lowest layers by the warm earth over which it is flowing.

**Turbulence:** Mechanical turbulence which is the result of friction between the air and the ground causes a mixing process which spreads the surface heat into the air aloft.

**Compression:** Anti-cyclonic weather systems in which air **subsides** or air flowing down the side of a mountain causing downward vertical currents. As the air descends, it reaches regions of increased atmospheric pressure and is compressed, causing **adiabatic** rising of its temperature. This phenomenon is called subsidence.

### **3 - Atmospheric Cooling**

#### **Atmospheric cooling**

**Radiation:** Air coming into contact with cool ground is cooled in turn.

**Advection:** A warm air mass passing over a cooler region will be cooled by contact.

**Expansion:** By adiabatic process, air which is forced upwards expands and cools.

### **4 – Temperature, Vertical Currents and Terrain**

The properties of the surface have a direct influence on the formation of vertical currents. Wet ground or a water surface will cause much less convection than an arid surface. Flight over a forest on a hot and sunny day will generally be less turbulent than flight over bare ground or fields.

## 5 - Changes of Temperature with Altitude and Inversions

### **Inversions**

Normally the temperature of the atmosphere diminishes with height. However, this is not always the case. Sometimes warmer air may be found at altitude. Such a reversal of normal conditions is known as an inversion if the temperature is actually increasing with height.

Inversions can occur on a clear, still night when the cold ground cools the air above it in the lower levels. The temperature at the top of an inversion so formed may be 15° or 20°C warmer than the temperature at the surface.

Inversions may also occur as cold air, which is denser than warm air, flows into a low lying area such as a valley and becomes trapped there. Warm air, lifted above colder air over a frontal surface, in another cause of an inversion.

Inversion will also be found in the stratosphere. At the tropopause, temperature steady up at  $-56^{\circ}$  in average and remains constant with altitude. This is a zero vertical lapse rate as the temperature does not change with altitude. Then, temperature start to rise with altitude, this is an inversion.

## 6 – Isothermal Layer

**Isothermal Layer:** Layer of the atmosphere where the temperature does not change with altitude.

**Isotherm:** On a weather map, a line joining points of equal temperature.

## 7 – Relative Humidity and Dewpoint

### **Humidity**

Humidity is the presence of water vapor in the air.

**Relative Humidity** is the relation which exists between the amount of water vapor present in the air and the quantity of vapor that same volume of air could contain if it were saturated.

Heating and cooling affect relative humidity as it affect the air capacity to hold water vapor. Hot air can hold more water vapor than cold air without being saturated. Heating of a region reduces relative humidity, while cooling increases relative humidity.

**Saturation:** When an air mass contains as much water vapor as it can hold at a given temperature, it is saturated. The water in surplus condenses and may fall as precipitations.

Hot air can contain more water vapor than cold air. For the same amount of water vapor, the warmer air will have a lower relative humidity.

### **Definitions**

**Dewpoint:** The temperature to which unsaturated air must be cooled, at a constant pressure, in order to become saturated.

**Super-cooled water droplets:** Droplets of liquid water which remain liquid at temperatures significantly below the freezing point.

**Dew:** Humidity which accumulates on objects through condensation on calm, clear nights.

**Frost:** When the dewpoint is below the freezing point, water vapor transforms directly to solid ice crystals by sublimation and accumulates on all surfaces.

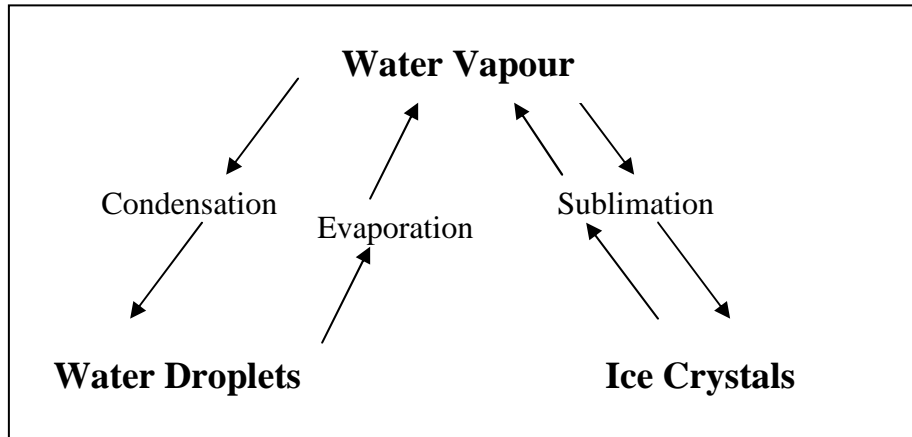
## **8 – The Transformations of Matter: Fusion, Condensation, Sublimation**

### **Transformations**

**Condensation:** When water vapor cools, it condenses, transforming into droplets of liquid water.

**Sublimation:** When water vapor transforms directly into ice crystals, or ice crystals transform directly into water vapor without passing through a liquid stage.

**Evaporation:** When water droplets are heated, they expand and transform into water vapor.



Water vapor = Gaseous State

Water Droplets = Liquid state

Ice Crystals = Solid state

## 9 – Types of Precipitation

### Precipitation

Precipitation occurs when water droplets (visible as clouds) attain mass and dimensions sufficient for gravity to pull them to earth.

In cloud where the temperature is above the freezing point, vertical currents stir the water droplets, causing them to collide and combine into progressively larger drops. The droplets acquire inertia until finally they fall as rain. This process is called coalescence.

Clouds which form at temperatures well below the freezing point are generally composed of small particles of frozen water called ice crystals. These crystals form directly from water vapour through a process called sublimation.



## **Types of Precipitation**

**Drizzle:** Tiny water droplets which seem to be suspended in the air.

**Rain:** Fat water drops.

**Hail:** Hard and transparent layer of ice covering a core of soft ice.

**Snow Pellets (Soft Hail):** Soft white ice, like a hailstone nucleus without the hard cover.

**Snow:** Agglomeration of ice crystals formed by sublimation.

**Ice Prisms:** Tiny ice crystals in the form of needles.

**Ice Pellets / Frozen raindrops:** hard transparent globular grains of ice.

## **10 – Wet and Dry Adiabatic Lapse Rates**

### **Vertical temperature distribution**

The rate of decrease of temperature with altitude is called the vertical lapse rate (or vertical thermal gradient).

### **ICAO Standard                      1.98°C / 1000 ft**

This means that in ICAO conditions, the outside temperature indicated in your airplane will drop 1,98° (you would see 2°) for every 1000 feet you climb upward. But this is only in ICAO (29,92'' and 15°C at ground level). In real world, vertical lapse rate is variable and may take many values. As an example, in the stratosphere it comes to zero / 1000' and even negative in inversions. Air stability will be very dependent on the vertical lapse rate value. This cooling (vertical lapse rate) is due to the fact that higher air is farther from the radiative heat source, the ground.

### **Adiabatic lapse rate:**

When for any reason air start rising, it will expand due to pressure decreasing. Doing so provoke that air mass rising to cool by expansion. Since this cooling is adiabatic, there is no exchange of heat outside the air mass and the cooling will be made at a precise rate. One factor affecting the adiabatic lapse rate is the relative humidity of the air mass rising.

There are different rates for different conditions of relative humidity:

- Dry adiabatic lapse rate                      3°C / 1000 ft

- Wet adiabatic lapse rate                      1.5°C / 1000 ft

The reason why dry and wet rates are different is because when water is forced to condense as the air mass is cooled by expansion (as it rises), it (water) is releasing latent heat inside the air mass fighting and reducing cooling effect. The wet adiabatic lapse rate will therefore be less than the dry rate.

Make sure to not confuse the vertical lapse rate with both adiabatic lapse rates. Vertical lapse rate is temperature taken at different altitude of different air molecules present at those different levels. As opposed to adiabatic lapse rate which is the rate of cooling of an air mass RISING through the air and cooling itself because of expansion.

Stability will be influenced strongly by value of the vertical lapse rate.  
Small vertical lapse rate = stable air.  
Large vertical lapse rate = unstable air.

When an air mass is warmer than its surrounding, it is less dense and would start moving upward by Archimedes principle (buoyancy)

Take note that the adiabatic lapse rate (dry) is greater than the vertical lapse rate which means this: an air bubble warmer than its environment will start rising. Doing so, it will cool itself by expansion at a faster rate than the immobile surrounding air. At a point, it will come to reach the same temperature as its environment and stop moving upward. The air would have then achieved stability. The larger the vertical lapse rate, the harder it is for an air bubble to meet outside temperature and the higher it will travel before being able to do so (unstable conditions).

### **Height of cloud-base**

Knowledge of surface temperature and dew point can help you determine (estimate) the height of the cloud base.

**Example:**

Surface Temperature 15 °C

Dewpoint 5 °C

Relative humidity Dry (unsaturated)

Elevation 1500 feet

1. Subtract the dewpoint from the temperature. Divide the remainder by the Lapse Rate (3). This will give the height of clouds above ground. As long as the air is not saturated (temperature above dew point) you shall use dry adiabatic lapse rate value.

$$10^{\circ}\text{C} / 3^{\circ}\text{C} = 3.333 * 1000 \text{ ft} = 3333 \text{ ft AGL}$$

2. To find the height of clouds above sea level, add the elevation to the answer from Step 1.

$$3333 \text{ ft} + 1500 \text{ ft} = 4833 \text{ ft ASL}$$

Pay attention to not confuse AGL and ASL value in those problems.

**Try solving the following problem:**

Find the altitude of the freezing level above MSL.

Surface temperature: 20°C

Dewpoint: 10°C

Elevation: 2000'

Answer: ( 11999' ASL)

One can push the complexity higher by finding the freezing level inside a cloud. You simply do the same math above the cloud base height but by using wet adiabatic lapse rate and dew point-freezing temperature difference.

In the last problem freezing level would be:

$$(20^{\circ}-10^{\circ}) / 3 \times 1000 = 3333 \text{ feet AGL for the cloud base.}$$

$$\text{Now : } (10^{\circ}- 0^{\circ}) / 1.5 \times 1000 = 6666 \text{ feet ACB (above cloud base ! )}$$

$$6666 + 3333 = 9999 \text{ feet AGL} + \text{elevation} = 11999 \text{ or } 12000 \text{ feet ASL.}<$$

# 405.04 – Clouds, Fog and Lifting Agents

## 1 – Classification of Clouds

### Two Types of Clouds

**Cumulus:** Cumulus clouds form in rising air currents and are evidence of unstable air conditions.

**Stratus:** Stratus clouds form in horizontal layers and usually form as a layer of moist air is cooled below its saturation point. Favored in more stable conditions.

### High Clouds

- base between 16 500 and 45 000 ft;
- composed of ice crystals;
- three types : CI, CC and CS, and;
- designated by prefix “cirro”.

### Cirrus (CI)

- very high, thin wavy clouds made up of slender, delicate curling wisps or fibers;
- generally no weather implications, and;
- may signal the approach of a distant warm front.

### Cirro Cumulus (CC)

- thin clouds, cotton or flake-like;
- rippled like the sand beneath the water’s edge of a sandy beach;
- rare;
- little indication on the weather to come;
- no significant effect on flight, and;
- may indicate strong upward vertical currents.

### **Cirrus Stratus (CS)**

- very thin high sheet of cloud;
- indicates possible bad weather approaching;
- no turbulence or precipitation;
- no significant effect on flight, and;
- sometimes causes a « halo » effect around the sun or moon.

### **Middle Clouds**

- cloud base between 6 500 and 23 000 ft;
- made up of ice crystals, water droplets and super-cooled water droplets, and;
- three types: AC, ACC and AS.

### **Alto Cumulus (AC)**

- layer or series of rounded masses of cloud lying in groups or lines;
- light turbulence;
- little or no precipitation, and;
- some icing may occur.

### **Alto Cumulus Castellanus (ACC)**

- altocumulus with a « turreted » appearance; can transform into cumulonimbus;
- a variation of altocumulus;
- significant vertical extension evidence of powerful vertical currents;
- showery conditions are possible;
- indicates unstable conditions, possible thunderstorms late in the day, and;
- moderate turbulence and icing.

### **Alto Stratus (AS)**

- thick layer of dense grey cloud generally covering the entire sky;
- appears beneath cirrostratus layers;
- may indicate the approach of a warm front;

- covers a wide area;
- light turbulence, and;
- occasional light rain or snow.

### **Low Clouds**

- base between the surface and 6 500 ft;
- composed primarily of water droplets, possibly super-cooled, and ice crystals, and;
- four types: SC, ST, NS, and SF.

### **Strato Cumulus (SC)**

- thin layer of rounded cloud;
- often seen in high pressure areas during the winter;
- blue sky visible through gaps in the clouds;
- base is generally above 2 000 ft, and;
- turbulence below the cloud, smooth air above.

### **Stratus (ST)**

- very low, flat base;
- normally hundreds of feet thick, and;
- poor visibility, often due to drizzle and fog.

### **Nimbo Stratus (NS)**

- low layer of flat grey cloud;
- thickened altostratus;
- associated with a warm front;
- summits to 25 000 ft;
- continuous rain or snow, and;
- light to moderate turbulence, icing.

### **Stratus Fractus (SF)**

- stratus broken up by strong winds (ragged cloud), and;
- normally forms in the precipitation below a nimbostratus layer ; may or may not be fused with the upper layer.

### **Clouds of Vertical Development**

- bases from 1 500 to 7 000 or 8 000 ft. with tops sometimes over 60 000 feet;
- made up of water droplets, super-cooled water droplets and ice crystals, and;
- four types : CU, TCU, CB, CF

### **Cumulus (CU)**

- thick, rounded and lumpy;
- flat base and rounded summit;
- form during the daytime and dissipate at night;
- the height of the cloud base depends on the temperature-dewpoint spread;
- light to moderate turbulence, and;
- no precipitation.

### **Cumulus Fractus (CF)**

- Cumulus which has begun to form or which has been broken up by the wind.

### **Towering Cumulus (TCU)**

- cumulus clouds that build up into high towering masses;
- severe turbulence and icing;
- snow showers in winter;
- light rain showers in summer, and;
- turbulent and beneath clouds and severe icing inside the cloud.

### **Cumulonimbus (CB)**

- develop from towering cumulus;
- mature clouds have a characteristic of an anvil head and the onset of precipitation;
- produce thunder and lightning;
- severe icing, turbulence and showers;
- hail often forms inside the cloud and sometimes outside as well, and;
- violent surface winds are common surrounding the cloud.

## **2 – Cloud Formation and Composition**

Clouds form by condensation or sublimation of water vapor when the following conditions are present :

- Relative humidity is high.
- There are condensation nuclei present. (Microscopic particles like dust, smoke, sea salt, seeds, pollen etc. in suspension in the air, on which water vapour condenses to liquid water droplets.)
- The air is being cooled.



### 3 – Precipitation and Turbulence Associated with Cloud Types

	Precipitation	Precipitation Cloud Types	Cloud Types
Drizzle, freezing drizzle, snow grains	Drizzle, freezing drizzle, snow grains	Continuous snow or rain	Stratus, Stratocumulus
Stratus, Stratocumulus	Continuous snow or rain	Intermittent snow and rain	Thick Altostratus, Nimbostratus
Continuous snow or rain	Intermittent snow and rain	Showers (Rain or snow)	Thick Altostratus, stratocumulus, cumulonimbus
Thick Altostratus, stratocumulus, cumulonimbus	Showers (Rain or snow)	Snow pellets, hail, showers of ice pellets	Altocumulus, towering cumulus, cumulonimbus
Altocumulus, towering cumulus, cumulonimbus	Snow pellets, hail, showers of ice pellets	Continuous ice pellets	Any rain-producing cloud (below the freezing point)
Snow pellets, hail, showers of ice pellets	Continuous ice pellets	No cloud necessary	No cloud necessary

**Turbulence:** Turbulence is most severe in cumuliform clouds which produce showery precipitation. Any rain-producing cloud (below the freezing point)

Ice prisms  
No cloud necessary

### 4 – Types of Fog

#### Fog

Fog is in fact a cloud, usually stratus, in contact with the ground. It forms when the air is cooled below its dewpoint, or when the dewpoint is raised to the air temperature through the addition of water. When the temperature drops and reaches the dewpoint, both temperature and dewpoint will then drop together (since the dewpoint can't be higher than the air temperature. Risk of fog is to be considered when surface temperature is less than 2 degrees from the dew point temperature.

**The types of fog formed by cooling are:** radiation fog, advection fog and upslope fog.

**The types of fog formed by the addition of humidity are:** steam fog, precipitation induced fog and ice fog.

Frontal fog is formed by both cooling and the addition of humidity.

### **Radiation Fog**

Ordinarily forms at night but can also form at sunrise. The ideal conditions for the formation of radiation fog are:

- clear skies;
- moist air, and;
- light wind

The ground cools, losing its heat through radiation. The air in contact with the surface loses its heat as well. If the air is moist and the temperature is falling close or to the dewpoint, fog will form.

### **Advection Fog**

Caused by a warm and moist air mass which drifts over a large body of cooler water or ground. This fog can form in winds exceeding 15 mph.

### **Upslope Fog**

Caused by cooling due to expansion as it moves up a slope. A light upslope wind is necessary for its formation.

### **Steam Fog**

Appears when a cool air mass passes over a warm water surface. Evaporation occurs until the air mass becomes saturated. The extra water vapour condenses in the form of fog.

### **Precipitation-Induced Fog**

Occurs when the air receives a surplus of moisture through evaporation of rain or drizzle.

### **Ice Fog**

Forms in moist air during extremely cold calm conditions. The tiny ice crystals composing it are formed by sublimation and are often called needles. Ice fog is caused by the addition of water vapour to the air through fuel combustion. The very cold air cannot hold any additional water vapour and the excess water sublimates into visible ice crystals. Ice fog may appear suddenly when an aircraft engine is started (dust and the water vapor resulting from fuel combustion are mixed together within the air by the spinning propeller.)

### **Frontal Fog**

Fog associated with warm fronts covers the most area and is caused by rain falling from the warm air, evaporating and saturating the cool air underneath. (See precipitation-induced fog.)

## **5 – Lifting Agents**

**Lifting agent:** is a phenomenon that permits the air to rise and expand so that cooling process may lead to cloud / fog formation.

**Orographic Lift:** Air flowing up the slope of sloped terrain, such as a mountain range, will continue to climb due to inertia, especially if it is unstable.

**Frontal Lift:** When different air masses meet, the cool air, whether advancing or retreating, undercuts the warm air and forces it to rise.

**Convection:** Air is heated by contact with the terrestrial surface which creates currents of rising air. (Thermals)

**Convergence:** In a depression, the wind blows across the isobars towards the centre of the depression. Air accumulates at the centre, resulting in an upward flow of air. The large scale expansion of the air mass will be responsible for the bad weather often associated with low pressure systems.

**Mechanical Turbulence:** Friction between the air and ground disturbs the flow of air. The unequal heating of various surfaces cause the formation of vertical currents.

# 405.05 – Air Masses and Stability

## 1 – Air Mass

**Definition:** A large segment of the troposphere with uniform properties of temperature and humidity in the horizontal.

## 2 – Classification of Air Masses

### Three Main Classes:

- Arctic Air Mass                      « A »
- Polar Air Mass                        « P »
- Tropical Air Mass                    « T »
- Classified by the temperature at the source of the air mass.

### Two sub-classes:

- Continental Air Mass                « c »
- Maritime Air Mass                    « m »
- Classified by the humidity of the air, according to whether the air originates over the continent or an ocean.

### **3 – Air Masses and the North American Climate (cA mA mP mT)**

Those four air masses are the most frequently seen in North America.

#### **Continental Arctic (cA)**

- forms over the polar regions (generally during the winter);
- dry;
- very cold;
- very stable, and;
- very low tropopause.

#### **Maritime Arctic (mA)**

- forms over Alaska or Siberia;
- spends little time over the Pacific;
- moist;
- cold;
- unstable in the lower layers, and;
- low tropopause.

#### **Maritime Polar (mP)**

- forms over the polar region of North-central Russia;
- spends considerable time over the Pacific;
- moist;
- cool;
- unstable, and;
- medium-height tropopause.

### **Maritime Tropical (mT)**

- forms over the Pacific or Atlantic;
- rarely appears north of the Great Lakes;
- often creates fog in the Maritime Provinces;
- moist;
- warm;
- highly Unstable, and;
- high tropopause.

## **4 – Modification of Air Masses**

Air masses are in constant motion. While the characteristics of an air mass are determined by the region in which it originates, these characteristics of temperature and humidity will change according to the conditions it encounters in its passage over the ground. For example, a continental arctic air mass which passes over an ocean will accumulate moisture and become a Maritime Polar or Maritime Arctic air mass.

## **5 – Weather in an Air Mass**

### **Cold Air Mass:**

Instability	Cumuliform Clouds
Turbulence	Showery precipitation
Good visibility	Risk of thunderstorms

### **Warm Air Mass:**

Stability	Stratiform clouds
Calm air	Drizzly precipitation
Poor visibility	

## **6 – Effects of Seasons and Geography on Air Masses**

As the temperature warms in the springtime in North America, the Arctic air masses tend to remain further north and not extend to the heavily populated areas of Canada or the United States. The rising temperature and the melting snow transform the Arctic air mass into a Polar air mass.

## **7 – Lapse Rate**

The thermal gradient is the rate of decrease of temperature with altitude in an air mass.

## **8 – Lapse Rate and Stability**

A strong lapse rate implies unstable air. Cool air in upper layers tends to descend, disrupting the warmer air in the lower atmosphere and causing it to rise.

A weak lapse rate implies stable air. If the temperature decreases little with altitude or if there is warmer air at altitude, there will be no tendency for vertical currents to develop.

## **9 – Atmospheric Heating and Stability**

**Strong lapse rate:** When the lower levels of the atmosphere are heated or when the upper levels are cooled.

**Weak lapse rate:** Occurs when lower levels are cooled or upper levels are heated



## 10 – Characteristics of Stable and Unstable Air

Summary of weather conditions

Characteristics	Stable Air	Unstable Air
Lapse Rate	Weak	Strong
Clouds	Stratus	Cumulus
Precipitation	Uniform intensity, drizzle	Showers
Visibility	Poor	Good
Winds	Steady	Gusty
Turbulence	Light	Moderate to Severe

## 11 – Atmospheric Heating and Stability

Ground which is being heated will heat the air in contact just above, creating unstable conditions.

Ground which is cooling will cool the air above, causing stable conditions.

## 12 – Visibility and Stability

Visibility is the distance at which prominent objects may be seen and identified by day and prominent lighted objects by night. Visibility is one of the most important elements for safe flight. Reduced visibility reduces the accuracy of a pilot's observations and interferes with safe navigation and traffic avoidance.

Flight Visibility (or "air to air visibility") is the average forward visual range from the pilot's seat of an aircraft.

Ground visibility is the visibility at an airport, as reported by an accredited observer.

**Restrictions to visibility:**

Cloud	Haze (HZ)
Precipitation	Smoke (FU)
Mist (BR)	Sand (SA)
Fog (FG)	Dust (DU)
Volcanic Ash (VA)	

Visibility is generally worse in stable air because the air moves mainly in the horizontal and the clouds form in layers. However, unstable air may also cause restricted visibility.

**Stable Air:** Pollution and dust are imprisoned in the lower levels; drizzle and fog.

**Unstable Air:** Smoke and impurities can be distributed vertically; may cause drifting or blowing snow.

## 13 – Convergence and Divergence

**Convergence:** The inward flow of air accompanied by an upward flow as the excess air escapes. A low pressure is characterized by convergence because the air flows towards the interior. This air will expand, cool and potentially condense. This is one reason why bad weather usually prevails in low pressure area.

**Divergence:** The outward flow of air is compensated for by a downward movement of air. That air will subside and warm itself lowering the relative humidity. This is why good weather usually prevails in high pressure region. A high pressure area is characterized by divergence because the air is flowing towards the exterior.

## **405.06 – Fronts**

### **1 – Definition of a Front**

**Definition:** An area of transition between two air masses.

### **2 – Terms and Definitions: Different types of fronts**

**Frontolysis:** The transition zone between two air masses enlarges and diffuses (the front dissipates). A front which diminishes in intensity.

**Frontogenesis:** The transition zone between two air masses becomes more abrupt and well defined (the front is formed). A front which increases in intensity.

#### **Cold Front:**

- a cold air mass which overtakes a warm air mass;
- plane of the frontal surface : 1 mile high / 50 miles long (steep slope);
- low ceiling and clouds of vertical development;
- visibility improves after the passage of the front;
- precipitation : Rain ; snow showers;
- turbulence ; difficult flying conditions;
- winds veer after the passage of the front;
- temperature : lower after the passage of the front, and;
- possible formation of single thunderstorms or a squall line.

**Warm Front:**

- a cold air mass retreating to an advancing warm air mass;
- plane of the frontal surface : 1 miles high / 150-200 miles long (gentle slope);
- the cloud band can cover 500 miles;
- precipitation can precede the front by 250 miles;
- low ceiling with stratus clouds;
- visibility : reduced;
- precipitation : strong as the front passes;
- turbulence : light;
- winds : veer gradually as the front passes;
- temperature : increases gradually after the front passes;
- signs of an approaching warm front : CCANS (cirrus, cirrostratus, altostratus, nimbostratus, stratus), and;
- embedded cumulonimbus may form in the cloud layer.

**Stationary Front:**

An area in which the cold air is neither advancing nor retreating.

**Occluded Cold Front (Cold Occlusion):**

- Cold air advances on a warm air mass and lifts the warm air in such a way that the warm air is completely disconnected from the ground;
- Cold air catches up to cool air;
- Creates a trough of warm air aloft (trowal), and
- Same characteristics as a warm front with a chance of cumulonimbus developing if the warm air is unstable and moist enough.

**Occluded Warm Front (Warm Occlusion):**

- Over the distance it has covered, the cold air may have undergone a transformation, becoming less cold than the cold air it catches;
- Cool air catches up to cold air;
- Creates a trough of warm air aloft (trowal), and;
- Same characteristics as a warm front with a chance of cumulonimbus developing if the warm air is unstable.

**Trowal:** A trough of warm air aloft

**Upper Front:** In Canada, the term « upper front » refers to a non-occlusion situation. Sometimes, cold air advancing across the country may encounter a shallow layer of colder air resting on the surface or trapped in a topographical depression. The advancing cold air rides up over the colder, heavier air. A station on the ground will not feel any temperature change or winds but will observe the cloud and precipitation associated with the front present at altitude.

### **3 – Frontal Formation**

According to the direction of the prevailing winds, winds developing in the cold air mass will come from the east and winds developing in a warm air mass will come from the west. The warm air mass to the south tends to push into the cold air to the north; the cold air mass to the north also tends to push into the warm air to the south. The combination of these tendencies creates a counter-clockwise rotating motion. A depression (the polar depression) is thus created and grows steadily.

Fronts are created and intensify in the polar depression See From The Ground Up pg. 130 (141 millennium edition) for the diagrams.

## **405.07 – Meteorological Hazards**

### **1 – Types of Turbulence and Convection**

**Turbulence:** is an irregular movement of air resulting in eddies and vertical currents. It ranges between some minor bumps of no consequence, to movements strong enough to cause momentary loss of control and structural damage.

#### **Types / Causes of Turbulence**

**Mechanical Turbulence:** Friction between the air and ground, particularly when the terrain is irregular and there are obstacles, creates eddies and therefore turbulence in the low levels.

**Thermal (Convective) Turbulence:** On hot summer days, the uneven heating of the surface by the sun causes turbulence. Isolated convective currents are formed, creating the turbulence.

**Frontal Turbulence:** Warm air lifted by the frontal surface and friction between the two contrasted air masses produces turbulence in the frontal zone.

**Wind Shear:** Changes of wind speed and direction with altitude create local turbulence. When the change in wind speed and direction is pronounced, the turbulence can be severe.

### **2 – Wind Shear**

Wind shear is the sudden « tearing » or « shearing » effect encountered along the edge of a zone in which there is a violent change in wind speed and /or direction. The effect on aircraft performance of encountering wind shear derives from the fact that the wind can change much faster than the airplane mass can be accelerated or decelerated. Severe wind shear can impose penalties on an aircraft's performance that are beyond its capacity to compensate, especially during the critical landing and take-off phases of flight.

### **Sources of wind shear near the surface.**

**Frontal Wind shear:** Wind shear is usually a problem only in fronts with steep wind gradients. If the temperature difference across the front at the surface is 5°C or more, and if the front is moving at a speed of 30 kts or more, wind shear is likely to be present. Whatever which direction the front is crossed; the wind direction change will always require a course correction to the right.

**Low-level wind shear:** Associated with thunderstorms. Low-level wind shear is the result of two phenomena, the gust front and downdrafts. Strong downdrafts develop during the maturing phase of the thunderstorm, striking the ground and spreading out horizontally along the surface well in advance of the thunderstorm itself. Winds can change 180° and reach speeds as great as 100 kts as far as 10 miles ahead of the storm.

**Temperature inversions (low-level jet stream:** Overnight cooling creates a temperature inversion a few hundred feet above the ground that can produce significant wind shear, especially if the thermal inversion is coupled with the low-level jet stream. This wind shear is at its most severe shortly after midnight and dissipates as daytime heating eliminates the inversion.

**Jet Stream:** Sheets of strong winds, generally between 100 and 125 kts and possibly reaching 250 kts in speed. The jet stream exists in the upper atmosphere, between 20 000 and 40 000 ft (or above).

**Surface Obstructions:** The irregular or turbulent flow of air around mountains and hills, and through mountain passes causes serious wind shear problems for aircraft approaching to land at airports near mountain ridges.

## **3 – Thunderstorm Formation**

### **Conditions for Thunderstorm Development**

The following conditions promote the formation of thunderstorms:

- unstable Air;
- high relative humidity, and
- lifting agent.

Lifting agents responsible for thunderstorms are:

- convection;
- orographic lift, and;
- frontal lift.

### **Two types of thunderstorms**

- air mass thunderstorms (Convection or orographic lift), and
- frontal thunderstorms.

## **4 – Structure of a Thunderstorm**

### **Stage 1: Cumulus stage**

- strong ascending currents dominate; unstable air up to upper levels;
- temperature inside the cell is higher than the temperature of the surrounding air;
- the diameter of the cell is between 1 and 2 miles (but can reach up to 6 miles), and;
- the vertical lapse rate is strong.

### **Stage 2: Maturity**

- ascending currents can attain an impressive height;
- descending currents begin in the centre and lower levels of the cell;
- precipitation begins, and;
- this stage generally lasts 15 to 20 minutes (but may last up to 60 minutes).



### **Stage: Dissipation**

- except for the summit where upward movement persists, descending currents prevail throughout the cell;
- precipitation diminishes and stops, and;
- the summit of the cloud spreads out into the classic “anvil” shape.

### **Thunderstorms are accompanied by:**

Thunder	Gusts and violent turbulence
Lightning	Abundant rain
Strong vertical currents	Sometimes hail
Icing	Poor visibility

There is two type of Thunderstorm: Air masses thunderstorms and Frontal thunderstorms.

## **5 – Hazards Associated with Thunderstorms**

### **Turbulence**

Descending currents can attain 2000 ft/min and ascending currents can attain 6000 ft/min. In some instance within microburst, downdraft may attain more than 6000 ft/min. That’s more than 60 mph going down! Turbulence can be severe, causing structural damage. Winds can gust up to 80 kts. Hail can cause serious damage to the aircraft. Dangerous icing can be caused by super-cooled water droplets striking the aircraft. Lightening damages vision. Lightening may hit the aircraft (probability is increased when the temperature is between -5°C to +5°C. Heavy rain can cause contamination of the wing surface and lead to an unexpected stall. Rain reduces visibility.

## **6 - Altimeter Errors Caused by Thunderstorms**

Thunderstorms are concentrated low pressure areas; the local fluctuations in barometric pressure mean the altimeter is unreliable.

## 7 – Flight around Thunderstorms and Thunderstorm Avoidance

### Thunderstorm Avoidance

- do not fly through thunderstorms;
- avoid taking off or landing near thunderstorms;
- do not fly under a thunderstorm;
- reduce your speed to the maneuvering speed at the first sign of turbulence, and;
- if you fly near a thunderstorm, stay at least 10-15 miles away and on the right-hand side of the CB. As a pilot, avoiding flying near a thunderstorm is safest procedure to follow. A thunderstorm is a highly concentrated area of low pressure (counter-clockwise and inward airflow). You will encounter favorable winds flying around the right-hand side of a thunderstorm cell.

## 8 - Contamination of Aircraft Surface on the Ground

**Weight:** accumulation due to snow and ice. Remove even if flight is not planned. Never assume snow will fall off by itself. Snow may even turn to ice during take-off.

**Critical Surfaces:** wings, control, rotors, propellers and upper surface leading to a pusher propeller, horizontal and vertical stabilizers and all stabilizing surfaces of an aircraft.

**Water:** Accumulation in pitot and static ports, air intakes, ventilation intakes. May freeze and cause malfunction.

**Pre-flight Inspection:** never let cold weather dictates how much time you spend on the pre-flight inspection; indeed, be more vigilant.

## 9 – Icing

### Icing

At temperatures below zero Celsius, super-cooled water droplets may come in contact with the lifting surfaces of the aircraft; they will freeze and stick to the surface. This process is called icing. Clouds, freezing rain and freezing drizzle may all lead to dangerous icing.

### Types of Icing

**Frozen Dew:** Generally clear and slightly crystalline; forms on aircraft parked outside on clear and cold nights. Dew condenses on the skin of the aircraft and then freezes as the aircraft surface cools. It is very dangerous to fly with frozen dew on the lifting surfaces; it must be removed before takeoff.

**Frost:** white, feathery, semi-crystalline, sometimes covering the entire surface of the aircraft. Forms when the moisture in the air sublimates onto the cold surface of the aircraft; this can occur in flight or on the ground.

**Rime Ice:** a deposit of opaque, milky white ice. Rime ice accumulates on the leading edges of the wings and on antennae; forms through the freezing of super-cooled water droplets on contact with the aircraft's surface. Rime ice tends to be brittle. When freezing, it traps air inside its structure giving its milky color.

**Clear Ice:** A heavy layer of clear ice which forms on all surfaces. Forms when a small portion of a water droplet freezes on impact, and the remainder spreads over the surface to freeze more gradually.

### Rate of Capture

The Rate of Capture of ice is higher for a thin wing flying at high speed; the number of droplets hitting the aircraft increases with speed. A thin wing captures more droplets than a thick wing.

## 10 – Dangers Associated with Icing

Surface	Effect
Controls	Reduces lift and therefore effectiveness ; ice can block the controls
Wings	Modifies the shape of the wing; destroys laminar airflow by provoking transition; increases weight. The stall speed increases.
Windscreen	Reduced visibility
Antennae	May block transmission
Pitot and Static ports	Obstructs the ports

## 11 – Smoke and Haze and their Effect on Visibility

**Haze:** Tiny water droplets and particles of dust which create a uniform veil over the sky. Smoke is caused by industrial pollutants and vehicle exhaust. Haze is encountered above all in urban areas when the air is very stable.

## 12 – Squall Line

Long line of thunderstorm cells accompanying the passage of a rapid cold front. Hazards associated with a squall line are similar to those of a thunderstorm but squall lines are harder to dodge since they are much larger systems. The only options are to fly away or to land before the system hits the region.

## 13 – Tornado

- Violent rotating depressions, associated with severe thunderstorms.
- Very deep, concentrated depressions.
- Resemble funnels suspended under a cumulonimbus; have a dark color due to the dust and debris suspended in the vortex.
- Very high winds (up to 300 kts).
- Rotates 99% of the time counterclockwise (some clockwise tornado in U.S.A have been spotted on some rare occasions !).

# **405 - METEOROLOGY (Objective 2 – Weather Reports)**

## **405.01 – METAR and TAF**

### **1 – METAR**

#### **METAR**

- regular aviation weather report;
- prepared and released each hour on the hour;
- valid at the time of issue;
- covers an area of 5 nautical miles around an aerodrome;
- altitudes are given in AGL, and;
- degrees are given in degrees true.

#### **SPECI**

- special aviation weather observation report;
- broadcast when important changes in the weather occur, and;
- valid at the time of issue.

### **2 – Decoding a METAR**

Each report is prefixed with the word “METAR” or “SPECI” for identification purposes

### **Station Identifier**

Composed of 4 letters (ICAO Standard)

Example: CYWG – Winnipeg

CY = Country (Canada)

WG = Aerodrome (Winnipeg)

In an identifier, the ‘‘Y’’ mean ‘‘yes’’ as in yes weather information can be obtained for this aerodrome.

**Date and Time:** Generally six digits, using Universal Coordinated Time (UTC).

Example: 132000Z = 13th day of the month, at 20:00 UTC.

**Surface Winds:** Wind direction is given in degrees true (3 digits) and wind speed is given in Kts. If gust conditions exist, the symbol G followed by the speed of the gust peak in kts will be used.

Example: 30015G25KT = Winds from 300o true, at 15 Kts, with gusts to 25 Kts.

**Dominant Visibility:** Measured in statute miles and fractions of statute miles. Defined as the prevailing visibility within a half mile or more in the horizontal plane.

Example: 3/4SM = Visibility of  $\frac{3}{4}$  statute miles.

**Runway Visual Range:** Gives runway visual range on a particular runway, and shows the tendency (D = diminishing visibility, U = rising, N = stable)

Example: R36/4000FT/D = runway 36, 4000 ft visual range, diminishing.

RVR is included when its value is less than 6000 feet or if visibility is less than 1 Sm.

**Current weather:** Reports the type of precipitation and intensity (- indicates light, + indicates heavy).

Example: -SN BLSN = light snow, blowing snow

### Codes Describing Current Conditions

SH	Showers	PE	Ice pellets
DR	“Drifting”	HZ	Haze
TS	Thunderstorm	FU	Smoke
FZ	“Freezing”	SA	Sand
MI	Thin	FG	Fog (vsby < 5/8)
BL	“Blowing”	BR	Mist (vsby > 5/8)
BC	Patches	DU	Dust
RA	Rain	+FC	Tornado
SN	Snow	VA	Volcanic Ash
DZ	Drizzle	FC	Funnel Cloud
SG	Snow Grains	SS	Sandstorm
IC	Ice Crystals	PO	Dust devils
GS	Snow Pellets	SQ	Squall
GR	Hail	DS	Dust Storm

**Sky Condition:** The height of the clouds is reported in hundreds of feet.

Example: 030 = 3000 ft, 140 = 14000 ft, 003 = 300 ft.



**Cloud amount:** Measured in « octas » (eighths of the sky).

Example: SCT020 BKN080 = Scattered layer at 2000 ft and broken layer at 8000 ft).

Code	Text	Means	Coverage
CLR	Sky clear	no cloud observed	0/8
FEW	few	traces of cloud up to 2 octas	2/8
SCT	scattered	3 to 4 octas	3/8 to 4/8
BKN	broken	from 5 to <8 octas	5/8 to less 8/8
OVC	overcast	8 octas	8/8

**Ceiling:** It is said that a ceiling exists at the first layer for which a condition of broken or overcast exists, or the vertical visibility reported when a condition such as snow, smoke or fog is present.

**Vertical Visibility:** Reported if the sky is obscured by a layer at the surface of the ground, such as fog or heavy precipitations. VV will constitute a ceiling as per next definition.

Example: VV003 = vertical visibility of 300 ft.

**Temperature:** Rounded to the nearest degree Celsius. Negative values are preceded by the letter « M ». The temperature and dewpoint are separated by a slash.

Example: 03/M01 = Temperature 3oC, Dewpoint -1oC.

**Altimeter setting:** In Canada and the US, the altimeter setting is given in hundredths of inches of mercury, in the form of 4 digits preceded by the letter A. Remember that altimeter setting is station pressure to which we add an imaginary column of air starting from station altitude descending (through the earth) to mean sea level forming a standardized pressure mimicking mean sea level pressure. This standardized pressure is the altimeter setting.

Example: A2937 = Altimeter setting of 29.37”Hg

International convention requires that the altimeter setting be indicated in whole hectopascals. The group is then preceded by the letter Q.

Example: Q1002 = Altimeter setting of 1002 HPa

**Remarks:** Identified by the code « RMK ». Includes types of clouds and the opacity of each layer, the sea level pressure in HPa and any other information of interest to aviation.

Example: RMK SLP 059 = Sea Level Pressure 1005.9 HPa

**Sky coverage:** In the METAR system, the code describing sky condition is based on the actual quantity of cloud present, without regard for the transparency of the cloud layers. However, the opacity of cloud (the part you cannot see through) is reported separately in the Remarks section.

Example: ST2SC3AC2 = Stratus covering 2/8 ; stratocumulus covering 3/8 ; and altocumulus covering 2/8 of the sky. Together they cover 7/8 of the sky.

**Partial Obscurement:** If only a portion of the sky is obscured by a phenomenon, such as fog, this will not be reported in the METAR but rather in the remarks section with the number of octas affected.

Example: FG5 = Fog obscuring 5/8 of the sky.

### 3 – AWOS METAR

METAR issued by an automated weather observation station, therefore less reliable and less complete than a regular METAR

## 4 – Issuing, Validity and Area of a TAF

### TAF

- international aerodrome weather forecast;
- lists in specific terms the weather conditions expected which will affect take-off and landing of aircraft at an aerodrome;
- contains forecast winds, wind shear, prevailing visibility, recent weather and sky condition;
- covers an area of 5 NM around the aerodrome;
- altitudes are given in AGL;
- degrees are given in degrees True;
- issued 4 times each day at 6 hour intervals, and;
- valid for a period of 20 minutes after time of issue or until replaced by another TAF.

## 5 – Decoding a TAF

Each report is preceded by the code « **TAF** » for identification.

**The station identifiers** and symbols for sky condition, precipitation and obstructions to visibility are the same as for the METAR.

**Date/Time of Issued:** Day of the month and time of issued (UTC) is found immediately after the station identifier block.

Example: TAF CYWG 121030Z = 12th day of the month, at 1030 UTC.

**Validity period:** International forecasts are valid for 24 hours from their time of issue. Domestic forecasts are valid for 12 hours from their time of issue. Forecasts are issued every 6 hours.

Example: 121111 = Valid on the 12th day of the month at 11:00 UTC, ending on the 13th day at 11:00 UTC. TAF stay valid until the end of their validity period or until replaced by a new such as an amended TAF.

**Forecast winds:** The same code as for METARS. When winds are forecast to be calm, the following code is used: 00000KT. When winds below 3 knots are expected, the following code is used: VRB03KT.

**Forecast Visibility:** Same format as in METARS. Visibility superior to 6 statute miles will be indicated as P6SM.

**Forecast Weather:** Same codes as METARS, immediately after the visibility block.

**Sky Condition:** Same format as in METARS.

**Forecast Changes:** The weather is rarely constant through a period of 12 or 24 hours. The validity period of the forecast is therefore divided into several “partial periods”, each representing a span of time during which a permanent change in weather conditions is expected.

Example: FM0400Z = Indicates the beginning of a new partial period, beginning at the hour indicated (04:00 UTC).

Example: BECMG 1214 = Indicated when there is a permanent change coming sometime within a range of time. In the example the change is expected at some time between 12:00 and 14:00 UTC.

Example: TEMPO 0914 = Indicates a temporary change in weather conditions to occur between the times indicated. The weather will change for the period between 09:00 and 14:00 UTC.

Example: PROB30 0407 = Indicates a probability of 30% that there will be a change in weather between 04:00 and 07:00 UTC. Used only for probabilities less than 50%.

## **405.02 – GFA and FD**

### **1 – Issue and Validity of a GFA**

Series of weather charts up-dated periodically, each describing the most probable weather conditions forecast below 400 millibars (24 000 ft) for a given area at a given time.

**GFAs** are issued 4 times a day, about 30 minutes before the beginning of the forecast period. They are valid at 0000Z, 0600Z, 1200Z and 1800Z. Each GFA is issued as a group of 6 charts: 2 charts valid at the beginning of the forecast period; 2 other valid 6 hours into the forecast period; and 2 others valid 12 hours into the forecast period.

One chart shows the clouds and weather while the other shows the icing, turbulence and freezing level. An outlook of IFR conditions for an additional 12 hour period is included on the last chart describing the cloud and weather conditions.

### **2 – Interpreting GFA charts**

- wind speed is in knots and direction is in degrees True;
- cloud heights are reported in hundreds of feet ASL. (AGL if indicated), and
- distances are in nautical miles and visibility is reported in statute miles.

#### **Layout**

Each GFA is divided into four sections: Title box, legend box, comments box and meteorological information section.






## Title Box

The title box includes the name of the chart, the issuing station's four-letter identifier, the name of the GFA region, the type of chart, the date and time of issue and the date and time of validity of the chart. The title box is in the upper right corner of the GFA. In the following example, the title box indicates the name of the GFA (GFACN33) and that it was issued by the office of weather and environmental services of Montreal. (CWUL). The region of the GFA in the example is ONTARIO-QUEBEC and the type of chart is "Clouds and Weather". The following field notes the time of issue of the chart (11:30 UTC on the 17th of September, 1999). The last field indicates the beginning of the validity period of the chart. This example is valid from 0000 UTC on the 18th of September 1999.

GFACN33 CWUL	
REGION / ONTARIO-QUEBEC	
CLOUDS AND WEATHER NUAGES ET TEMPS	
ISSUED AT EMIS A	17/09/1999 1130Z
VLD:	18/09/1999 0000Z

## Legend

The legend displays the symbols which may be used in the meteorological information section of the GFA. It also includes a scale of distance in NM to facilitate calculations. The symbols used correspond to those used in a significant weather forecast chart. In the following example, the symbols for thunderstorm (TS), hail (PL), freezing rain (FZRA), and freezing drizzle (FZDZ) are indicated in the legend.

LEGENDE / LEGENDE			
	:TS		:PL
	:FZRA		:FZDZ
 0 50 100 100 NM (Tous en 100° N / Tous en 100° N)			

## **Abbreviations and Symbols**

Only standard meteorological abbreviations are used on a GFA. The symbols used on the GFA correspond to those on similar meteorological products described in the A.I.M., such as significant weather forecast charts.

## **Comments box**

The comments box provides information the forecaster considers important (Ex. the formation or dissipation of fog, increase or decrease in visibility, etc.) It also contains descriptions of elements difficult to show graphically (ex. Light icing). The standard phrases, “HGTS ASL UNLESS NOTED » AND « CB TCU AND ACC IMPLY SIG TURBC AND ICG. CB IMPLIES LLWS” are also included in the comments box. An IFR outlook for a period of 12 hours after the validity period of the GFA is included in the comments box of the Clouds and Weather map of the 12-hour forecast GFA.

In this example, the forecaster has made two comments: the fog or mist will dissipate after 1400 UTC ; and the stratocumulus ceilings will become scattered after 1500 UTC.

The comments box of the 12-hour forecast Clouds and Weather GFA includes a 12-hour IFR outlook in the lower section of the box. The IFR outlook is always general in nature, indicating the main areas where IFR conditions are expected, the cause of the IFR conditions and the weather conditions associated. In the example, IFR conditions caused by low ceilings (CIG), rain (RA) and mist (BR) are forecast. These IFR conditions are due to air flowing from the north-west of James Bay (JAMSBA) and Hudson’s Bay (HSNBA) towards shore (ONSHR) and up slope (UPSLP).


The IFR outlook is based on the following elements:

**CATEGORY: CEILING / VISIBILITY**

**IFR:** less than 1000 ft AGL and / or less than 3 SM

**MVFR:** From 1000 to 3000 ft AGL and / or 3 to 5 SM.

**VFR:** more than 3 000 ft AGL and more than 5 SM

<p><b>COMMENTS / COMMENTAIRES</b></p> <p>1. FG/BR DS IPTG AFT 14Z</p> <p>2. SC CIGS BECMG SCT AFT 15Z</p> <p>HGTS ASL UNLESS NOTED CB TCU AND ACC IMPLY SIG TURBC AND ICG. CB IMPLIES LLWS</p> <p> Environment Canada Environnement Canada</p>
<p><b>IFR OTLK</b></p> <p>IFR CIG/RA/BR S STLAWRC VLY. LCL IFR IN ONSHR/USLP NWLY FLO OFF JMSSA AND HSNBA.</p>

**Meteorological Information**

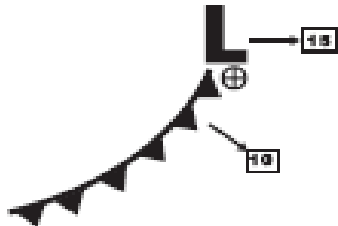
The Meteorological Information section of the map is a graphic representation of the cloud and weather conditions forecast or the icing, turbulence and freezing level forecast for a given time.

**Cloud and Weather Chart**

The Cloud and Weather GFA provides a forecast of the cloud layers and / or surface phenomenon, visibility, weather conditions and obstructions to visibility at the time of validity of the particular chart. Lines joining areas of equal barometric pressure (isobars) are shown at 4 Mb intervals. The fronts and pressure systems responsible for the weather conditions are also represented along with their speed and motion at the time of validity of the chart.

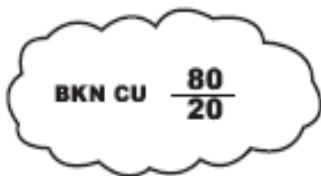


**Fronts and Pressure systems:** The motion of fronts and pressure systems, when the forecast velocity is 5 kts or more, is indicated by an arrow and a speed. In case of speeds lower than 5 kts, the letters QS (quasi-stationary) are used. The centre of a depression moving Eastward at 15 kts with an associated cold front moving South-East at 10 kts would therefore be represented as follows:



**Clouds:** The base and summit of the forecast clouds between the surface and 24 000 ft ASL are indicated on the Clouds and Weather GFA. The summit of convective clouds (TCU, ACC, CB) is indicated, even if they extend above 24 000 ft. Cirrus are not represented. The type of cloud will not be indicated unless it is considered important; CU, TCU and CB are always shown when their presence is forecast.

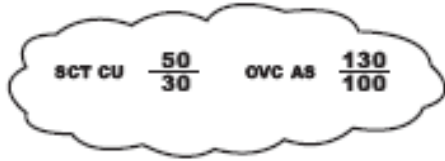
A rounded border surrounds regions of heavy cloud cover, when the sky condition is broken (BKN) or overcast (OVC). A region of broken cumulus clouds with bases at 2000 and summits at 8000 would be indicated as follows:



When there are no well-defined areas of cloud cover and when visibility is forecast to remain above 6 SM, the solid border is not used. In these areas the sky condition is represented by the terms SKC, FEW or SCT. In the following example, random scattered clouds with bases at 3 000 ft ASL and summits at 5 000 ft ASL are expected:



When multiple cloud layers are forecast, the quantity of cloud reported for each level is based on the actual amount of cloud at that level, not on cumulative observation from the ground as in a METAR. The base and summit of each layer are indicated. For example, a scattered cumulus layer with base at 3 000 ft ASL and summit at 5 000 ft ASL, and an overcast altostratus layer with base at 10 000 ft ASL and summit at 13 000 ft ASL would be indicated as follows:



Unless otherwise indicated, all heights are shown in hundreds of feet ASL (ex. « 2 » means « 200 ft ASL » ; « 45 » means « 4500 ft ASL ») When a ceiling exists the height of the ceiling will be indicated in hundreds of feet AGL. (Ex. ST CIGS 5-10 AGL means “stratus ceilings between 500 and 1000 ft AGL.”) Layers in contact with the surface are designated by the abbreviation OBSCD (« obscured »). The vertical visibility of surface layers is measured in hundreds of feet AGL. Thus a local obscured ceiling with a vertical visibility of 300 to 500 ft. AGL would be indicated as follows:

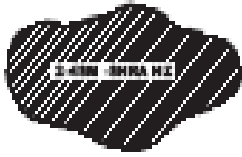
LCL OBSCD CIG 35 AGL

**Visibility:** forecast visibility is measured in Statute Miles. When the forecast prevailing visibility is greater than 6 SM, it is indicated as « P6SM ». A forecast visibility which varies between 2 and 4 SM with light rain showers is indicated as follows:

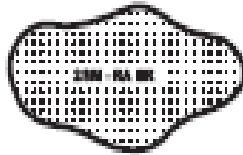
2-4SM -SHRA

**Weather Conditions and Obstructions to Visibility:** Forecast weather phenomena are always indicated immediately after the visibility section. Obstructions to visibility are mentioned only when the visibility is inferior or equal to 6 SM. (Ex. 4SM -RA BR). Only standard abbreviations are used to describe weather phenomena and obstructions to visibility. Zones of intermittent precipitation or showers are shown by a dashed green line surrounding an area covered with diagonal hash marks. Areas of continuous precipitation are surrounded by a solid green line and

covered with points. Areas where obstructions to visibility not related to precipitation are present and where the visibility is less than 6 SM are indicated by a dashed orange border.



Intermittent precipitation or showers



Continuous precipitation



Obstructions to visibility not related to precipitation

Weather conditions and obstructions to visibility indicated on the GFA can include spatial qualifiers describing the extent of coverage of the phenomenon represented.

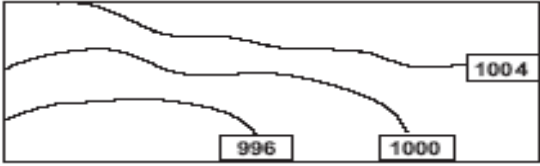
Convective clouds and showers:

<b>ABBREVIATION</b>	<b>Description</b>	<b>COVERAGE</b>
<b>ISOLD</b>	<b>Isolated</b>	<b>less than 25%</b>
<b>SCT</b>	<b>Scattered</b>	<b>fm 25 to 50%</b>
<b>NMRS</b>	<b>Numerous</b>	<b>greater than 50%</b>

Non-convective clouds and precipitation, low stratus ceilings, precipitation ceilings, icing, turbulence and restrictions to visibility:

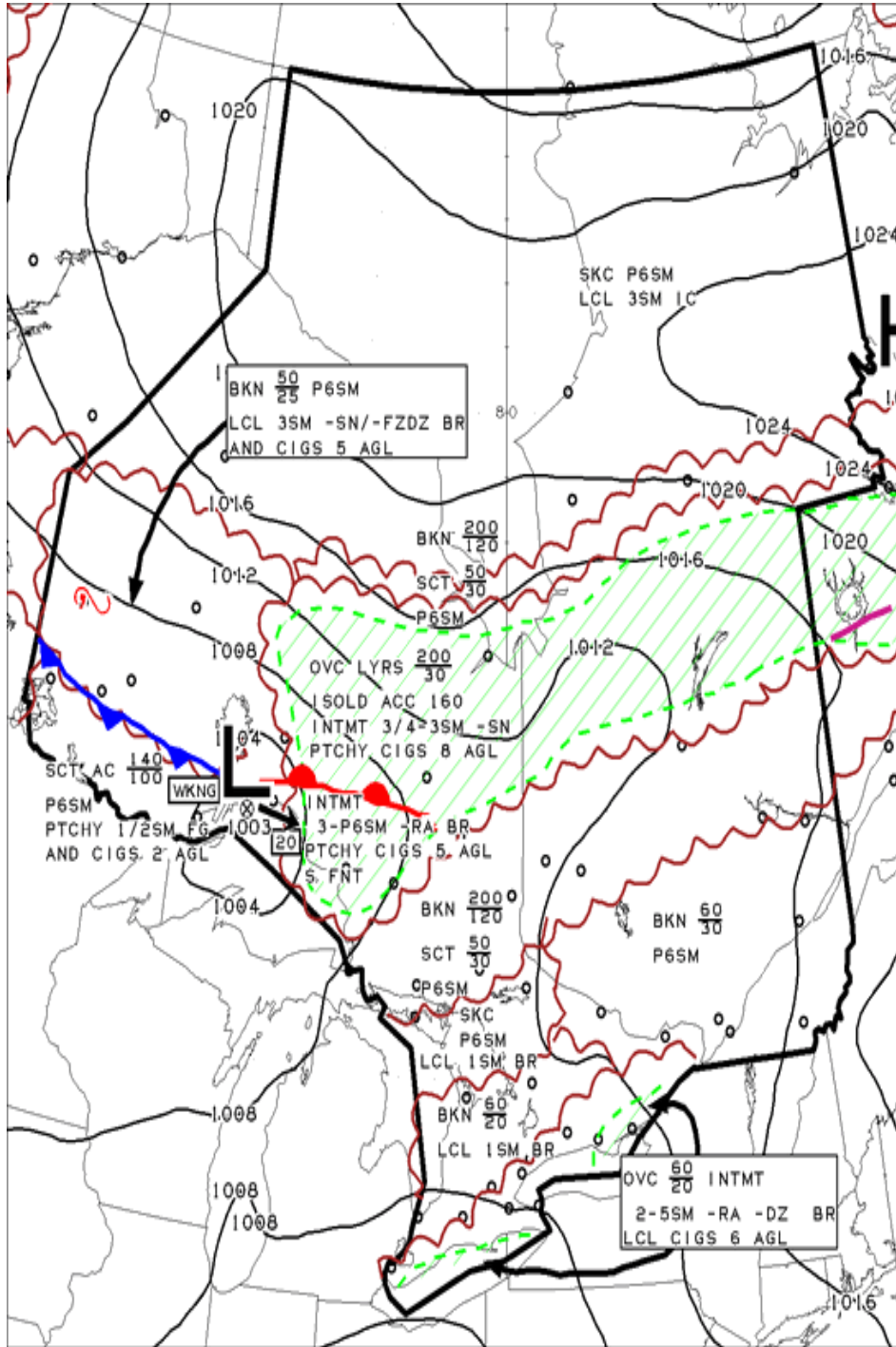
<b>ABBREVIATION</b>	<b>Description</b>	<b>COVERAGE</b>
<b>LCL</b>	<b>Local</b>	<b>less than 25%</b>
<b>PTCHY</b>	<b>Banks (of clouds)</b>	<b>fm 25 to 50%</b>
<b>XTNSV</b>	<b>Extensive</b>	<b>greater than 50%</b>

**Isobars:** isobars (lines joining points of equal mean sea level (MSL) pressure are indicated on the Clouds and Weather GFA. The isobars are drawn at 4 mb intervals, starting from 1 000 mb.



**Surface winds:** The speed and direction of the surface winds forecast to have a sustained velocity of at least 20 kts, are indicated by flags accompanied by the speed of the wind. Gusts are indicated by the letter « G », followed by the peak gust speed in knots. In the following example, the forecast surface wind is from the West (270° True) with a speed of 25 kts and peak gust speed of 35 kts.



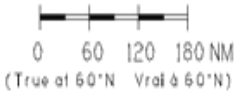


**GFACN33 CWAQ**  
 REGION  
 ONTARIO - QUÉBEC  
 CLOUDS AND WEATHER  
 NUAGES ET TEMPS

ISSUED AT 28/03/2005 1131Z  
 EMIS A  
**VLD 28/03/2005 1200Z**

LEGEND/LÉGENDE

- TS
- PL
- FZRA
- FZDZ



COMMENTS/COMMENTAIRES

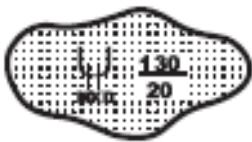
HGTS ASL UNLESS NOTED  
 CB TCU AND ACC IMPLY  
 SIG TURB AND ICG,  
 CB IMPLIES LLWS.



## Map of Icing, Turbulence and Freezing Level

The Icing, Turbulence and Freezing Level GFA chart describes the areas of icing and turbulence forecast as well as the freezing level expected at a given time. The chart includes the type, intensity, base and summit of each area of icing or turbulence. Weather generators on the surface, such as fronts and pressure areas are also indicated. This chart must be used in conjunction with the Clouds and Weather GFA issued for the same time.

**Icing:** Icing is represented when moderate or severe icing is forecast for a given area. The base and summit of each icing layer, measured in hundreds of feet above mean sea level, as well as the type of icing (Ex. « RIME » for Rime ice, « MXD » for mixed icing, « CLR » for clear ice.) are indicated. Areas of light icing are indicated in the comments box. A moderate region of mixed icing, with base at 2 000 ft ASL and summit at 13 000 ft ASL would be show as follows:

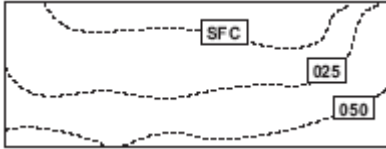


If icing is expected during only part of the forecast period, the period during which icing is forecast will be indicated in the comments box.

**Turbulence:** Turbulence is represented on the GFA when moderate or severe turbulence is forecast for the region. The base and summit of each layer of turbulence is indicated in hundreds of feet ASL. If the turbulence is due to mechanical turbulence, low-level wind shear, mountain wave, a low-level jet stream or clear air turbulence an abbreviated notation giving the cause of the turbulence will be included. The following example shows a region of clear air turbulence (CAT) with base at 8 000 ft ASL and summit at 20 000 ft ASL.



**Freezing Level:** Contour lines showing the freezing level are indicated on the Icing, Turbulence and Freezing Level GFA as dashed lines. The freezing level is measured above sea level ; the contour lines are at intervals of 2 500 ft beginning at the surface. Changes in the freezing level such as layers at altitude above the freezing level and changes over time are explained in the comments box on this chart.



### Modification of GFA charts

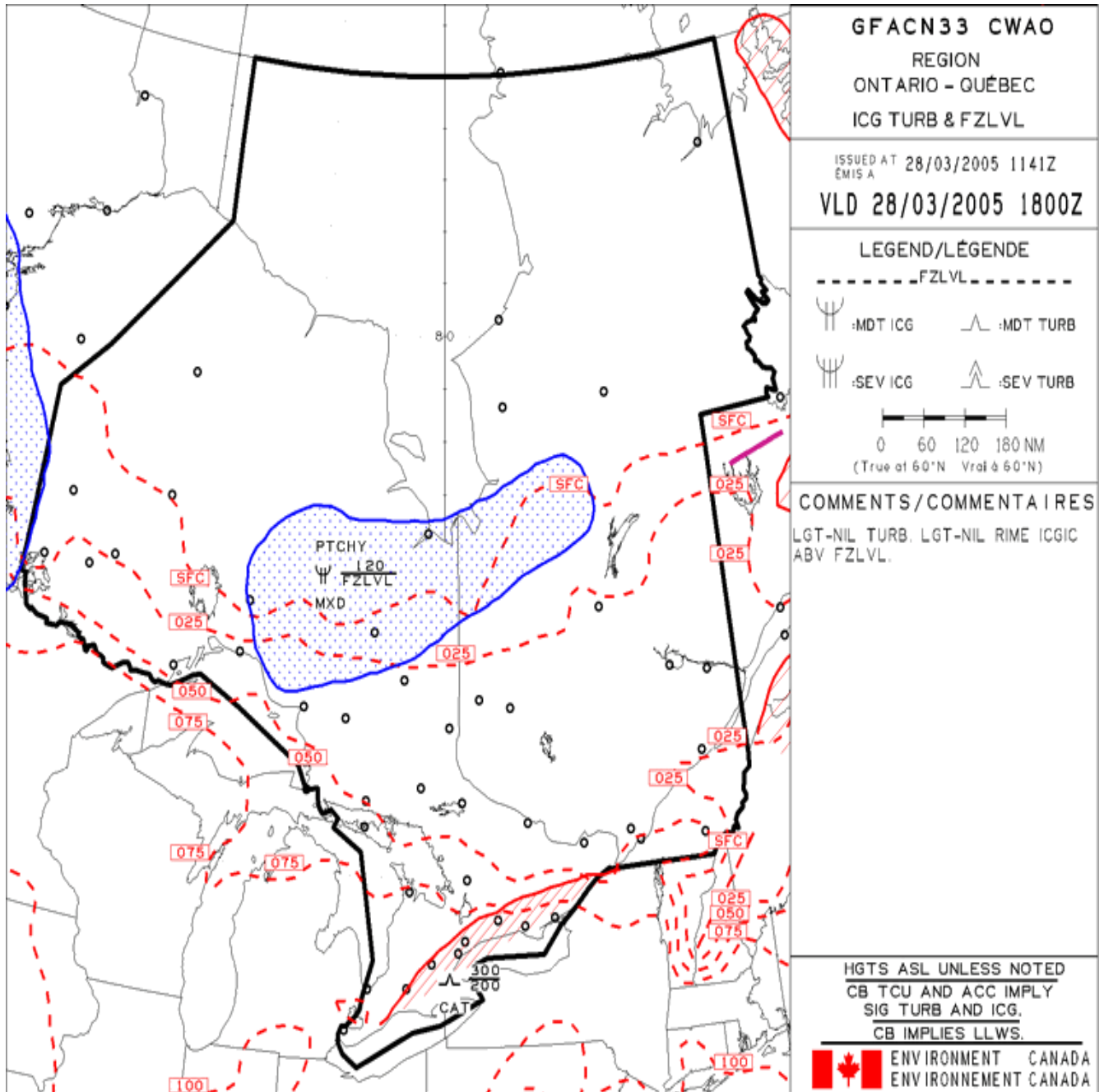
The GFA is automatically modified by AIRMET bulletins issued when weather conditions significant to aviation occur which were not forecast, or when phenomena expected to appear fail to do so. Each AIRMET indicates which GFA it modifies. Note that the GFA is modified by SIGMET bulletins even if this is not explicitly stated in the SIGMET itself.

### Correction of GFA charts

A GFA will be re-issued if one or more of the charts composing the original GFA contain a significant error which might result in an erroneous interpretation of the weather data. In some cases only the chart(s) containing erroneous information will be re-issued, with an appropriate explanation in the comments box.

When a GFA is re-issued, the code « CCA » is added to the first line of the title box to indicate the first correction, « CCB » the second correction, « CCC » the third correction and so on.

GFACN33 CWUL CCA REGION/RÉGION ONTARIO-QUÉBEC	
CLOUDS AND WEATHER NUAGES ET TEMPS	
ISSUED AT EMIS A	17/09/1999 1211Z
VLD :	17/09/1999 1200Z





### 3 – Interpreting FD reports

#### FD: Forecast of Winds and Temperatures Aloft

Temperature and Winds Aloft forecasts give an estimate of winds and temperatures to be found at determined altitudes. The time of issued and period of validity are indicated on the report. The data is collected by 32 stations in Canada, 2 times each day at 0000Z and 1200Z. Winds are given in degrees True and altitudes are in ASL. Temperatures are not given for the 3 000 ft level. Winds and temperatures for the 3 000 ft level are omitted if the station altitude is above 1 500 ft. That is, no data for level of less than 1500’ AGL. The negative (“-“) sign is omitted for temperatures at the 30 000 ft level and up, as all temperatures are negative at these altitudes.

STN VBI -	for use	3000	6000	9000	12000	18000
FDCN01 CWAO FCST BASED ON 281200 DATA VALID 281800	17-21	9900	2711+0 1	2716-05	2931-09	2938-22
FDCN02 CWAO FCST BASED ON 281200 DATA VALID 290000	21-06	1314	2421+0 1	2526-04	2530-08	2522-20
FDCN03 CWAO FCST BASED ON 281200 DATA VALID 291200	06-17	1642	1726+0 7	1921+0 0	2219-07	2328-20

STN VBI -	for use	24000	30000	34000	39000	45000	53000
FDCN1 KWBC DATA BASED ON 281200Z VALID 281800Z	1700- 2100Z.	2850- 31	29714 6	289054	289262	274257	282456
FDCN2 KWBC DATA BASED ON 281200Z VALID 290000Z	2100- 0600Z.	2740- 30	27634 6	277455	278561	265058	791159
FDCN3 KWBC DATA BASED ON 281200Z VALID 291200Z	0600- 1700Z.	2435- 32	24604 7	246957	256459	263856	859950

**Examples:**

**FDCN01 CWA0 FCST BASED ON 281200 DATA VALID 281800:** This FD report is based on data collected on the 28th day of the month at 1200Z and is valid on the 28th day of the month at 1800Z.

**for use 17-21:** The information in this report can be used for flight planning between 1700Z and 2100Z.

**2523** means winds from 250 degrees True at 23 kts.

**9900** means light and variable winds with speed under 5 kts.

**2711+1** means winds 270° True at 11 kts, temperature +1°C.

« -50 + 100 » Technique

**791159** means:  $(79 - 50) = 290^\circ$  True,  $(11 + 100) = 111$  kts, temperature -59°C

**859950** means:  $(85 - 50) = 350^\circ$  True,  $(99 + 100) = 199$  kts, temperature -50°C

## **405.03 – Weather Services and Other Weather Maps**

### **1 – Aviation Weather Information Service (AWIS)**

**Aviation Weather Information Service:** The NavCanada FSS system provides weather information intended to help pilots before and during flight. The service puts pilots in contact with specialists who help pilots make decisions and calculations based on factors relating to weather conditions.

### **2 – Aviation Weather Briefing Service (AWBS)**

The AWBS is a fully interpretive weather briefing service which is available from the Flight Information Centers. Access is available through a toll free number. These FICs are equipped with a complete set of weather products, including satellite and radar imagery. The briefer who work for the FIC are specialists trained to interpret the weather data for the needs of users from the aviation industry, as well as offer advice on particular weather situations. Documents for long distance flights are also available on request.

### **3 – Flight Service Stations (FSS)**

**Flight Service Stations**, staffed by flight information specialists, are situated at various aerodromes across Canada. They offer the following services:

- Enroute Flight Information Service (FISE) ;
- Flight Planning Service: The FSS offers a pre-flight planning service which provides pilots with weather briefings, NOTAMs, RSC/JBI reports and other information. The FSS also accepts and files flight plans and flight itineraries. A bulletin board for aeronautical information is maintained and made accessible to pilots. This service helps pilots obtain all the information they require to plan a safe flight;
- surface weather observation service;
- Aviation Weather Information Service (AWIS);

- Aviation Weather Briefing Service (AWBS);
- VFR Alerting Service ;
- NOTAM service, and
- PIREPs.

**FSS will be eventually be consolidated within 5 FIC (Flight Information Centre)**

## **4 – Pilot’s Automatic Telephone Weather Answering Service PATWAS**

In order to respond to frequent and repetitive requests, a continuous recording of certain local weather information intended for aviation is issued by some FSS and is available by telephone. PATWAS recordings generally include: issuing station name and introduction; instructions; SIGMETs; AIRMETs; METAR and SPECI weather observation reports for given stations; TAF aerodrome forecasts for given stations; FD Winds and Temperatures Aloft forecasts; freezing level; icing and turbulence; certain PIREPs; and times of sun-rise and sun-set.

## **5 – Significant Meteorological Advisories SIGMET**

Short term alerts to aircraft in flight concerning potentially hazardous weather conditions. These alerts are issued for the following phenomena : active thunderstorm cells ; squall lines ; severe hail ; severe turbulence ; severe icing ; significant mountain wave effects ; hurricanes ; far-reaching sand or dust storms ; volcanic ash ; low-level wind shear.

## **6 – Other Types of Weather Maps**

**High Altitude Significant Weather Forecast Charts (SIGWX):** are valid at specific hours of the day: 0000, 0600, 1200, 1800 UTC. They indicate significant weather phenomena (icing, turbulence and convective activity) expected for aircraft in flight between FL 250 and FL 630

(roughly between 380 and 75 hPa) in Canadian airspace. These charts are issued by the National Weather Service of the United States government.

**Significant weather phenomena, as defined by ICAO, are the following:**

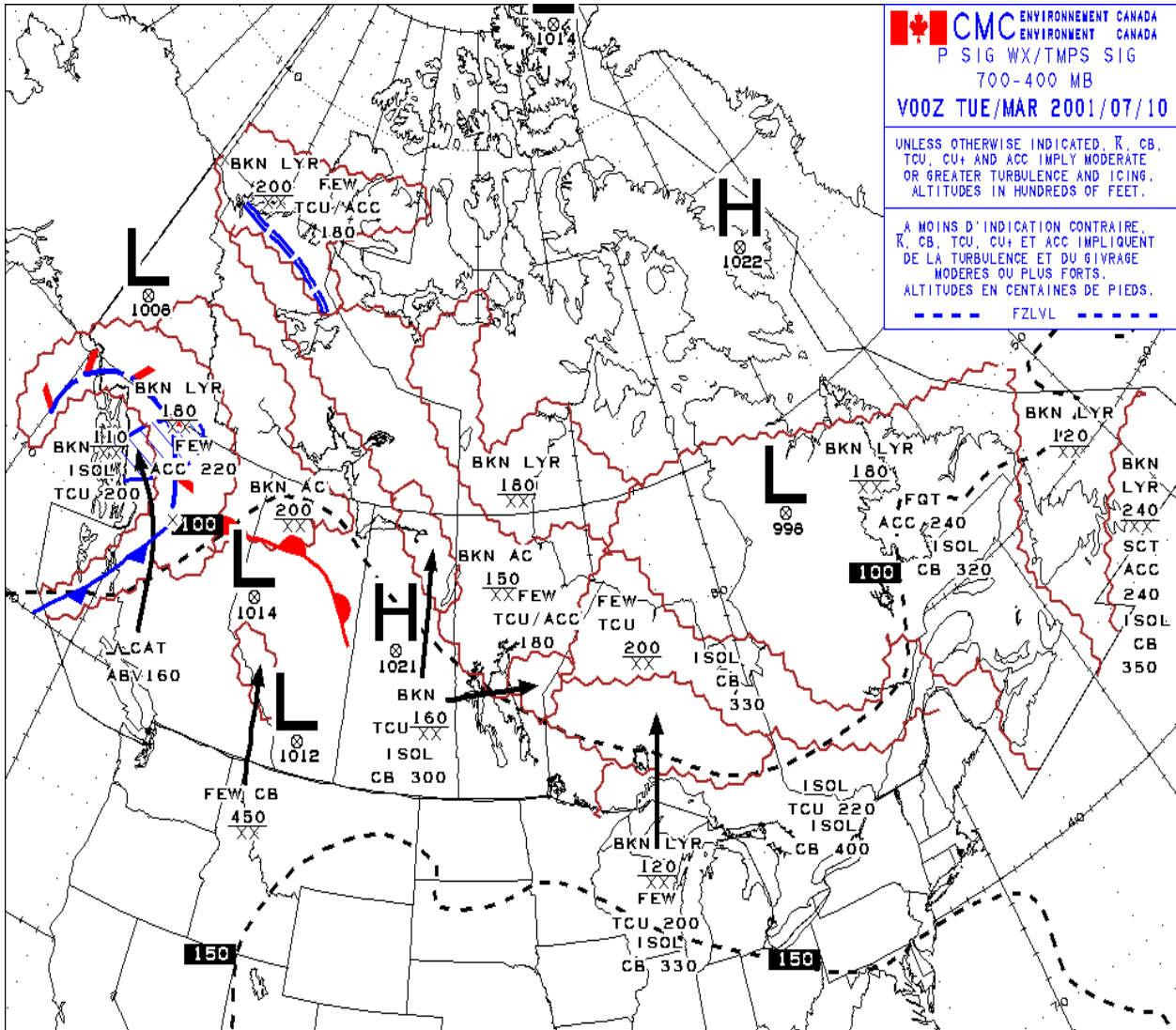
- thunderstorms and cumulonimbus;
- tropical cyclones;
- severe squall lines;
- moderate or severe turbulence;
- moderate or severe icing;
- wide-spread sand or dust storms;
- well-defined convergence zones;
- fronts on the surface, with speed and direction of movement;
- height of the tropopause;
- jet streams; and
- volcanic eruptions.

This product is issued by the National Weather Service of the US Government, the equivalent of the Canadian Weather Service.

**Mid-level SIGWX Charts:** are valid at specific hours: 0000, 0600, 1200 and 1800 UTC. They indicate significant weather phenomena (icing, turbulence and convective activity) expected for aircraft in flight between FL 100 and FL 240 (roughly between 700 and 400 hPa) in Canadian airspace, and are issued by the Canadian meteorological centre of Environment Canada. Mid-level SIGWX forecasts are based on information collected from all the aviation weather forecast centers of the country. The significant weather phenomena described in the forecast are as follows:

- thunderstorms and cumulonimbus;
- areas of significant cloud cover;
- tropical cyclones;
- severe squall lines;
- moderate or severe turbulence;
- moderate or severe icing;

- wide-spread sand or dust storms;
- surface fronts, with speed and direction of movement ; and
- freezing level.



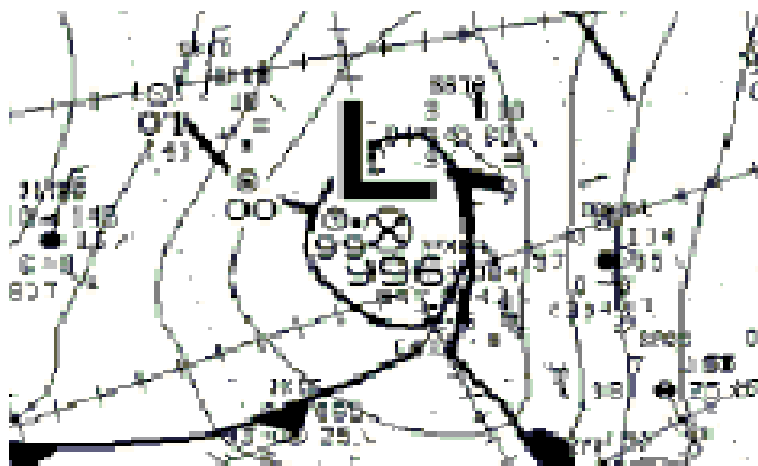
**The Surface Analysis Chart** shows the distribution of mean sea level pressure at a given time, with the position of the centers of high and low pressure areas and fronts indicated. This analyses are issued 4 times each day, at 0000, 0600, 1200 and 1800 UTC (available for use around 0330, 0930, 1530 and 2130 UTC) by the Canadian meteorological centre of Environment Canada.

Isobars are drawn automatically by computer at 4 hPa intervals (4 millibars). Note: 1 millibar = 1hectopascal (hPa). Fronts (transition zones between air masses) are added by hand. There may be other information included on the analysis:

NEW indicates that the element has formed recently;

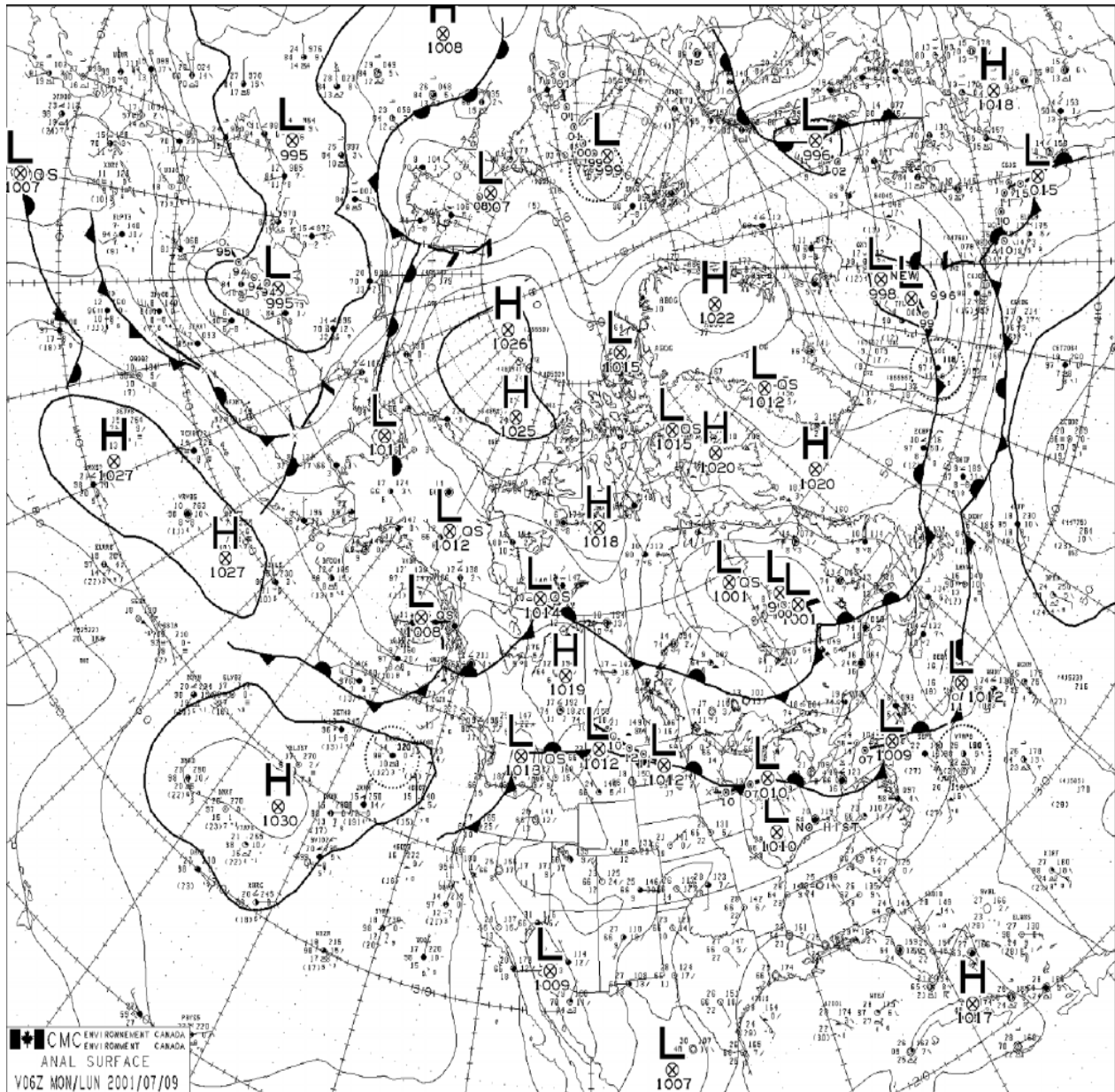
QS (« Quasi-stationary ») indicates that the element has not changed position in the last 6 hours..

The history of a depression may be indicated. If the depression has been present for more than 6 hours, it will be represented by a series of circles linked by a dashed line.



In this example, the centre of the depression (996 hPa) is moving South-East. Its pressure changed from 1001 hPa 18 hours before this analysis, to 1000 hPa 12 hours prior, and 999 hPa 6 hours prior.

On the NavCanada AWW (Aviation Weather Website), the most recent analysis is available, or the one issued 6 hours earlier.



**Upper Level Analysis (ANAL) Charts** are produced automatically by computer, twice a day at 0000 and 1200 UTC. They are available for four levels: 250, 500, 700 and 850 hPa. These highly specialized products give temperature, wind speed and the heights of the various pressure levels in the atmosphere. NOTE: 1 millibar = 1 hectopascal (hPa). Hectopascals are the unit of measure for products issued by the Canadian meteorological centre.

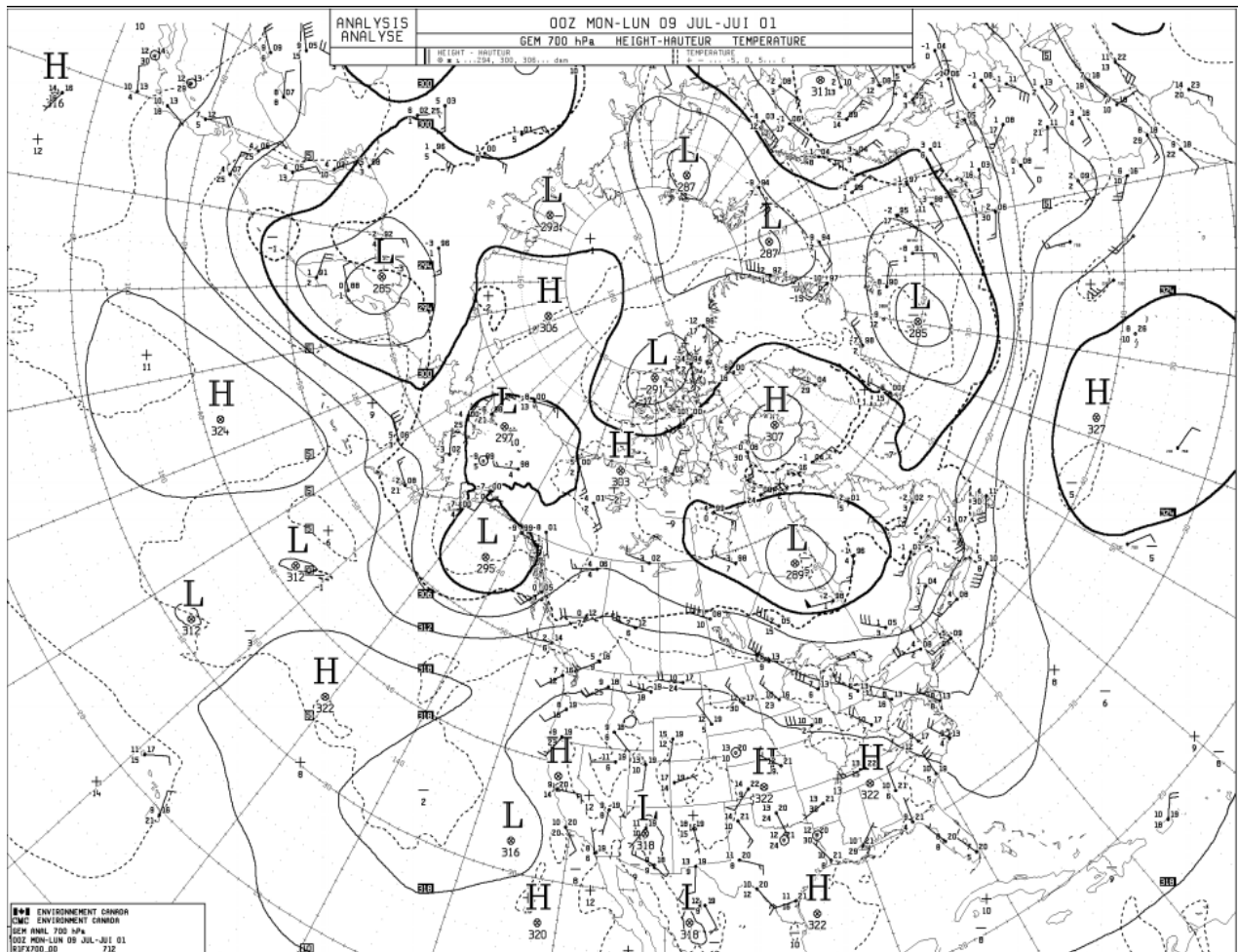


The weather analysis offered on the AWWs is very technical in nature, used by meteorologists to prepare their forecasts. A detailed description of these charts would exceed the scope of this guide; however a short description is in order.

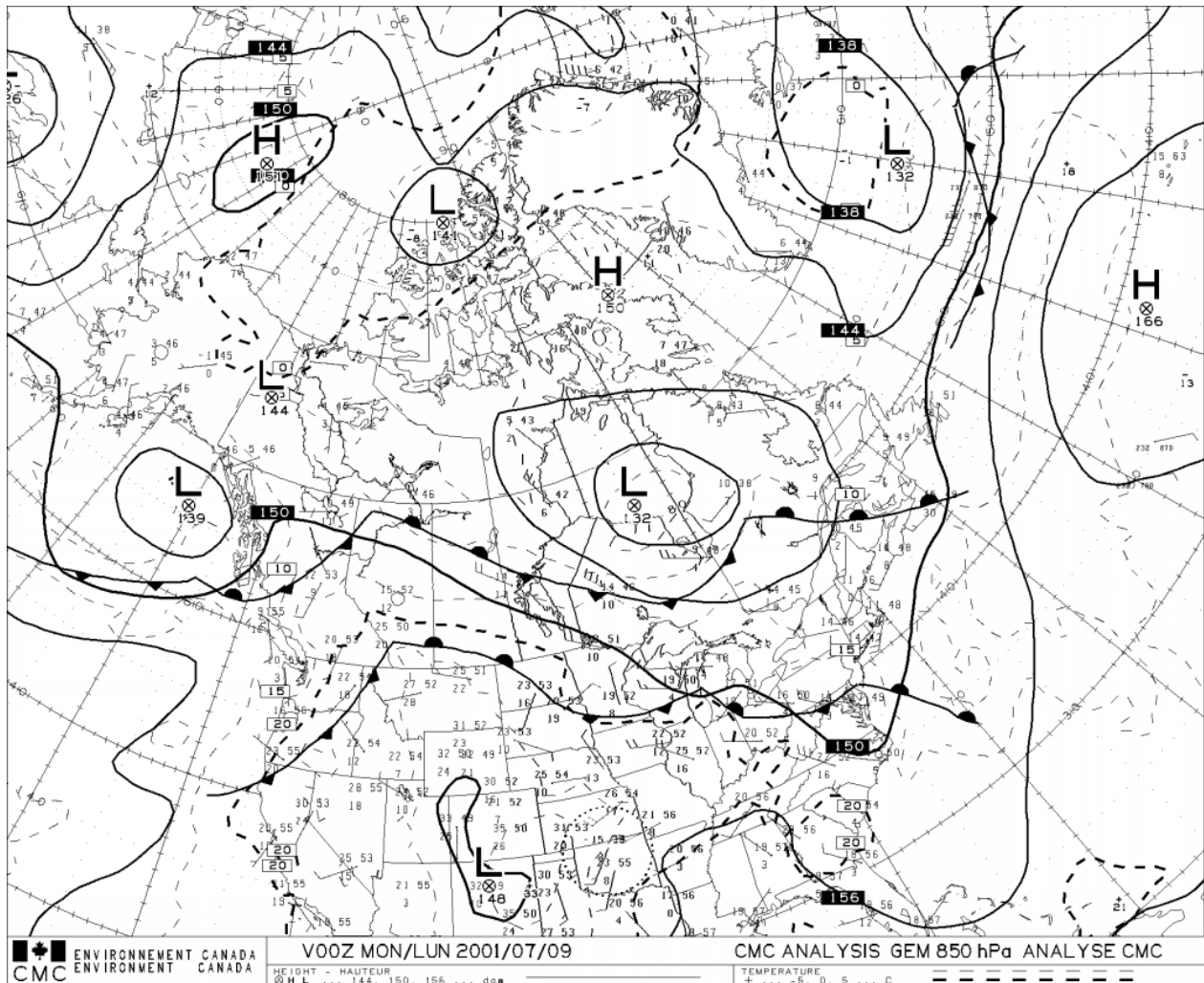
**Example of Upper Level Analysis chart for 250 hPa:** this chart serves essentially to show the position and intensity of the jet stream. It also serves to show the topology of this level of pressure and the temperature.

**Example of Upper Level Analysis chart for 500 hPa:** this analysis chart also shows the topology of the pressure level, as well as the temperature and winds. It can be used to identify depressions at altitude. It also permits meteorologists to determine if there are areas where the temperature is increasing or decreasing, which can be a strong sign of developing depressions at the surface.

**Example of Upper Level Analysis for 700 hPa:** this chart shows the topology of this pressure level as well as the winds and temperature.



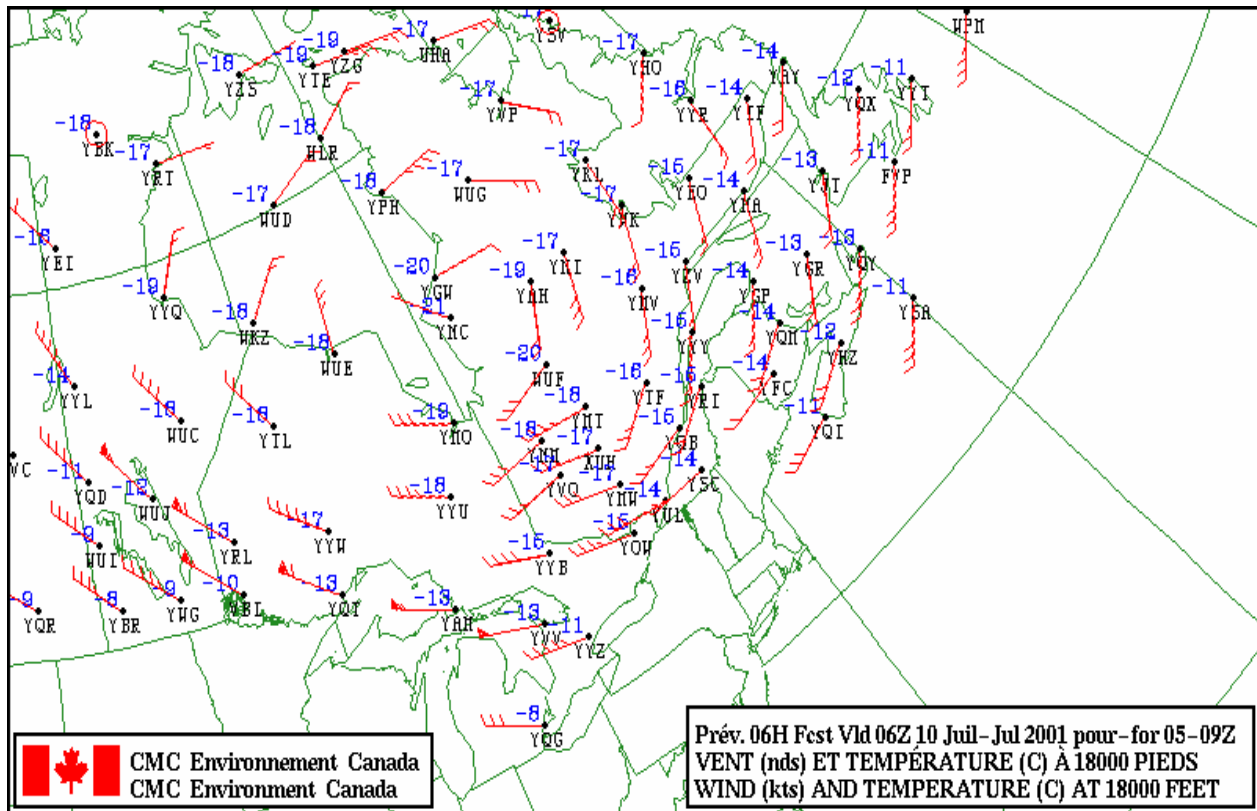
**Example of Upper Level Analysis chart for 850 hPa:** this chart shows the topology of this pressure level, the temperature and winds. The temperature analysis can help determine the precipitation which will affect the surface.



### Upper Level Wind Chart

This chart provides the forecast of temperature and winds, in graphic form, for a given flight level. The information is divided into distinct geographic regions: East, North, and West. The information presented on the chart is essentially the same as the FD forecasts. The major difference, however, is that only one flight level can be seen at once due to the graphic nature of the product. The information, generated by computer, is derived from digital weather forecast models.

These Upper Level charts are prepared by computer and show the forecast wind direction and speed, as well as the temperature. The wind direction is given in relation to True North. The temperature is in whole degrees Celsius and presumed to be negative above 24 000 ft. The National Weather Service (United States Gov't) produces these charts 4 times each day. They are valid at 00, 06, 12 and 18 UTC. The 18 000 ft level and all levels above are pressure altitudes. FL240 and FL340 are available on AWWWS.



## **7 – Flight Planning and Weather Information**

Up-to-date weather information must be obtained and analyzed before each flight in order to properly prepare for all significant weather which might affect the conduct of the flight. Meteorological data is also required for flight planning in order to choose a cruising altitude and calculate groundspeed, drift, flight time and fuel consumption.

Basic information to obtain and review before a VFR cross-country flight is:

- METARs and TAF: For departure, destination and enroute aerodromes.
- FD: For the expected cruising altitudes
- GFA: For an overview of the weather affecting the region.
- NOTAMS: all significant information / changes for pilots

## **8 – Automatic Terminal Information Service (ATIS)**

Automatic Terminal Information Service, or ATIS, is a continuous broadcast of recorded noncontrol information in busier airports. ATIS contains essential information such as weather information, active runways, available IFR approach, NOTAMs and any other pertinent information. Pilots are to listen to ATIS on the appropriate frequency prior to contacting the appropriate control unit. The goal of this is to reduce controller's workload and relieve frequency congestion.

The recording is updated every hour or when deemed necessary. It comes with a letter designator so that the controller may know that the pilot had the latest version of the ATIS. On initial contact, the pilot will state which letter designator he has heard.

## REVIEW QUESTIONS:

1. From the standpoint of weather the most important component of the atmosphere is:  
\_\_\_\_\_
2. The process by which water vapor changes directly to solid ice is called:  
\_\_\_\_\_
3. In which layer of the atmosphere does most weather occur? \_\_\_\_\_
4. What happens to the average vertical lapse rate at the tropopause?
  - a. It remains constant
  - b. it is reduced to zero
  - c. it reverses
  - d. it increases rapidly
5. Draw, in order, the different layers and transition layers of the atmosphere.
6. The lowest temperature at altitude is found in the \_\_\_\_\_.
7. What are the two types of cloud (by shape) and with what atmospheric conditions are they associated? \_\_\_\_\_
8. \_\_\_\_\_ clouds are a thin sweep of delicate white filamentous clouds. They can look like puffs or hairs.
9. What do you call a dark grey layer of cloud from which steady rain or snow is falling?  
\_\_\_\_\_
10. What type of cloud is associated with thunderstorms? \_\_\_\_\_

11. What is sea level pressure in the ICAO standard atmosphere? \_\_\_\_\_
12. What clouds are classified in the Vertical development category?
13. The force per unit of surface exerted by the atmosphere at a given altitude is called:  
\_\_\_\_\_
14. If the air pressure increases, the temperature \_\_\_\_\_ and the density \_\_\_\_\_.
15. Warm air is denser than cold air. True or false?
16. If you are flying from a high pressure to a low pressure area, will your altimeter over- or under-read?
17. “Convergence” means... \_\_\_\_\_
18. What causes winds to be deflected to the right and blow parallel to isobars in a high pressure system? \_\_\_\_\_
19. Explain Buys Ballot’s Law.  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
20. According to Buys Ballot, if a North wind is blowing, the low pressure area is to the :  
\_\_\_\_\_

21. What is the term for the wind you encounter at the edge of the ocean during the day?
- a. sea breeze
  - b. land breeze
  - c. Katabatic wind
  - d. Anabatic wind
22. A squall line signals the approach of: \_\_\_\_\_
23. What term refers to wind that blows down snow-covered slopes at night?
24. During a climb from the surface to 3000 feet, the wind can be expected to:
- a. Veer and increase;
  - b. Veer and decrease;
  - c. Back and increase;
  - d. Back and decrease.
25. A wind which is changing direction to the left and diminishing in intensity is said to be :  
\_\_\_\_\_
26. When an air mass is heated and no additional water vapour is added, relative humidity will : \_\_\_\_\_
27. The atmosphere is heated by 4 processes, depending on the altitude and layer. List and give a short definition for each.
- a. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

28. Use the ICAO standard adiabatic lapse rate to calculate the temperature at 10 000 feet, if the temperature on the surface is 30oC. \_\_\_\_\_
29. The phenomenon of temperature increasing with altitude is called:  
\_\_\_\_\_
30. A strong vertical lapse rate is an indication of \_\_\_\_\_.
31. A volume of air distinguished by uniform properties of humidity and temperature in the horizontal is called a(n) : \_\_\_\_\_
32. Air Masses are classified by their \_\_\_\_\_ and \_\_\_\_\_.
33. What type of front line occurs when a cold air mass catches a warm air mass?
34. In what direction does air rotate around the centre of a low pressure area?  
\_\_\_\_\_
35. The term « Stationary front » refers to:  
\_\_\_\_\_
36. Clouds form when three things are present:  
a. \_\_\_\_\_
37. What type of cloud is generally associated with drizzle? \_\_\_\_\_
38. Fog can form by one or both of the following two methods:  
\_\_\_\_\_



39. What conditions favor the formation of radiation fog?  
\_\_\_\_\_
40. For a thunderstorm to form, the following criteria must be met:  
\_\_\_\_\_
41. Icing is a danger to aircraft because ice accumulation changes the shape of the wing and causes a decrease in lift, increase in weight and increase in drag. True or False
42. What is a METAR? \_\_\_\_\_
43. In an FD, at FL 370 what does the code 839950 mean?  
\_\_\_\_\_

# 406 - Theory of Flight (Objective 1 - Systems)

## 406.01 – Aircraft components and Systems

### 1 – The 3 Axes

#### **Axes of an aircraft in flight**

An aircraft in flight rotates around 3 axes. These axes pass and meet through the centre of gravity the aircraft i.e. the central balance point of the aircraft's total weight.

**Longitudinal axis:** Extends from the nose to the tail through the length of the aircraft, passing through the fuselage. The movement of the aircraft around this axis is called “ROLL”; this movement is controlled by the ailerons.

**Lateral Axis:** extends from one wingtip through the fuselage to the other wingtip. The movement of the aircraft around this axis is called “PITCH”; this movement is controlled by the elevator

**Vertical or Normal Axis:** passes vertically through the centre of gravity, meeting the Longitudinal and Lateral Axes at their point of intersection. Movement of the aircraft around this axis is called “YAW”; this movement is controlled by the rudder.

### 2 – Primary Effects of Controls

#### **Ailerons**

Hinged control surfaces attached to the trailing edge of the wing near each wingtip. They move together but in opposition i.e. When the left aileron rises, the right aileron descends. They are controlled by moving the stick from left to right. They are used to move the aircraft around the longitudinal axis. When the stick is moved to the right, the right aileron moves up and the left

aileron moves down. The right wing drops and the left wing rises, the aircraft rolls to the right; the angle of bank increases until the stick is returned to the neutral (centered) position.

In practical application it is generally necessary to apply counter-pressure (small amounts of stick in the opposite direction of the roll) to maintain a constant bank angle while in a turn.

### **Elevator**

Hinged control surface attached to the trailing edge of the horizontal stabilizer. It is controlled by moving the stick forward and back. When the stick is moved forward, the elevator descends, creating lift at the tail. The empennage rises and the nose of the aircraft descends. This movement around the lateral axis of the aircraft is called « PITCH ». Changes in pitch are used primarily for speed control. The “**STABILATOR**” functions along the same principle as the elevator, but consists of a single horizontal moving surface.

### **Rudder**

Hinged control surface attached to the trailing edge of the vertical stabilizer (“fin”) It is connected to the rudder pedals by a system of cables. It is used to move the nose of the aircraft from left to right. This movement is called YAW; it is a rotation around the vertical axis. Pressure on the left rudder pedal moves the rudder to the left, creating lift on the right side of the fin and moving the tail to the right and nose to the left.

All Aircraft’s movements are done around the center of gravity.

## 3 – The Trim System

### **Trim Tab**

Helps the pilot maintain a constant attitude by reducing the control pressure required during various phases of the flight.

Adjustable tab attached with hinges to the trailing edge of a control surface.

Designed to move above or below the chord line of the control surface to which it is attached, thereby creating an aerodynamic force on the surface which helps the pilot keep the control surface in the desired position. For example, to keep the elevator in a high position the trim tab would be moved down, exerting an upward force on the surface and relieving the pilot of the need to pull back on the stick.

**Servo Tabs:** are devices found on larger airplanes. They are connected directly to the control column and are used to ease the strain on the controls. The pilot moves the control surface by controlling only the servo tab; the control surface is free floating in the air.

**Anti-servo Tabs:** Trimming devices used on stabilators.

The **SGS-2-33A** is equipped with a trim system on the elevator. There are three types of trim mechanisms in use in the glider fleet:

- a tension system mounted on the left side of the cockpit floor, beneath the spoiler handle. (“bungee trim”);
- a tension system mounted on the floor of the glider in front of the stick. (“kick trim”), and;
- a ratchet system incorporated in the base of the stick. (“Ratchet trim”).

## **4 – Secondary controls**

### **Spoilers**

- reduce Lift;
- increase Drag, and;
- consist of large movable metal plates on the upper surface of the wing of the 2-33A, which can be raised perpendicular to the airflow.

### **Dive Brakes**

- large metal plates on the lower surface of the wing of the 2-33A, which can be lowered down into the airflow, and;
- increase drag; no effect on lift.

### **Flaps**

- High-lift devices
- Increase the camber of the wing
- In some cases increase the lifting surface of the wing
- Increase performances on takeoff and landing
- Permit a steeper angle of approach while limiting airspeed.
- Reduce stall speed

## **5 – How to Perform a Coordinated Turn**

Simultaneously apply stick and rudder in the direction of the turn. Maintain sufficient rudder to keep the yawstring centered. If too much rudder is applied, the yawstring will move in the direction of the turn. If insufficient rudder is applied, the yawstring will move to the outside of the turn. Apply some back pressure to increase the angle of attack and create more lift.

## **6 – Control balancing and flutter**

### **Dynamically balanced controls**

By having some of the control surface in front of the hinge, the air striking the forward portion helps to move the control surface in the required direction. The design also helps to counteract adverse yaw when used in aileron design. (FTGU)

### **Mass balance**

Weight of streamlined shape placed in front of the hinge of a control surface. Serves to reduce the risk of elastic vibrations (flutter) on the control surfaces. Flutter can occur at high speeds and can lead to failure of the affected component.

### **Static Balance**

The exact distribution of weight on a control surface is very important. For this reason, when a control surface is repainted, repaired or component parts replaced, it is essential to check for proper balance and have it rebalanced if necessary. To do this, the control surface is removed, placed in a jig and the position of the centre of gravity checked against the manufacturer's specifications. Without any airflow over the control surface, it must balance on its specified C-of-G. This is known as static balance. (FTGU)

**Flutter:** Caused by elastic vibrations which are produced at high speeds.

## 7 – Aircraft Construction

### Definitions

**Aircraft:** Any machine capable of deriving support from the atmosphere from the reactions of the air.

**Airplane:** Power-driven heavier-than-air aircraft, deriving its lift in flight from aerodynamic reactions on surfaces that remain fixed under given conditions in flight.

**Glider:** heavier-than-air aircraft, deriving its lift in flight from aerodynamic reactions on surfaces that remain fixed under given conditions in flight.

**Airframe:** Total structure of the aircraft including fuel systems and fuel tanks but excluding instrumentation and engines.

### Parts of an Airplane

**Fuselage:** The central body of the airplane, designed to accommodate the crew, passengers and cargo.

### Types of construction

- Truss type (ex. SGS 2-33A). Generally used in the construction of ultra-light and amateur-built aircraft;
- N-Girder, and;
- Warren Truss. Steel tubes welded or bolted together forming a frame.

**Longerons:** (3 or 4 long tubes running lengthways) are the principle members of the wing. The frame is covered with fabric

**Monocoque** (ex. Katana)

Series of round formers or bulkheads held together by stringers (long strips running lengthwise)

The skin is of metal and carries part of the load; this is known as « stressed skin ».

**Semi-monocoque** (Ex. Transport aircraft: Airbus 320)

**Wings:** Create lift to carry the aircraft in the air

Wing configuration:

- monoplane: One set of wings, and;
- biplane: Two sets of wings.

**Wing positioning:**

- high wing: top of the fuselage;
- mid wing: middle of the fuselage, and;
- low-wing: below the fuselage.

**Leading Edge:** the forward part of the wing which meets the relative airflow.

**Trailing edge:** rear edge of the wing from which the air flows off the wing.

**Wing Root:** inner edge of the wing, where it attaches to the fuselage.

**Wingtip:** Outer edge of the wing, furthest from the fuselage.

**Aileron:** Control surfaces attached to the trailing edge near the wingtip. Used to bank the aircraft. When one rises, the other descends.

**Ribs:** Run from leading to trailing edge. Give the wing its cambered airfoil shape.

**Spars:** Main component of the wing. Beams running from wing root to wingtip. They carry most of the load and stiffen the wing against torsion or twisting.

**Flaps:** movable part of the wing structure, located between the ailerons and wing root.



**Struts:** beams extending from the fuselage diagonally to mid-wing. They provide external bracing for the wing.

**Cantilever:** Wings without external bracing.

**Landing Gear:** Absorbs the shock of landing and also supports the weight of the aircraft and allows it to maneuver while it is on the ground.

**Types:**

- tricycle;
- tail-wheel (classic), and;
- monowheel ( SGS 2-33A).

All types can be either fixed or retractable

**Empennage:** provides longitudinal and directional control and stability

**Fin or Vertical Stabilizer:** vertical surface placed ahead of the stern-post to provide directional stability.

**Rudder:** Hinged vertical control surface attached to the vertical stabilizer, providing directional control (yaw).

**Stabilizer:** horizontal airfoil placed at the rear of the fuselage to provide longitudinal stability.

**Elevator:** mobile surface attached to stabilizer, providing longitudinal control (pitch).

**Trim tab:** adjustable surface, fixed or mobile, attached to the elevator and/or rudder. Helps the pilot by eliminating the need to exert excessive pressure on the flight controls during the various phases of flight.

**Power Plant or Engine:** Moves the aircraft forward through the air (power plants and propulsion are not discussed in this manual.)

# **406 - THEORY OF FLIGHT (Objective 2 – Theory)**

## **406.01 – Principles of Flight and Forces Acting on a Glider**

### **1 – Bernoulli’s Theorem**

#### **Bernoulli’s Principle**

In a closed system, total energy remains constant. In other words, in a closed energy system, when one factor increases, another diminishes in equal measure. Air flowing over the upper surface of an airfoil is affected by this principle. It is forced to accelerate due to the curvature of the upper surface of the wing, which causes a decrease in its pressure. The air below the wing is therefore at a higher relative pressure and exerts an upward force on the lower surface of the wing. This pressure difference contributes to the creation of lift.

### **2 – Newton’s Laws of Motion**

#### **Newton’s three Laws of Motion**

1. A body in motion tends to remain in motion; a body at rest tends to remain at rest (Inertia).
2. A force must be applied to affect the uniform motion of an object. (Acceleration)
3. The application of a force generates an equal and opposite reaction (action-reaction).

### **3 – Lift**

**Definition:** Force allowing the aircraft to be suspended in the air, working against the weight of the aircraft.

## Lift and Drag

Depends on:

- angle of Attack;
- aerodynamic profile;
- surface area of the wing = S;
- the square of the velocity (True airspeed) =  $V^2$ , and;
- the density of the air =  $\rho$ .

### Formulae:

- lift  $C_L * \frac{1}{2} * \rho * V^2 * S$
- drag  $C_D * \frac{1}{2} * \rho * V^2 * S$

Where  $C_L$  and  $C_D$  are the coefficients of lift (L) and drag (D)

When the Angle of Attack increases, lift and drag increase as well.

The relation between lift and drag is obtained by dividing the coefficient of lift by the coefficient of drag  $C_L / C_D$ . The optimum ratio is obtained at  $0^\circ$  angle of attack. At this angle the wing is generating maximum lift for minimum drag.

## 4 – Drag

**Definition:** Resistance to the motion of the aircraft through the air

Types:

- parasite Drag, and;
- induced Drag

### Parasite Drag

Caused by all parts of the aircraft which do not create lift.

Types:

- **Form Drag:** Caused by the shape or contours of an object, generating resistant to displacement through the air.

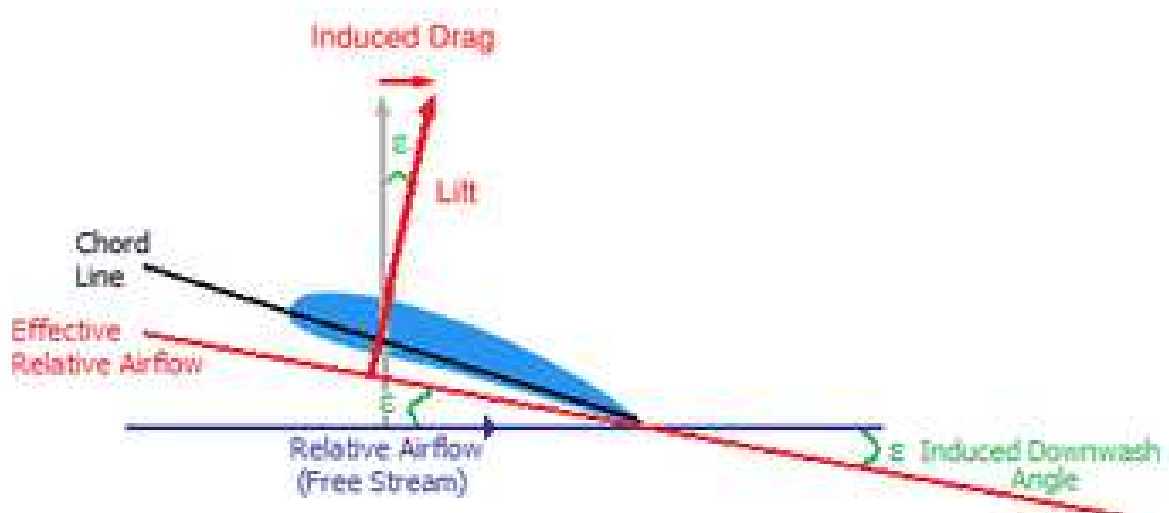
- **Skin Friction:** Arises due to the tendency of air to adhere to the surface of the object over which it is flowing. (Viscosity)
- **Interference Drag:** Resistance caused by joints (ex. where the wing fastens to the fuselage, or where the struts meet the wings)

### Induced Drag

Caused by those parts of the aircraft which are actively involved in the creation of lift. Inherent to the generation of lift ; therefore impossible to eliminate completely. Wingtip vortices and turbulent layer over the wings are manifestations of induced drag.

### Advanced Induced Drag Theory (not part of your exams!)

Induced drag comes from the lift vector being canted backward in relation to the aircraft trajectory. How is it possible? Wing vortices are the answer! When flowing on the upper surface of the wing, vortices add a downward component to the airflow which contributes to locally reduce the angle of attack of the wing. When this happen lift get redirected slightly backward to stay perpendicular to the local relative wind therefore producing a rearward component which is called Induced Drag!!! The stronger the vortices (i.e. at high angle of attack) the deeper reduction of local angle of attack and the stronger the Induced Drag Gets!



## **Wingtip Vortices**

Because the pressure over the wing is less than the ambient pressure, the air flowing over the upper surface tends to flow inwards towards the fuselage. The air flowing under the lower surface of the wing tends to flow outwards and then up around the wingtip, because the ambient pressure is lower. When they meet at the trailing edge of the wing, the streams from the upper and lower surfaces are moving in opposite directions. This creates a series of small vortices which combine into one large vortex at each of the wingtips of the aircraft. These are wingtip vortices.

## **Ways to reduce wingtip vortices**

### **Wing fences:**

- resemble fences mounted vertically on the upper surface of the wing;
- control and direct the streams of air flowing off the upper surface of the wing;
- normally located near the centre of the wing profile, and;
- improve low-speed control and stall characteristics.

### **Winglets:**

- mounted vertically on the wingtips;
- small airfoil surfaces, and;
- break up the wingtip vortices which flow towards the upper surface of the wing.

## **5 – Angle of Attack**

**Definition:** Angle between the chord line and the relative airflow.

**Chord line:** Fictitious line joining the leading edge and the trailing edge of a wing.

## 6 – Angle of Incidence

**Definition:** Angle between the chord and the longitudinal axis of the aircraft. This angle is determined during design and constructed into the aircraft.

## 7 – Lift, Drag and Angle of Attack

### Lift

As angle of attack increases, lift increases. Lift continues to increase until the critical angle of attack is reached. Once past the critical angle, lift decreases and the wing stalls. Two ways of increasing the lift:

- Increasing the angle of attack (to or below the stalling angle), which increase the  $C_L$  term in the formulae by deepening the low pressure above the wing and the downward air deflection, and or;
- Increase speed which has a squared effect on lift production. By doubling the speed, lift gets four time stronger.

### Drag

Drag increases rapidly as angle of attack increases towards the critical angle of attack. Drag is at its highest at Low speed (just before stalling) and at High speed passing through its minimum between those two extremes.

Low speed Drag is composed of mainly Induced Drag and Pressure Drag due to separation of the boundary layer which creates a vacuum behind the wing.

High speed Drag is mainly composed of skin friction drag.

## 8 – Lift / Drag ratio $C_L/C_D$

Calculated by dividing the coefficient of lift by the coefficient of drag.

## 9 – Centre of Pressure and Stall Angle

### Centre of Pressure (C.P.)

If the total distribution of pressure is considered a single force, it can be represented by a single vector. The junction between this line and the chord of the wing is called the centre of pressure. The Centre of Pressure is the resultant of all lift forces.

### Stall

Occurs when the wings are no longer capable of producing sufficient lift to counteract the effect of gravity on the aircraft's mass. Symptoms of an Approaching Stall:

- loss of horizon;
- reduced wind noise;
- dropping of indicated airspeed;
- slack controls, and;
- buffeting (vibrations, may be absent during flight in precipitation).

### Recovery

**Left Column:** Recovery method presented in the 242 (method will work with most types of gliders). Use this terminology when answering exam questions.

**Right Column:** Recovery method for use in the 2-33 (due to its particular properties).

THEORY	PRACTICE
Center controls immediately	Center controls immediately and call « STALL! »
Release enough back pressure to restore lift (Reduce angle of attack)	Release enough back pressure to restore lift.
If a wing drops, apply opposite rudder to stop the rotation	If a wing drops, apply opposite rudder to stop the rotation
If spoiler / dive brakes are open, close them immediately.	If spoiler / dive brakes are open, close them immediately.
Once lift is restored, level wings with aileron (if required).	Once lift is restored, level wings (if required) with coordinated application of aileron and rudder.
Ease out of dive	Ease out of dive
Trade excess speed for altitude	Trade excess speed for altitude. (Only if flying with a FI)
Assume normal attitude.	Assume normal attitude.

When the angle of attack increases, the centre of pressure moves towards the front of the wing until the angle of attack reaches the « critical angle ». At this point, the centre of pressure moves abruptly aft on the wing, which is now stalled.

A wing will generally stall at an angle of attack around 18°, but this varies according to the shape of the airfoil.

**The wing will stall in any attitude and at any speed if the critical angle of attack is exceeded.**



## **Factors affecting the stall**

**Weight:** For a given configuration or speed the only way to increase lift is to increase the angle of attack. If the aircraft carries more weight, the airplane will be flying at a higher angle of attack in order to create enough lift to support it. Since the separation between the operating angle of attack and critical angle of attack is smaller, the aircraft will stall at a higher speed.

**C-of-G:** If the centre of gravity shifts towards the front of the aircraft the stall speed increases and the aircraft gain stability. If the centre of gravity shifts aftward, the stall speed decreases and the aircraft loses some of its stability. (for more details see lesson 406.04.04)

**Turbulence:** The stall speed increases when entering in an upward current because vertical airflow causes momentary changes in the relative airflow and therefore the angle of attack, possibly causing it to exceed the critical angle.

**Turns:** In order to maintain altitude in a turn lift must be increased by increasing angle of attack. In a turn the load factor increases, causing an increase in stall speed. Just as if the weight was increased.

**Flaps:** By increasing the lifting capacity of the wing for a given angle of attack, flaps decrease the stall speed.

**Climatic Conditions:** Snow, frost and ice increase the stall speed by sharply reducing the lift-generating capacity of the wing by deforming the airfoil shape. They also create a large increase in drag.

## **10 – Forces Acting on an Aircraft in a Turn**

The lift force always acts at 90° from the span. In a banked turn, lift therefore acts at an angle from the vertical corresponding to the angle of bank of the aircraft. Consequently, the vertical

components of lift and weight are no longer in equilibrium. Unless the angle of attack is increased to generate more lift, the aircraft will accelerate downwards (losing altitude).

The lift vector can be separated into two components:

- one component acts vertically and keeps the aircraft in the air (opposing weight), and;
- one component acts horizontally which keeps the aircraft turning (“centripetal force”).

**Centrifugal Force:** Illusory force opposing centripetal force, the result of the body’s reaction to the forces maintaining the aircraft in the turn. It appears to act opposite to the centripetal force, that is, towards the outside of the turn.

**Weight:** Effect of gravity acting on the mass of the aircraft; vector is directed towards the centre of the Earth.

As the angle of bank increases, the total lift is redirected to the horizontal component (centripetal force) sharpening the turn. Therefore, less lift is available to counteract gravity. Thus, to maintain altitude, the total lift generated must be increased relative to straight and level flight. This extra lift is generated by increasing the angle of attack, by the pilot exerting an aftward pressure on the controls.

**The greater the angle of bank (in a coordinated level turn):**

- the greater the load factor ;
- the greater the rate of turn ;
- the smaller the radius of turn ; and
- the higher the stall speed.

**The greater the speed of the aircraft in a turn:**

- the slower the rate of turn ; and
- the larger the radius of turn.

### **Climbing and descending turns**

In a descending turn, the lower wing meets the relative airflow at a greater angle of attack and creates more lift. As the upper wing is moving faster, it also creates more lift and. The two forces compensate one another and the angle of bank tends to remain the same.

In a climbing turn, the lower wing meets the relative airflow at a smaller angle of attack and creates less lift. As the upper wing is moving faster, it creates more lift. These two forces act in such a way that the angle tends to increase.

## **11 – “Thrust” in Gliding Flight**

### **Thrust**

Force generated by the engine and propeller, which pushes air backwards in order to cause a reaction towards the front. Thrust can be generated in various ways, moving the aircraft forward in different manners. The effect is the same whether generated by a propeller moving a large amount of air backwards slowly, or a jet engine moving a small amount of air backwards rapidly.

### **“Thrust” in gliding flight**

A glider must always keep a slight nose-down attitude to maintain forward motion and keep enough air over the wings to maintain lift. This forward motion is generated by the **forward component of the weight**, which comes from the aircraft assuming a nose-down attitude. If the nose of the glider is raised above the horizon, airspeed will drop off and the wing will not generate sufficient lift to counteract weight.

## **12 – Weight**

Force acting vertically towards the centre of the Earth, caused by gravity acting on the mass of the aircraft. The resultant of all weight vectors of the aircraft is called the centre of gravity.

## **13 – Equilibrium**

An aircraft is in equilibrium when thrust is equal and opposite to drag and / or when lift is equal to weight. In equilibrium the aircraft is not under any acceleration.

## **14 – Couples**

When two of the forces are equal and opposite, the aircraft is said to be in a state of equilibrium. When two forces, for example lift and weight, are equal, opposite and parallel, but do not pass through the same point, they are said to be forming a couple.

A couple generates a rotating force around a given axis (couples act around the centre of gravity.)

- If weight is forward of lift, the couple created will rotate the aircraft's nose downwards.
- If lift is forward of weight, the couple will rotate the aircraft's nose upwards.
- If drag is above thrust, the couple will rotate the aircraft's nose upwards.
- If thrust is above drag, the couple will rotate the aircraft's nose downwards.

## **406.02 – Camber and Airfoil Profiles**

### **1 – Function of an Airfoil**

Creates a reaction with the air flowing over it (i.e. lift)

#### **Types of Airfoil**

**Conventional Airfoil:** The wing is thick, allowing for a more robust structure and lower weight. The conventional airfoil has good stall characteristics. The camber is further aft, increasing lift. The thickest part of the wing is at 25% chord. This profile creates more lift and drag. Suits well slower aircrafts.

#### **Laminar Flow Airfoil:**

This wing is generally thinner in profile than a conventional airfoil. The leading edge is sharper and the upper and lower surfaces are nearly symmetrical. The thickest part of the wing is located at 50% chord. The wing profile looks almost symmetrical. This kind of profile will generate way less drag than a conventional one but also less lift. This is suitable for high speed and high performance aircraft such as an F-18. Stall characteristics are usually more violent than with a conventional airfoil.

### **2 – Airflow and Pressure Distribution around an Airfoil**

#### **Air flows around the upper and lower surfaces of the wing**

The air is forced to accelerate over the upper surface, creating a zone of lower pressure and generating lift. As angle of attack increases, the region of maximum pressure (centre of pressure) increases (that is, the lift vector grows) and moves forward. When the critical angle of attack is reached the region of maximum pressure shrinks (the lift vector shortens) and moves rapidly backwards.

### **3 – Relative Airflow**

**Definition:** Direction of the airflow in relation to the moving or stationary wing. Relative airflow travels parallel but opposite to flight direction. If the wing moves forward and down through the air mass, the relative wind will be coming aftward and upward towards the aircraft. (i.e. always opposite the aircraft's movement through the air.)

### **4 – Camber**

**Camber:** The curve of the upper and lower surfaces of the wing.

### **5 – Area, Span, Chord and Aspect Ratio**

**Area:** surface area of the wing

**Chord:** Imaginary line joining the leading edge to trailing edge by the shortest route.

**Span:** Maximum distance between the wingtips.

**Aspect Ratio:** Ratio between the length of the wing span and its depth (Chord). A high aspect ratio wing will generate more lift and less induced drag. For example, a wing with a span of 24 ft and a chord of 6 ft has an aspect ratio of 4, while a wing with a span of 36 ft and a chord of 4 ft will have an aspect ratio of 9, for an identical area of 144 square feet. High aspect ratio wings are preferred for glider construction, where high lift and low drag are critical.

## 6 – Laminar Airflow and Boundary Layer

### Definitions

**Boundary Layer:** Thin layer of air covering the surface of the wing (and of any object traveling inside a fluid for that matter) which is influenced in speed and direction by the airfoil shape. The boundary layer may be of two types: Laminar and Turbulent.

**Laminar Layer:** Smooth and regular-flowing part of the boundary layer. It produces little friction drag but is very fragile to separation.

**Turbulent Layer:** Thicker, more turbulent part of the boundary layer. Situated aft of the transition point. It produces way more friction drag but it is way more resistant to separation. This is why Golf ball uses hole provoking transition to keep its boundary layer attached as long as possible, preventing the growth of disastrous pressure drag.

**Transition Point:** The point where the airflow ceases being laminar and becomes turbulent.

**Separation Point:** Point where the turbulent layer (in the airfoil case) is no longer in contact with the wing surface. It stops following the wing camber, leaving behind it a huge vacuum Which turns to be pressure drag. This happen at large angle of attack

**Influence of angle of attack on the laminar airflow:** As angle of attack increases, the transition point moves forward.

### Methods to control the Boundary Layer - Suction Method:

Series of thin slots in the wing running out from the wing root towards the tip. A vacuum sucks the air down through the slots, preventing the airflow from breaking away from the wing and forcing it to follow the curvature of the wing surface. The air sucked in siphons out through the ducts inside the wing and is exhausted backwards to provide extra thrust.

**Vortex Generators:**

Small plates about an inch in height, placed standing on edge in a row spanwise along the leading edge of the wing. They are fixed at a certain angle of attack, and when the wing moves through the air they generate vortices. They prevent or delay the separation of the boundary layer by re-energizing it. This system is lighter and simpler than the suction method.

## 8 – Dihedral

Angle between the wings and the horizontal plane. In an aircraft with dihedral, the wingtips are farther from the ground than the wing roots while the airplane is at rest.

## 9 – Factors Affecting Lift and Drag

**Streamlining:** Technique of designing an object to minimise air resistance (i.e. the drag it generates).

**Wing profile:** Thickness and curvature of the upper and lower surfaces of the wing. The purpose for which the aircraft is intended has a strong influence on the shape of the wing of that aircraft. An aircraft intended for low-speed, high lift flight will have a thick wing which generates high lift but also high drag. An aircraft intended for high-speed, high-altitude flight will have a thin wing profile which generates less drag (as well as less lift).

**Angle of Incidence:** The angle between the chord line of the wing and the longitudinal axis of the aircraft. A well-situated wing improves in-flight visibility, take-off and landing characteristics and also reduces drag in cruising flight. Most modern aircraft have a small positive angle of incidence which ensures a small angle of attack in cruise flight.

**Wingtip configuration:** Specially designed wing tips have proved effective in controlling induced drag and wingtip vortices. Wingtip vortices destroy part of the lift (by reducing the local effective angle of attack), generate drag (induced drag) and promote instability at high angles of



attack and low airspeeds. Wingtip tanks, wingtip plates, droop wingtips and winglets are examples of various wingtip configurations.

**Wash-out:** The wing is twisted in such a way that the angle of incidence at the wing tip is less than the angle of incidence at the wing root. Thus the wing will stall at the wing root before the wingtips stall, meaning the ailerons remain effective during the first stages of the stall.

**Wing Fences:** Fin-like vertical surfaces attached to the upper surface of the wing. They are used to control airflow over the wing, providing better low-speed handling and stall characteristics.

**Slats:** Auxiliary airfoils which deploy at high angles of attack from the leading edge of the wing, smoothing airflow over the wing and delaying the stall. When the angle of attack decreases the pressure of the air against the slat pushes it back into the leading edge of the wing.

**Slots:** Passageways built into the wing a short distance from the leading edge. At high angles of attack, the air flows through the slot and over the wing, tending to smooth out the turbulence caused by eddies and delays the stall.

## 406.03 – Load Factors and Aerodynamic Loading

### 1 – Load, Aerodynamic Load, Load Factor, Gust Loading

**Wing Loading:** The total weight of the aircraft divided by the surface area of the lifting surfaces.  
(lb/pi<sup>2</sup>)

**Dead weight:** Weight of the aircraft while immobile on the ground.

**Dynamic Loading:** Additional load added to the dead weight due to acceleration and/or change of direction of the aircraft.

**Load Factor:** Relation which exists between the real load supported by the wings and the total weight of the aircraft: In other words, the ratio between the dynamic load and the dead weight. Often expressed in “G’s”.

**Gust Loading:** When the speed or direction of the relative airflow changes abruptly, the aircraft structure undergoes rapid and significant changes in loading.

### 2 - Spoilers and Dive Brakes

**Spoilers:** Plates installed on the wings to increase drag and reduce lift. Spoilers deploy on the upper and lower surfaces of the wing. They destroy the lift generated by the wing, permitting the pilot to maintain a safe airspeed while increasing rate of descent. The spoilers of the SGS 2-33 are mechanically linked to the wheel brake, permitting much more effective braking.

**Dive Brakes:** Plates installed on certain high-performance aircraft. They are designed to ensure an optimal descent without requiring the engine to be throttled back to the point where there is a risk of shock cooling. When deployed, airbrakes generate drag without changing the shape of the wing.

### 3 – Load Factors in the Turn

#### Load Factors

In straight and level flight (equilibrium) the aircraft is under a load factor of 1 G. As the angle of bank increases, the load factor increases. (When in a coordinated turn) At an angle of bank of 60 degrees, the load factor is 2 G's.

Bank Angle	Load Factor
15	1.04
30	1.15
45	1.41
60	2.00
75	3.86
77	4.45
90	infinite

#### Calculation of Stall Speed in the Turn:

Stall Speed in a turn =  $Stall\_Speed \times \sqrt{Load\_Factor}$

$$Load\ Factor = 1 / \cosine\ (bank\ angle) = \frac{1}{\cos(bank\_angle)}$$

### 4 – Weight, Load Factor and Stall Speed

The greater the angle of bank in a turn, the greater the load factor; this implies an increase in stall speed. The greater the weight of the aircraft, the more the load factor and stall speed will increase; this means that high-bank turns at high weight can cause structural damage and possibly a premature stall, and are more dangerous close to the ground.

## 5 – Structural Limitations and Load Factor

**Load Factor:** Ratio between the real load supported by the wings and the weight of the aircraft.

### Maximum Load Factor

The greatest load factor for which the aircraft has been designed. This limit should never intentionally be exceeded; doing so risks permanently damaging or deforming the structure of the aircraft. The Average Maximum Load Factor for light aircraft in the Normal category is +3.8 G and -1.52 G.

### Structural Airspeed Limits

**Never Exceed Airspeed ( $V_{NE}$ ):** Maximum speed at which the aircraft can be flown in calm air. An airspeed over the  $V_{NE}$  may cause structural damage through flutter or loss of control. End of the yellow arc.

**Maximum Normal Operations Speed ( $V_{NO}$ ):** Maximum design cruising speed, which should not be exceeded in turbulent air. The maximum safe speed for operations in the Normal category. The end of the green arc and start of the yellow arc.

**Maneuvering Speed ( $V_A$ ):** Maximum speed at which the controls can be fully deflected without exceeding the maximum load factor.

### Calculation of maneuvering speed:

$$V_A = \text{Stall\_Speed} \times \sqrt{\text{maximum\_Load\_Factor}}$$

**Maximum Flap Extension Airspeed ( $V_{FE}$ ):** Maximum airspeed at which the aircraft can be flown with flaps extended. Greater airspeed may damage the flaps. End of the white arc.

**Stall Speed ( $V_S$ ):** Clean configuration full weight and power off stalling speed. Start of the green arc

**Landing configuration stall speed ( $V_{SO}$ ):** Landing configuration stalling speed. That is flaps extended, landing gear extended, power off and full weight configuration. Start of the white arc.

<b>Limits for the SGS 2-33A</b>	
$V_{NE}$	98 mph
$V_A$	65 mph
$V_{NO}$	50 mph
$V_{FE}$	N/A

## **406.04 – Stability, Weight and Balance**

### **1 – Stability**

**Stability:** The natural tendency of an aircraft to maintain its straight-and-level flight attitude and to return to it when disturbed, without intervention of the pilot. Stability is divided into longitudinal, lateral and directional stability.

#### **Types of stability**

**Static:** Initial tendency of the aircraft towards the original flight attitude when disturbed.

Static stability may be positive, neutral or negative.

**Dynamic:** Overall tendency of the aircraft towards the original flight attitude, after a diminishing series of oscillations.

**Inherent Stability:** Refers to characteristics of stability built into the aircraft during the design process.

**Positive:** The aircraft will create forces or moments which will eventually return it to its original position.

**Neutral:** Stabilizing forces are absent. The aircraft will not return to its original position without input, but will not depart further from its original position either.

**Negative:** The aircraft will generate forces or moments which will displace it further from its original position unless corrective input is applied. (Unstable)

Longitudinal, Lateral and Directional Stability: Stability related to displacement in terms of pitch, roll or yaw.

## **2 – Improving Stability**

### **Longitudinal Stability**

Longitudinal stability is stability around the lateral axis and is called « pitch stability ».

Two factors influence longitudinal stability :

**Horizontal Stabilizer:** The size and position of the horizontal stabilizer can affect stability. When, after a deviation, the angle of attack of the wing increases, the centre of pressure moves forward forcing the nose of the aircraft up and the tail down. When the tail descends, the horizontal stabilizer meets the air at a greater angle of attack, generates more lift and therefore tends to raise the tail, therefore promoting stability.

**Center of Gravity:** Obviously the position of the centre of gravity plays an important role in longitudinal stability. If the aircraft is loaded so that the centre of gravity is too far aft, the aircraft will tend to fly with a nose-high attitude. The inherent stability of the aircraft will be neutralized and, while it will be possible to correct by moving the elevator down, the aircraft will be uncontrollable in some extreme situations.

## **Lateral Stability**

Lateral stability is stability around the longitudinal axis; it is called «Roll Stability». Lateral stability is obtained using:

**Dihedral:** Dihedral is the angle each wing makes with the horizontal plane. If the aircraft is disturbed, it will slip towards the low wing. The low wing will generate more lift and tend to roll the aircraft upright to regain straight and level flight.

**Keel Effect:** The Centre of Gravity of most high-wing aircraft is quite low. When the aircraft is disturbed and one wing rolls below the other, the weight of the aircraft acts as a pendulum and tends to return the aircraft to its original position.

**Sweepback:** The leading edge of each wing is swept aftward. When one wing descends, the leading edge of the low wing becomes perpendicular to the relative wind. This wing generates more lift and raises back into level flight.

**Proper Weight Distribution:** Proper distribution of the aircraft's load helps it maintain roll stability. Passengers, fuel and cargo should be distributed so there is approximately equal weight on each side of the aircraft. Directional stability

Directional stability is stability around the normal (Vertical) axis.

The most important element affecting directional stability is :

**Vertical stabilizer (fin):** The aircraft always tends to fly straight into the relative wind. If the aircraft is subjected to a yawing moment, the airflow will hit the side of the fin and generate a force which will push the tail (and thus the aircraft) back in line with the relative wind.

**Sweepback:** When an unwanted yaw movement occurs, the advancing wing will show more of its span to the relative airflow than the retreating wing therefore creating more drag and helping it to return to its original position.

<b>AXIS</b>	<b>MOVEMENT</b>	<b>CONTROL</b>	<b>STABILITY</b>
Longitudinal	Roll	Ailerons	Lateral Stability, around the Longitudinal Axis
Lateral	Pitch	Elevator	Longitudinal Stability, around the Lateral Axis
Normal	Yaw	Rudder	Directional stability, around the Normal Axis

### **3 – Purpose of Centre of Gravity Limits**

#### **Limits**

Limits are normally expressed in inches from the datum line. For some aircraft, the C-of-G limits are expressed as a percentage of Mean Aerodynamic Chord (the average chord of the wing).

The position of the Centre of Gravity affects the stability of the aircraft. The engineers who design aircraft specify the forward and aft C-of-G limits which must not be exceeded. They exist to guarantee that the pilot will have sufficient deflection of the elevator during all phases of the flight.

### **4 – Flight Characteristics under Various C-of-G Configurations**

**C-of-G too far forward:** The aircraft will be nose-heavy; significant control pressure will need to be applied on the elevator and the aircraft will be harder to trim. If the aircraft stalls or falls into a spiral dive, it will be difficult and possibly very slow to recover from the dive. This is critical at low altitudes.

The aircraft, being nose-heavy, requires aft control pressure to create downwards « lift » from the tailplane in order to keep the nose up. This downward force effectively adds itself to the aircraft's weight and extends the vector acting downwards. This increase in downward force means that more upward force (Lift) must be generated for a given flight profile, which results in an increase in stall speed.



**C-of-G too far aft:** The aircraft will be tail-heavy; this is the more dangerous of the extremes. An aircraft with a C-of-G too far aft can be dangerously unstable, and the stall and spin characteristics will be abnormal. Recovery from unusual attitudes will be difficult if not impossible because the pilot will potentially need more control movement on the elevator than there is available. The responsibility to ensure proper weight distribution rests on the shoulders of the pilot; correct loading will respect C-of-G limitations.

The stall speed will decrease with an aft loading because, in order to maintain a normal flying attitude, the pilot will have to apply forward pressure, creating positive lift from the tail surface which will help support the aircraft in flight. Loading aircraft aft WITHIN LIMITS is used on large aircraft to reduce induced drag, gain a few knots and save fuel. For this, they transfer fuel in the horizontal stabilizer. What happens is that a forward loaded aircraft gets nose heavy and back pressure is needed to keep normal flight. The horizontal stabilizer is therefore creating a downward lift adding to the weight which will require more lift from the wing to balance the normal weight and the fake added weight of the downward lift. This creates in turn more drag that would have to be compensated by burning more fuel. This is eliminated by loading the aircraft aft but within limit. This principle is valid for large aircraft as no appreciable gain will be made on a slow-light aircraft.

## **5 – Spins and Spirals**

### **Spin**

A spin is an auto-rotation resulting from an aggravated stall. If a disturbance causes the wing of an aircraft to drop while the wing is stalled, or if the rudder pedals are used to generate a yawing movement at the moment of stall, the descending wing will have a greater angle of attack in the relative airflow. Therefore the down-going wing will create less lift (because already stalled) and will tend to fall more rapidly, increasing the rate of rotation. The drag of the down-going wing increases abruptly, making the angle of attack and degree of the stall worse still. The nose of the aircraft drops and auto-rotation sets in.

**Characteristics:**

- speed high but constant;
- wings stalled;
- radius of turn constant;
- rate of descent constant, and;
- load Factor (G) constant.

**Recovery Procedure:**

**Left Column:** Recovery method presented in the 242 (method will work with most types of gliders). Use this terminology when answering exam questions.

**Right Column:** Recovery method for use in the 2-33 (due to its particular properties).

<b>THEORY</b>	<b>PRACTICE</b>
Centre controls (close spoiler/dive brakes if they are open)	Centre controls (close spoiler/dive brakes if they are open) and call “SPIN!”
Apply full rudder opposite the direction of rotation	Apply full rudder opposite the direction of rotation
Gently apply and hold forward pressure on the stick	Gently apply forward pressure on the stick and hold until rotation stops.
Center rudder and level wings	Level wings using coordinated application of rudder and ailerons
Gently pull out of dive (if speed is increasing excessively use dive brakes)	Gently pull out of dive (if speed is increasing excessively use dive brakes)
	Trade excess speed for altitude (only with a FI)
	Assume normal flying attitude

**Make sure not to confuse Spin and spiral characteristics**

## Spiral Dive

A spiral is a very steep uncoordinated descending turn, characterized by an exaggerated angle of bank, and rapidly increasing airspeed and rate of descent. If the airspeed increases past the structural limits of the aircraft, severe damage can occur.

### Characteristics:

- speed increasing
- wings not stalled
- radius of turn decreasing
- rate of descent increasing
- load Factor (G) increasing

### Recovery Procedure:

**Left Column:** Recovery method presented in the 242 (method will work with most types of gliders). Use this terminology when answering exam questions.

**Right Column:** Recovery method for use in the 2-33 (due to its particular properties).

<b>THEORY</b>	<b>PRACTICE</b>
Level wings using coordinated application of controls	Center controls and call « SPIRAL! »
	Level wings using coordinated application of rudder and aileron
Ease gently out of the dive (if speed is excessive, deploy dive brakes)	Ease gently out of the dive (if speed is excessive, deploy dive brakes)
	Trade excessive speed for altitude (only if with a FI).
	Assume normal flying attitude.

**Make sure not to confuse Spin and spiral characteristics**

## 6 - Weight and Balance Calculations

### Find the Centre of Gravity by the Calculation Method

For the following example, we have chosen an airplane with a basic weight of 1575 lbs and a maximum gross weight of 2600 lbs. The datum line (arbitrary line designated by the manufacturer, from which distances are measured) is the fire-wall. The centre-of-gravity limitations are between 35.5" and 44.8".

**In a table, write:** (the step numbers below also appear in the table)

1. The aircraft (empty weight); pilot; passengers; fuel; oil; baggage; cargo; etc.; as well as their weights and respective lever arms (distance from the datum line)
2. Calculate the moment of each item: multiply the weight of the empty airplane by the moment-arm (horizontal distance in inches between the datum line and the centre of gravity). Multiply the weight of each item (passenger fuel etc) by the distances they are located from the datum line.
3. Make the sum of the weights.
4. Take the sum of the moments.
5. Divide the total moment by the total weight to find the moment-arm of the loaded aircraft (that is, the position of the centre of gravity of the aircraft once loaded).

Item (1)	Weight (1)	Moment-Arm (1)	Moment (2)
Empty Weight	1,575	+36	56,700
Pilot	165	+37	6,105
Passenger (Front)	143	+37	5,291
Passenger (Rear)	165	+72	11,880
Infant (Rear)	77	+72	5,544
Baggage	90	+98	8,820
Fuel (60 GalUS at 6 lb)	360	+45	16,200
Oil 2.4 GalUS at 7.5 lb)	18	-15 (negative because the moment-arm is negative)	-270
<b>TOTAL</b>	<b>2,593 (3)</b>		<b>110,270 (4)</b>

(6)  $110,270 / 2,593 = 42,52''$

The total moment-arm is 42.52'' (110 270/2 593). The total weight (2593 lbs) of the loaded airplane is less than the maximum authorised gross weight (2600 lbs). The moment-arm is within the recommended centre-of-gravity limits (35.5'' to 44.8''). Therefore, the aircraft is properly loaded.

## **406.05 – Aerodynamics**

### **1 – Aileron Drag (Inverse Yaw)**

When an aircraft is banked to perform a turn, one aileron descends while the other rises. The descending aileron moves into the area of high pressure air beneath the wing, causing an increase in drag relatively to the upgoing aileron which moves in an area of lesser pressure. The extra drag on the rising wingtip tends to produce a yawing moment in the direction opposite the turn.

**Differential ailerons** were designed to minimize aileron drag. The down-going aileron does not have the same range of travel as the up-going aileron, reducing the difference in drag created and therefore reducing the yaw effect.

**Frise ailerons** have the same effect on aileron drag, using a different design. The control surface is mounted so that when deflected a part of the up-going aileron descends below the wing into the high-pressure airflow beneath the wing, creating drag which balances the extra drag created by the down-going aileron on the opposite wing.

## **2 – Secondary Effects of Controls**

### **Secondary Effect of the Ailerons**

When an aircraft rolls, it tends to slip towards the inside of the turn. The relative airflow therefore impacts the side of the fuselage. Because the surface in front of the C-of-G is smaller than the surface behind the C-of-G, a yawing moment in the same direction as the turn is generated. This yaw is the secondary effect of the ailerons.

### **Secondary Effect of the Rudder**

When rudder is applied, the aircraft yaws in the direction of the rudder pedal depressed. The wing outside the turn moves through the air more rapidly than the inside wing, thereby creating more lift and producing a rolling moment in the direction of the turn. This roll is the secondary effect of the rudder.

## **3 – Load Factor and Bank Angle**

In a coordinated level turn, the greater the increase in bank angle, the greater the increase in load factor. The centrifugal force which appears in the turn and the mass of the aircraft create a resultant called “apparent weight” or “G”. The centrifugal force increases with the angle of bank, and the load factor (G) increases in proportion.

## 4 – Stall Speed and Bank Angle

The greater the increase in bank angle, the greater the increase in load factor (Apparent weight). This extra weight supported by the wings causes an increase in stall speed.

## 5 – Speeds for Endurance; Range; Angle and Rate of Climb.

**Best airspeed for range:** Also called the best L/D, or best glide speed. The best glide speed for maximum distance with minimum loss of altitude. Best Lift / Drag Ratio = Best Glide Speed

**Best airspeed for endurance:** Airspeed which will give you the most time in the air. Better time aloft but less distance covered.

Best endurance = Minimum sink speed in glider

**Best Rate of Climb ( $V_y$ ):** The speed at which the greatest amount of altitude is gained in a given time. The rate of climb is not affected by the wind; it is based purely on the performance of the aircraft and is unrelated to groundspeed. This speed is NOT to be used to clear obstacle.

**Best Climb Angle ( $V_x$ ):** This speed will give the greatest increase in height in the least distance over the ground. The angle is affected by the wind; a strong headwind will make for a steeper climb angle, because the rate of climb will be the same but the groundspeed will be reduced.

This is the speed to use to clear obstacles.

## 6 – Effects of Temperature and Density on Flight Characteristics

### Effect of temperature and density on performance

The density of the air decreases as altitude and temperature increase. The density of the air is an important factor in the production of lift. The denser the air, the more lift is generated. This is why an aircraft departing a high-elevation airfield on a hot day requires more runway length to take off. The aircraft will experience a reduced rate of climb, a more rapid approach speed and

longer landing roll-out as well. To take into account the effect of altitude, pressure and temperature, one calculates the density altitude to find an equivalent ICAO standard atmosphere altitude. That computed value is then compared with performance data provided by the aircraft manufacturer.

## 7 – Manufacturer’s Recommended Approach Speeds

(The manufacturer’s standard approach speeds for the SGS 2-33A are found in chapter 402 Glider Operations)

The recommended airspeed for powered approaches and short landings is equal to 1.3 x the engine-off stall speed plus the wind speed if taken into account.

## 8 - Transport Canada Recommended Approach Speed

The recommended approach speed recommended by Transport Canada is equal to **1.3 x the stalling speed + wind speed.**

**Example :**

Stalling speed :	50 kts
Multiplied X 1.3	65 kts
Wind speed	15 kts
<b>Approach speed</b>	<b>80 kts</b>



# 406 – THEORY OF FLIGHT (Objective 3 – Instruments)

## 406.01 – Pressure Instruments

### 1 – Pitot-Static System

**Static pressure:** Is the barometric pressure, the weight of the air above the station measuring the pressure.

**Dynamic Pressure:** Is the pressure that builds up on a surface due to its movement's through the air. It is function of the airspeed, so knowing the value of dynamic pressure tells you about the airspeed. The air that is impacting perpendicular to the surface is creating that pressure. It cannot be measured directly by a barometric instrument as the static pressure will always be present in the reading. The instrument will be in fact measuring total pressure (static + dynamic) so static has to be subtracted somehow.

#### **Pressure ports**

**Pitot:** Measures total pressure. Located on the leading edge of the wing outside the slipstream, facing into the direction of flight. On a glider the pitot tube is often mounted on the nose.

The Airspeed Indicator is the only instrument connected to the pitot (total pressure) intake.

**Static:** This port allows the internal pressure of each instrument to adjust to the ambient barometric pressure outside the aircraft. The ports are generally located on both sides of the fuselage, sheltered from turbulence and the air striking the aircraft from the front. On the 2-33, the static pressure port is located on the same tube as the dynamic pressure port (i.e. on the nose of the glider).

**The Airspeed indicator, the Vertical Speed Indicator and Altimeter are all connected to the static pressure system. All barometric instruments are connected to static pressure source.**

## 2 – Construction of the Airspeed Indicator

### Airspeed Indicator (ASI)

Indicates the speed at which the aircraft is moving through the air mass (not the speed over the ground). The dial is calibrated in knots (kts) and in statute miles per hour (mph). The instrument functions by reading the difference between the total (dynamic + static) pressure from the pitot tube and the static pressure from the static port. The end product is the value of dynamic pressure created by the forward movement of the airplane through the air.

The airspeed indicator displays the Indicated Airspeed (IAS).

True Airspeed (TAS) is indicated airspeed corrected for temperature, density and instrumentation errors. It is the actual airspeed flowing over the wings of an aircraft.

### Parts

This instrument is composed of an aneroid capsule into which the total pressure is channeled. The static pressure port is linked to the sealed case of the instrument; this keeps the pressure inside the casing equal to the external pressure. The static pressure collected by the pitot port and the static pressure from the static port cancel each other and the aneroid capsule is affected only by the dynamic pressure. The capsule expands when the pressure increases (i.e. when the airspeed increases) and contracts when the pressure decreases (i.e. when the airspeed decreases). This expansion is transmitted to the needle on the face of the instrument by a mechanical linkage of levers.

### Markings

RED LINE	Never Exceed Speed ( $V_{NE}$ )
YELLOW ARC	Caution range (used in calm air only)
GREEN ARC	Normal operation range
WHITE ARC	Flap extension range

### **3 – Use of the ASI and Common Errors**

#### **Errors**

**Density:** The varying density of the atmosphere affects the accuracy of the airspeed indicator. Air which is less dense (i.e. at altitude) will cause the airspeed indicator to display a speed lower than the true airspeed, because there are fewer particles of air per volume entering the aneroid capsule, meaning the capsule will inflate less quickly for a given speed. Calibrated airspeed corrected for density gives True Airspeed

**Position:** The eddies which form on the wings and struts as they pass through the air are in part responsible for this error. The other part is the angle of attack at which is flying the aircraft. The pitot tube is fixed and therefore error is induced by its position to the relative wind. These eddies are the reason why the pitot tube is mounted as far as possible in front of the leading edge of the wing. The remaining error is recorded in an airspeed correction table in the Operator's Handbook. Indicated airspeed corrected for position errors gives calibrated airspeed.

**Lag:** The mechanical error caused by friction between the moving pieces inside the instrument.

**Icing:** Ice formation on the Pitot tube or static port will cause display errors.

**Water:** Water inside the pressure system can cause erratic readings on the ASI.

### **4 – Indicated and True Airspeed**

**Indicated Airspeed (IAS):** Uncorrected airspeed, as displayed on the dial of the airspeed indicator.

**Calibrated Airspeed (CAS):** IAS corrected for instrument and position error.

**True Airspeed (TAS):** CAS corrected for density and temperature errors.

## 5 – Converting Indicated Airspeed into True Airspeed

To convert indicated to true airspeed, add 2% of the indicated airspeed for every 1 000 ft of pressure altitude. This doesn't take into account any instrument, positional or compressibility error.

**Example:** Find the true airspeed of an aircraft traveling at 130 kts indicated at 10 000 ft.

- There are 10 levels of 1 000 ft in 10 000 ft..
- $2\% \times 10 = 20\%$
- $IAS = 130$
- $TAS = 130 + (20\% \times 130)$
- $156 = 130 + 26$
- Answer = 156 kts

## 6 – Operating Principle of the Vertical Speed Indicator

**Vertical Speed Indicator (VSI):** Indicates in feet per minute the rate of increase or decrease in altitude of an aircraft. Measures changes in the pressure difference between a capsule (linked directly to the static port) and the sealed casing (linked to static pressure but with a greatly reduced flow rate).

This arrangement causes the capsule to expand in descent or contract in climb, as the pressure inside the capsule rises or falls more rapidly than the pressure in the casing. The movement of this capsule is amplified and transmitted to the needle on the instrument by a mechanical linkage of levers.

## **7 – Lag in the VSI**

**Error:** this instrument can take as long as 9 seconds to display the accurate rate of climb or descent. However it will indicate the correct tendency virtually instantaneously

## **8 – Altimeter: Operating Principle and Errors**

### **Altimeter**

Measures the atmospheric pressure caused by the weight of the column of air above the altimeter. This weight changes as the aircraft climbs or descends, and the instrument indicates this as a change in altitude.

The main components of the altimeter are the aneroid capsules contained inside the casing. These capsules are sealed and pressurized to the standard sea level pressure. When the instrument casing fills with air at lower pressure the capsules expand, and the change in volume is transmitted through mechanical linkages to the needle and displayed on the dial as an increase in altitude.

### **Altimeter Errors**

**Pressure:** Atmospheric pressure varies from one area to another, even for the same height above sea level. If the altimeter is not properly set to the local altimeter setting, it will display an incorrect altitude. If the atmospheric pressure is lower than the altimeter setting in use, the instrument will read high; if the atmospheric pressure is higher than the altimeter setting in use, the instrument will read low.

**From high to low, look out below; from low to high, watch the sky.**

**Temperature:** The altimeter is calibrated to display the correct altitude when used in an ICAO standard atmosphere. This implies a temperature of 15°C. If the temperature is colder than the ICAO standard, the real altitude will be lower than the indicated altitude. (Read HIGH) Since cold air is denser, it tends to accumulate at lower levels. This causes a steep pressure gradient. If the temperature is warmer than the ICAO standard, the real altitude will be higher than the

indicated altitude. (Reads low) Warm air is less dense, which tends to create a shallow pressure gradient. If an aircraft flies from a warm region to a colder region, the altimeter will read high, creating a potential hazard.

**Mountain Effect:** A local area of lower pressure is created by the acceleration of air flowing through the mountain range (Venturi Effect), by the Mountain Wave and by lower temperatures. The altimeter will read high.

## 9 – Altimeter Setting

**Altimeter Setting:** The barometric pressure value used to calibrate the altimeter to local pressure. The Altimeter Setting scale is generally graduated in Inches of Mercury (“Hg). The standard Altimeter Setting is 29.92”Hg.

**Standard Pressure Region:** In the Northern Domestic Airspace and at altitudes over 18 000 ft ASL, the altimeter shall be set to 29.92”Hg except for take-off and landing, when aerodrome pressure shall be used if available.

**Altimeter Setting Region:** In the Southern Domestic Airspace and Low-Level Airspace the altimeter shall be set to the altimeter setting of the nearest station.

**Transition:** The transition between Standard Pressure and Altimeter Setting regions is always done on the Standard Pressure side of the transition level. That is, the altimeter is set to standard pressure when the aircraft has passed through 18 000 ft on the climb, or prior to passing through 18 000 ft in descent.

Likewise, the pilot shall change to 29.92”Hg after entering the Northern Domestic Airspace and display the current altimeter setting of the nearest station before entering the Southern Domestic Airspace.

## 10 – Blockage of Pitot or Static Port

<b>Complete blockage of pitot tube:</b>	ASI acts like an altimeter
<b>Partial blockage of pitot tube:</b>	ASI reads low, possibly near 0
<b>Partial blockage of static port:</b>	ASI reads low in the climb Altimeter lags (reads low) in the climb ASI reads high in descent Altimeter lags (reads high) in descent VSI lags in climb and descent
<b>Complete blockage of static port:</b>	Altimeter and VSI fail ASI shows same effect as partial blockage

## 11 – Creating an Alternate Static Pressure Source

If no alternate static source is available and that you absolutely need the altimeter and the airspeed indicator working in order to terminate your flight safely, you may consider breaking the glass of the VSI so as to create an emergency alternate static source port.

## **406.02 – Other Instruments**

### **1 – Construction of the Magnetic Compass**

Built around two north-seeking magnets. These magnets are fixed on a float, to which is also attached a compass card. This assembly is mounted on a pivot and is free to rotate. The whole assembly is mounted within the compass bowl which is filled with alcohol or white kerosene to dampen oscillations of the magnetic system caused by turbulence. The Lubber Line indicates the direction in which the aircraft is flying. It must be precisely aligned parallel to the longitudinal axis of the airplane.

### **2 – Deviation**

Deviation is the angle between the direction indicated by the compass and the magnetic meridian. This error is caused by the effect of the engine and airframe on the magnetic field detected by the compass.

### **3 – Terrestrial Magnetic Field and Errors of the Compass**

#### **Terrestrial Magnetism**

The Earth is a magnet. Like all magnet, it has a North and South magnetic pole. Lines of force flow between the poles, creating a magnetic field which encircles the Earth. The needle of a compass is influenced by the Earth's magnetic field and aligns itself with these lines of force, thereby orienting itself in relation to the poles. The North-seeking end of the compass will point to Magnetic North.

#### **Compass Errors: Deviation and Magnetic Dip**



## **4 – Magnetic Dip, Northerly Turning Error and Acceleration Errors**

### **Magnetic Dip**

The Earth's lines of force are horizontal at the equator but become vertical towards the poles. This causes the compass to tend to dip in the Northern latitudes.

### **Compass Errors**

#### **Northerly Turning Error: SAND**

- In turns away from North, the compass LAGS.
- In turns away from South, the compass LEADS.

#### **Acceleration and Deceleration Error: ANDS**

- When accelerating on an East or West heading, the compass will indicate a turn to the North.
- When decelerating on an East or West heading, the compass will indicate a turn to the South.

## **5 – Calibrating the Magnetic Compass**

### **“Swinging the Compass”**

The effect of deviation is corrected by “swinging the compass”. The aircraft is lined up on each bearing at 30° intervals and the compass heading is compared to the real direction. The differences are recorded on the “For-Steer” card which is mounted in the cockpit for reference.

## **6 – Variation**

Angle between the True meridian and the Magnetic Meridian

## 7 – Reading the Magnetic Compass

The numbers representing headings are inscribed in tens and in hundreds. The pilot reading the number 33 knows he is flying on a heading of  $330^\circ$  or North-west. The cardinal directions are indicated by letters (N, S, E, W). The headings are painted on the opposite side of the compass card to permit the pilot to read them on the face of the instrument. The compass card seems to turn the wrong way in a turn.

## 8 – Verifying the Compass Heading on the Ground and in the Air

**On the ground:** line up on a runway, stop the airplane, allow the compass to settle and check the compass reading against the runway direction.

**In flight:** over-fly a runway in straight and level flight, avoiding any abrupt movement of the controls and check that the compass reading corresponds to the runway direction.

## 9 – Gyroscopes and Precession

### Gyroscope

A rotor, spinning at high speed in a universal mounting (Called a “gimbal”) so its axle can point in any direction.

**Gyroscopic Inertia:** The tendency of a body in rotation to maintain its plane of rotation unless a force is applied.

**Precession:** The tendency of a body in rotation, on which a force is applied perpendicular to the axis of rotation, to turn  $90^\circ$  in relation to its axis of rotation, in the same direction of the rotation, to take up a new plane of rotation parallel to the force applied.

In other words, when a force is applied to the gyroscope so as to change its plane of rotation, the force is taking effect only 90° farther down on the rotation path.

The Heading Indicator, Artificial Horizon and Turn and Bank Indicator are all gyroscopic instruments.

### **Heading Indicator (Directional Gyro, “DG”)**

Rotor mounted vertically, turning on a horizontal axis at around 12 000 rpm. The rotor is mounted in an inner gimbal, which turns freely around the horizontal axis. This gimbal is mounted inside a second gimbal. The card of the instrument is attached to this assembly by a system of gears. DG obeys the principle of Rigidity in Space. The position of the rotor and the gimbals is fixed in three-dimensional space; the aircraft turns around the gyroscope.

The Heading Indicator does not seek north and must be periodically calibrated to the compass.

The Heading Indicator must be recalibrated at regular intervals to correct for the following errors:

**Precession error:** caused by friction between the moving pieces of the instrument. Error of about 3° every 15 minutes.

**Apparent precession:** of 15°/hour, caused by the rotation of the Earth beneath the gyro.

Both, friction and apparent precession must be corrected for every 15 minutes.

### **Limitations**

- climbs, descents and turns must not exceed 85 degrees, and;
- the gyroscope must have about 5 minutes to spin up to operational RPM before the instrument can be used for accurate readings.

### **Artificial Horizon**

Horizontally mounted rotor, turning around the vertical axis. The rotor is mounted in a universal gimbal, freely rotating around the pitch and roll axes.

### **Limitations of the Artificial Horizon**

- **Electric:** Movements in pitch of 85 degrees, 360 degrees of roll
- **Pneumatic:** 70 degrees of pitch and 90 degrees (vertical) of roll.

### **Errors of the Artificial Horizon:**

- when accelerating the artificial horizon indicates a climbing right turn;
- when decelerating the horizon indicates a descending left turn, and;
- when turning the gyroscope precesses to the side of the turn.

## **10 – Turn and Bank Indicator**

### **Turn and Bank Indicator**

The basic principle behind the turn indicator is gyroscopic precession. When the aircraft turns to the right or left, the rotor « leads » around its axis of rotation and displaces the gimbal. The movement of the gimbal is transmitted through mechanical linkages to the needle on the face of the instrument. A spring returns the gyro to its previous position once the aircraft stops turning.

**The ball (Slip Indicator):** is affected by **gravity and centrifugal force**. It is simply a steel ball sealed into a curved glass tube filled with liquid.

The needle indicates the direction and rate of turn. It reacts only to yaw. The ball indicates the coordination of the turn; that is, if there is any slipping or skidding. In a turn, if the ball is opposite the needle, the aircraft is skidding, If the needle and ball are on the same side, you are slipping. If the ball is centered, the turn is well-coordinated.

### **Turn Coordinator**

- electrically powered;
- same principle as the turn indicator but the instrument reacts to both yaw and roll, and;
- the needle is replaced by an airplane figure.

### **Yawstring**

Gliders use a yawstring to indicate the coordination of turns. The yawstring is a short piece of light string or yarn. If the string is streaming straight back towards the pilot, the glider is well coordinated. If the yawstring is streaming towards the inside of the turn, the aircraft is skidding. If the yawstring is streaming towards the outside of the turn, the aircraft is slipping.

### **Skidding turn**

If the pilot uses excessive rudder in a turn, the aircraft will skid towards the outside of the turn. This can be corrected by releasing some pressure on the rudder pedals, or by increasing the bank angle.

### **Slipping Turn**

In a turn, the pilot does not apply sufficient rudder (or applies opposite rudder) for the bank angle adopted, which causes the aircraft to fall into the inside of the turn. This can be corrected by increasing the rudder applied in the direction of the turn or by reducing the bank angle.

### **Coordinated Turn**

A coordinated turn is performed by the coordinated use of the rudder and ailerons. When a turn is correctly executed, the ball will be centered or yawstring will point straight back, and drag will be minimized.

## REVIEW QUESTIONS:

1. Spars are major wing components which run from the chord to the trailing edge. They carry the loads absorbed by the aircraft. True or False
2. What is the main role of the undercarriage? \_\_\_\_\_
3. What is the term used to designate the curved shape of an aircraft wing?  
\_\_\_\_\_
4. Angle of Attack is the angle formed between the \_\_\_\_\_ and the \_\_\_\_\_.
5. The imaginary line which connects the leading edge to the trailing edge of a wing is called: \_\_\_\_\_
6. On the chord line, the point which corresponds with the resultant of all the forces of lift is called : \_\_\_\_\_
7. What are the two layers of airflow found on the upper surface of the wing?  
\_\_\_\_\_
8. List two functions of the spoilers. \_\_\_\_\_
9. List the four forces acting on an aircraft in flight: \_\_\_\_\_
10. What kind of drag is caused by the lift-creating surfaces? \_\_\_\_\_
11. What is “washout” and what does it do? \_\_\_\_\_  
\_\_\_\_\_

12. If I bank my aircraft to the right, what are the ailerons doing?  
\_\_\_\_\_  
\_\_\_\_\_
13. What is the secondary effect of yaw? Give a brief description.  
\_\_\_\_\_  
\_\_\_\_\_
14. What is the main purpose of trim? \_\_\_\_\_
15. The total weight of the aircraft divided by the surface of the lifting surfaces is called:  
\_\_\_\_\_.
16. The actual weight carried by the wings divided by the total weight of the aircraft is called:  
\_\_\_\_\_.
17. In a level turn at a constant speed, the higher the angle of bank the :  
a. higher the rate of turn;  
b. smaller the load factor;  
c. smaller the radius of the turn;  
d. all of the above.
18. The tendency of an aircraft to return to its initial situation after being disturbed is called :
19. Stability about the lateral axis is called: \_\_\_\_\_ stability. Lateral stability is stability about the \_\_\_\_\_ axis.
20. You are on take-off and at the end of the runway, there is a 150' tall tower. What climb speed will you use and why? \_\_\_\_\_  
\_\_\_\_\_

21. List the characteristics of a spin. \_\_\_\_\_
22. List the characteristics of a spiral dive. \_\_\_\_\_
23. What does the lubber line of a compass indicate? \_\_\_\_\_
24. If you are turning away from the South, what error will the compass display? \_\_\_\_\_
25. When accelerating on an East-West heading, the compass tends to indicate a turn towards the \_\_\_\_\_.
26. The ASI is linked to which pressure source? \_\_\_\_\_
27. What pressure source does the vertical speed indicator use? \_\_\_\_\_
28. When an aircraft passes from region of higher pressure to a region of lower pressure, the altimeter will indicate:
  - a. no change;
  - b. an altitude above the actual altitude ;
  - c. an altitude below the actual altitude;
  - d. a variation from low-high-low.
29. When flying from a warm air mass to a cold air mass, the altimeter \_\_\_\_\_ due to the increase of the \_\_\_\_\_.
30. Mountain effect causes the altimeter to \_\_\_\_\_.
31. What is the  $V_{NE}$ ? \_\_\_\_\_
32. What does the yellow arc on the airspeed indicator indicate?



33. The vertical speed indicator has a lag of :\_\_\_\_\_

34. What information does the turn-and-bank indicator give you? \_\_\_\_\_

35. What instrument(s) are gyroscopic instruments? \_\_\_\_\_

# 410 – Engines

## 410.01– Basic Concepts of Aero Engines

### 1 - Horsepower

- Standard unit used to measure the power produced by an engine.
- Represents the amount of work required to lift a weight of 33 000 lbs 1 foot in 1 minute (1Hp).

### 2 - Indicated Horsepower

Power developed inside an internal combustion engine. The energy released by combustion of fuel without reference to any kind of losses engine normally has. The theoretical power of a frictionless engine

### 3 - Brake Horse Power (BHP)

- a) Due to friction and other losses, all indicated power is not available for useful work.
- b) The available power after friction and other losses have been deducted is called Brake Horsepower. It is the actual power driving the propeller

### 4 - Types of Combustion Engines

#### Horizontally Opposed Cylinders:

Two rows of cylinders are mounted flat and in direct opposition on the same camshaft. There are 4, 6 or 8 cylinders. The principle advantage is the flat profile, which provides a small frontal surface and correspondingly low drag. This is the engine-type most commonly mounted in light aircraft.

**Radial:**

The cylinders are mounted in a star shape around a barrel-shaped crankcase. The engine always has an odd number of cylinders. The power-to-weight ratio of this engine is acceptable, is reliable, easy cooling and it is easy to maintain, but its particular form factor considerably increases parasite drag and reduces forward visibility.

**Inline:**

The cylinders are set side by side all along the crankshaft. Each piston works separately on an individual crank-throw. The practical limit is six cylinders per row. If more power is needed, they are configured on two rows or more; hence the “V”, “X” and “H” which have two crankshafts side-by-side. Some inline engines are inverted, to provide better forward visibility. It causes little drag, but it is heavier and of limited size.

**5 - Jet Engines**

Jet propulsion functions on Newton’s Third Law, which declares that any action creates and equal and opposite reaction.

Certain types of aircraft are equipped with a jet engine. Modern military aircraft such as the F-14, F-15 and CF-18 use various types of jet engines. Large commercial aircraft such as the Boeing 747 are also equipped with jet engines.

In a jet engine, the air admitted into the engine is compressed and injected forcefully into the combustion chamber by a compressor powered by a turbine. The turbine is in turn powered by the energy of hot exhaust gases.

In the combustion chamber, fuel is mixed with the compressed air and ignited, producing a very hot gas at a very high pressure. This hot gas is exhausted out of the engine, turning the turbine as it passes. The remaining energy is converted to thrust as the hot air is ejected backwards in a continuous high speed stream, propelling the aircraft forwards.

## **6 - Basic Engine Components (piston engine)**

Each cylinder contains a piston which moves up and down. The piston is equipped with rings which ensure a tight seal between the piston and cylinder walls.

The connecting rod links the piston to the crankshaft, which in turn is connected to the propeller.

Spark plugs, intake and exhaust valves are situated in the cylinder head. The intake valve permits fuel-air mixture to enter the combustion chamber, while the exhaust valve permits the evacuation of exhaust gases into the exhaust system.

The camshaft is turned by the crankshaft. It permits the movement of the valve stem and rocker. The camshaft rotates at half the speed of the crankshaft. The cylinders and cylinder heads are finned to better dissipate accumulated heat.

The fuel-air mixture is ignited by dual spark plugs mounted in the cylinder head. They receive electric current from separate set of magnetos via the distributors.

The intake valve is connected to the carburetor where the mixture of fuel and air takes place. The exhaust valve is connected to the exhaust system which serves to evacuate the by-products of combustion out of the aircraft and away from the cabin.

## 410.02 – Operation and Cycles of the Combustion Engine

### 1. The Four Stroke Cycle

Nearly all piston engines are constructed for a four-stroke cycle. This means that the piston moves four times (twice upwards and twice downwards) in each cycle. During this time the crankshaft completes two complete revolutions.

The four strokes are: Induction stroke ; compression stroke ; power stroke ; and exhaust stroke.

#### **Induction Stroke:**

The intake valve is open. The piston moves downwards from the top of the cylinder, creating suction and pulling the premixed fuel-air mixture into the combustion chamber via the intake valve. The exhaust valve remains closed.

#### **Compression Stroke:**

With both valves closed, the piston rises towards the top of the cylinder, compressing the mixture. The volume of the combustion chamber above the piston when it is at the bottom of the cylinder, compared to volume when the piston is at the top of the cylinder, is called the *compression ratio*. Compression ratio of around 10:1 is common in atmospheric piston engine.

#### **Power Stroke:**

With both valves closed. The compressed mixture is ignited by the spark plug(s) (two in aircraft piston engines). As it burns the gas expands, exerting pressure which pushes the piston towards the bottom of the cylinder with considerable force. This force is sufficient to power the engine through the other three strokes as well as provide the energy required for useful work.

#### **Exhaust Stroke:**

The exhaust valve is open. The piston rises to the top of the cylinder, pushing the burnt gases out through the exhaust valve. The intake valve remains closed.

## 2. Timing

The purpose of timing is to improve the performance of the engine. The valves require a certain amount of time to open and close and the fuel/air mixture possesses inertia that may be exploited to increase the amount of mixture inducted into the cylinder. They are therefore adjusted to open early and close late in order not to waste any of the induction or exhaust strokes.

**Valve lead:** timing the valve to open early.

**Valve lag:** timing the valve to open late.

**Valve overlap** is allowing both valves to remain open simultaneously. This happens at the end of the exhaust stroke. By opening early, the exhausting gas helps the incoming fuel air mixture by the suction created when leaving through the exhaust piping.

## 3. Valve Clearances

A clearance is necessary between the valve stem and the rocker to prevent the valve being forced off its seat when it gets hot and expands. This is called valve clearance.

- Too much clearance can cause loss of power, vibrations and excessive wear.
- Too little clearance can warp the valves and cause serious trouble.

#### **4. Two-Stroke Engines**

The two-stroke engine takes only two strokes to complete a full cycle. These engines are less efficient than four-stroke engines, which is why the power generated by a two-stroke engine is always less than half the power of a similar sized four-stroke engine.

The principle of the two-stroke engine is to shorten the period wherein the fuel is inducted into the combustion chamber. This in turn reduces the time spent exhausting the burnt gases to a small fraction of a cycle rather than taking a whole cycle each for induction and exhaust. In a two-stroke engine, the fuel-air mixture is inducted through the intake port when the piston is at the bottom of the cylinder, and then compressed as the piston rises and fired when the piston reaches the top. During the power stroke, the piston moves downwards and uncovers the exhaust port, allowing the escape of burnt exhaust gases.

### **410.03 – The Carburetor**

#### **1. The Carburetor**

The carburetor serves to measure the appropriate quantity of fuel, vaporise it and mix it with air in precise proportions, then distribute this mixture to the cylinders.

##### **Components of the Carburetor:**

**Venturi:** air is drawn through the venturi where its speed is increased due to the form of the chamber. The higher speed causes the pressure to diminish.

**Nozzle:** permits the passage of fuel from the float chamber to the venturi, where the low pressure around the nozzle sucks the fuel (which is under atmospheric pressure) from the jet in the form of a fine spray.

**Throttle Valve:** controls the volume of mixture passing from the venturi to the cylinders.

**Intake Manifold:** distributes the fuel-air mixture from the carburetor to the individual cylinders.

**Float Chamber:** contains enough fuel to ensure a continuous supply to the engine.

**Float Valve (Needle Valve):** opens and closes the fuel line flowing into the float chamber. Controlled by the float.

**Air Intake:** ensures that the air pressure inside the float chamber is always equal to atmospheric pressure, whether in climb or descent.

**Idle Jet:** used to allow the engine to continue to run when there is too little air passing through the venturi to pull fuel through the main nozzle.

## **2. Fuel-Air Mixture**

The proportion of air to fuel is controlled by the pilot via the mixture control in the cockpit. The throttle controls the flow of air penetrating into the engine and creates the turbulence at the butterfly valve which promotes mixing of the fuel and air.

With regards to the fuel-air mixture delivered from the carburetor to the cylinders, the proportion of fuel to air is measured by weight (mass) and not by volume.

The chemically correct mixture is about 15:1; that is, fifteen parts air to one part fuel.



The engine operating temperature is affected by the fuel-air ratio of the mixture entering the combustion chamber:

The engine will run hotter when the mixture is lean than when the mixture is rich, because a lean mixture burns more slowly and therefore more heat is absorbed by the walls of the combustion chamber due to the longer exposure to high temperatures.

The engine will run cooler when the mixture is rich than when the mixture is lean. The mixture burns more rapidly, exposing the cylinder walls to high temperatures for less time. Also, the extra fuel contained in a rich mixture promotes cooling by carrying away excess heat with the exhaust.

### **3. Mixture control**

A mixture control system is necessary because as altitude increases, air density drops off. Carburetors are calibrated to operate at sea level. This means that the proper fuel-air mixture is achieved with full rich setting at sea level.

As altitude increases, the weight of a given volume of air drops off. Therefore at high altitude, the proportion of air (by weight) in relation to fuel (also by weight) diminishes, even if the same volume of air is taken in. In consequence, the mixture will run too rich, wasting fuel, and causing loss of power.

To correct this situation, the carburetor is equipped with a mixture control system. This control governs the quantity of fuel drawn through the nozzle, re-establishing the proper fuel-air mixture ratio.

The mixture control can be used to establish a rich or lean fuel-air mixture as required.

#### **4. Rich Mixture**

An over-rich mixture (Excess fuel), as well as lowering the temperature of combustion, causes a waste of un-burnt fuel which is expelled through the exhaust system.

An over-rich mixture also contributes to fouling of the spark plugs and the combustion chamber. Excessively rich mixtures can cause a rough-running engine, a considerable loss of power or even engine failure.

Used during high-power flight operations (take-off, landing).

#### **5. Lean Mixture**

An over-lean mixture can cause rough running, detonation, back-firing, over-heating or a considerable loss of power.

Continuous operation of an engine at over-lean mixture settings can cause an engine failure.

Used for cruise flight.

#### **6. When to Lean the Mixture**

The mixture must be leaned for any of the following reasons:

- At cruise power, i.e. around 75% under maximum power.
- For any flight at altitudes over 5 000 ft.
- For take-off at high-altitude aerodromes.
- After climbing to a higher altitude.

## **7. Why Lean the Mixture**

Proper leaning of the mixture is both practical and economical and will result in:

- Fuel economy;
- Smoother running engine ;
- More efficient engine ;
- Greater range at cruise;
- Less spark plug fouling;
- More desirably engine temperatures; and
- Cleaner combustion chambers.
- Reduce carburetor icing hazards

## **8. Carburetor Icing**

There is a risk of ice forming in the induction system when the temperature is between  $-5^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ .

Carburetor icing is usually indicated by a loss of power (drop in RPM). When sufficiently serious, it can cause a total engine failure by interrupting the flow of air to the engine.

Carburetor Icing has two distinct sources:

- The progressive drop in temperature as the energy is taken from the air and used to vaporise fuel. (Latent Heat of Vaporisation)
- Cooling caused by the lower pressure existing in the carburetor.

There are three types of carburetor ice:

- Fuel vaporisation ice ;
- Impact ice ;
- Throttle ice.

This problem does almost never occur in engines equipped with a fuel injection system rather than a carburetor. However, some fuel injection system does use a venturi exposing it to icing.

## **9. Prevention of Carburetor Icing**

Modern aircraft are equipped with systems to direct heated air to the carburetor air intake. The application of “carb heat” using the cockpit control activates this process. The air is warmed by passage over the exhaust system.

The application of carb heat will cause an initial drop in engine RPM due to a mixture which is richer (hot air being less dense). If ice is present, the melting ice passing through the system will cause engine roughness before the proper function is restored.

## **410.04– Fuel System**

### **1. Fuel System**

Stores and distributes fuel at the proper pressure in order to supply the requirements of the engine.

Even the simplest systems have several fuel tanks to store enough fuel to provide a reasonable flight time.

The tanks are usually positioned in the wings, although other tanks can be added. A selector switch allows the pilot to select the reservoir he wishes to use to supply the engine.

### **2. Gravity Feed Fuel System**

This is the most simple fuel system. It is still often used in high-wing low-performance aircraft.

The fuel tanks are located in the wings, higher than the carburetor. The fuel flows from the tanks to the carburetor under the influence of gravity, passing through a selector valve.

A drain allows removal of water and sediment trapped at the strainer. A primer sprays raw fuel into the intake manifold system or directly into the cylinders to aid starting, particularly in cold weather.

### **3. Fuel Pump Fuel System**

This type of system uses an engine-driven fuel pump to provide the pressure needed to push fuel to the engine.

This system is used on all low-wing aircraft as well as high-performance aircraft.

In addition to the main pump, this kind of system has auxiliary electric pumps or booster pumps for use if the main pump fails.

A fuel pressure gauge, mounted on the cockpit panel, gives a visual indication that the fuel system is working by giving a reading of the pressure of fuel entering the carburetor.

#### **4. Components of the Fuel System**

##### **Fuel Tanks:**

Position, size and shape vary considerably,

Constructed of materials that will not react chemically with any aviation fuel.

A drain is provided at the lowest point of the tank. Overflow drains are also incorporated to release fuel and prevent tanks from bursting when fuel expands in the tanks.

The top of each tank is vented to the outside to maintain atmospheric pressure inside the tank

##### **Fuel lines and filters:**

Connect the reservoirs with the carburetor;

Made of a variety of materials; and

One or more filters are present between the tanks and the carburetor.

#### **5. Fuels**

Fuels for modern high-compression engines must burn slowly and expand evenly rather than explode quickly.

Fuels which possess this quality are known as high-octane fuels.

## 6. Octane Rating

The Octane Rating of a fuel is determined as follows:

- Octane is a substance which possesses minimum detonating qualities.
- Heptane is a substance which possesses maximum detonating qualities.

The ratio of octane to heptane is expressed as a percentage. Thus, 73 Octane fuel means that the fuel would have the same burning characteristics as a chemical mixture of 73% octane and 27% heptane. The fuel as itself is not composed of octane nor heptane. These are used for comparison purposes

## 7. Classification of Fuels

The octane rating of a fuel is generally given as two set of numbers. The first number indicates the rating for a lean mixture, and the second number gives the rating for a rich mixture.

For example, grade 80/87 fuel has a rating of 80 for a lean mixture and 87 for a rich mixture.

Octane ratings do not exceed 100. If the fuel has a rating above 100, the anti-detonation properties of the fuel are expressed as a performance number, which represents 100% octane with additional additives to burn yet slower.

## 8. Applications and Different Fuel Grades

Application	Grade or Type	Colour
Low power	Grade 80 (or 80/87)	Red
Medium power	100 (High lead)	Green
Medium power	100 LL (Low Lead)	Blue
Jet Engine	Kerosene	Clear or straw yellow

## 9. Notes

If the required fuel for your aircraft is not available, use the next highest grade available, never a lower grade.

The responsibility to ensure that the aircraft is refilled with the proper fuel rests with the pilot. The Pilot's Operating Handbook always specifies which fuel to use.

## 10. Problems of the Fuel System

Three main problems affecting the fuel system are common in light aircraft:

### **Detonation:**

- Abnormally rapid combustion of fuel in the cylinders,
- Causes overheating of the engine and damage,
- Indicators include a rapid increase in cylinder head temperature and a rapid increase in pressure in the cylinders.
- **Causes:** Use of incorrect fuel; overheating, sometimes caused by too little airflow around the engine; and an over-lean mixture.
- **Temporary remedy:** Set mixture to full rich.
- **Permanent remedy:** Use only fuel with the octane rating recommended by the manufacturer.

### **Pre-ignition:**

- Pre-ignition is a premature ignition of the mixture due to glowing carbon deposits, or « local hot spots ». This phenomenon is often confused with detonation.
- Often occurs when trying to start a hot engine. Pre-ignition generally results in a backfire through the intake manifold.
- Damage to an engine through pre-ignition can be disastrous, causing warped pistons, cracked cylinder heads and other serious damage.



### **Vapour Lock:**

- Occurs in the fuel lines.
- Can be caused by a high atmospheric temperature, which causes the gas in the fuel lines to vaporize and block the flow of liquid fuel in the lines.

## **410.05 – Cooling, Lubrication and Lubricants**

### **1. Cooling System**

In an internal combustion engine, the burning fuel creates enormous heat. This heat is absorbed by the engine components. If there is no method of dissipating this heat, it will cause overheating which may cause the melting and fusing of the metal pieces (engine failure).

Some aircraft engines use liquid cooling, but the most popular cooling method is air cooling, where cool air is circulated around the cylinders. This system is lighter than liquid cooling system. Horizontally opposed and radial engines are air-cooled. Some in-line engines are also air cooled; others are still liquid cooled.

### **2. Parts of the Cooling System**

To facilitate air cooling, modifications have been incorporated. The outside walls of the cylinders are finned. The fins, which are small rings of metal around the cylinders, increase the surface area of the cylinder. Cooling air flows between the fins, absorbing the heat and carries it away. The air enters the engine compartment through openings in the front of the engine cowl and is expelled through openings at the rear of the cowling.

Cooling fans are sometimes installed in front of the engine. They assist the circulation of air at high altitude, where the air density is low or when the aircraft is sitting on the tarmac.

On some aircraft, the exhaust gases are directed through augments tubes, or jet pumps, which produce suction strong enough to increase the flow of cooling air around the cylinders.

Cowl flaps control the openings which channel air around the cylinders.

### 3. Lubrication System

Oil has four important functions:

- **Cooling:** carries away excessive heat generated by the engine.
- **Sealing:** provides a seal between the piston rings and cylinder walls, preventing loss of power and excessive oil consumption.
- **Lubricating:** Maintains an oil film between moving parts, preventing wear through metal-to-metal contact.
- **Cleaning:** Cleans and flushes the interior of the engine of contaminants which enter or are formed during combustion.

### 4. Requirements of Good Oil

**Viscosity:** is a measure of flow characteristics of a fluid. Stickiness or consistency.

Good viscosity gives proper distribution of oil throughout the engine and prevents rupturing of the oil film which lubricates the engine parts over the wide range of temperatures in which aero engines work.

Oil possessing a high viscosity index is one in which the changes in viscosity with changes in temperature are low.

The use of oil of too high viscosity for existing conditions will cause high oil pressure.

The use of oil of too low viscosity for existing conditions will cause low oil pressure.

**High flash point:**

- **Flash point:** the temperature above which a liquid will ignite.
- This temperature must be higher than the highest temperature of the engine.

**Low carbon content:**

If a small quantity of oil works past the scraper ring, it will burn, leaving behind carbon deposits which might accumulate on the cylinder walls. The risk is low if the oil has low carbon content.

Good oil will also have low wax content.

Oils which have good resistance to deterioration and the formation of lacquer and carbon deposits are said to have good oxidation stability.

**Low pour point:** Pour point: temperature at which a liquid solidifies. A low pour point is necessary for starting the engine in cold weather.

## 5. Methods of Lubrication

**Force Feed:** Oil is forced under pressure into the engine as a fine mist.

The oil is contained in a separate reservoir. A pressure pump forces the oil through the hollow crankshaft to lubricate the engine. The oil then drains into a sump from which it is pumped by the scavenging pump to ensure that the oil does not accumulate in the engine. The oil then passes through an oil cooler before returning to the reservoir.

A bypass around the filter is provided to prevent damage in case of failure (in case of neglect or carelessness) to clean the filter. The pressure-relief valve provides a means of regulating the oil pressure. Oil pressure is monitored by means of an oil pressure gauge on the instrument panel of the aircraft.

### **Wet-Sump Lubrication:**

The engine oil supply is contained in a sump, or pan, under the crankcase.

The oil passes through a filtering screen in the bottom of the sump into the suction side of a gear-type pressure pump. The pump moves the oil around the outside of its gears and imparts a predetermined pressure to it.

- A pressure relief valve is incorporated into the pump to ensure a steady supply of oil during all phases of engine operation. The pressure pump, which is engine driven, delivers oil through passageways in the crankshaft and pushrods to all the bearings of the engine for cooling and lubrication.

Some internal parts and surfaces of the engine may be splash lubricated or may be sprayed by oil flung off rotating parts of the crankcase and connecting rods.

After circulation, the oil drains through return tubes back to the sump. An oil cooler may be located in the return line to dissipate heat. The advantage of the wet sump is that it is light and simple. However, the capacity of the sump is limited by the size and design of the nacelle or cowling.

### **Splash:**

The oil is contained in a sump or reservoir, at the base of the engine.

The engine is churned by the revolving crankshaft into a heavy mist which splashes over the various engine parts.

This method of lubrication is no longer used in aircraft manufactured today, but can still be found in vintage aircraft.

## **410.06 – Exhaust, Ignition and Electrical Systems**

### **1. Exhaust system**

The exhaust system of a piston engine is basically a scavenging system that collects and disposes of the high-temperature noxious gases produced by the engine, including dangerous carbon monoxide.

The principle function of the exhaust system is to prevent potentially dangerous gases from penetrating into the airframe and cabin.

There are two main types of exhaust system in current use for piston engines : the short-stack system; and the collector system.

### **2. Short-Stack System**

The short-stack system is used on low-powered engines without turbochargers.

It is relatively simple, consisting of a downstack from under each cylinder, a collector tube on each side of the engine, and an exhaust ejector on each side of the cowling.

Shrouds encircle each collector tube. Outside air passing through one of these is heated by the high exhaust temperatures and carried to the cabin to provide cabin heat. The other carries heated air to the carburetor hot air system.

### **3. Collector System**

The collector system is used on most large engines and on all turbocharged engines.

Individual exhaust headers empty into a welded, corrosion-resistant collector ring that collects the exhaust from all the cylinders. One outlet from this ring route the hot exhaust to the turbocharger. An exhaust tailpipe carries the exhaust gases away.

#### **4. Ignition System**

The purpose of the ignition system is to provide the spark which fires the fuel-air mixture in the cylinders at the right time.

The system consists of:

- two magnetos;
- two spark plugs per cylinder;
- two ignition leads; and
- a magneto switch.

#### **5. Magneto**

If a wire is wound around a magnet, a current will be induced in the wire.

A magneto performs the following functions:

- generates a low-voltage current;
- transforms the low voltage into a high-voltage current; and
- distributes the current to each spark plug for ignition as required.

## **6. Other Components of the Ignition System**

The high-tension current is directed through a collector ring to the distributor. The distributor has a rotating arm which aligns with separate segments as it rotates. Each segment is connected to one spark plug.

Each segment is connected to an individual spark plug and distributes the current to the right plug at the exact time it is required to fire.

## **7. Dual Ignition**

Modern aircraft engines generally have two spark plugs per cylinder and two magnetos. One plug from each cylinder is connected to one magneto and the other plug to the other magneto.

**Dual ignition has two purposes:**

- **Safety:** if one ignition system fails, the other will continue to fire the engine.
- **Performance:** Two spark plugs provide more thorough, more even combustion.

The magneto switch has three positions: LEFT, RIGHT and BOTH.

When the pilot checks the magnetos before take-off, he checks the change in RPM as he switches between magnetos:

- From BOTH to RIGHT;
- Back to BOTH;
- From BOTH to LEFT ; and
- Back to BOTH;

If the pilot encounters rough engine running in the air, he can determine and select the magneto which is functioning properly to allow the engine to run better.

## **8. Shielding**

All the elements of the ignition system are surrounded with a metal covering which is grounded.

This is called « shielding » and prevents the electrical fields generated by the ignition system from interfering with the radio and electrical system.

## **9. Ignition Timing**

Ignition timing means timing the magneto to fire at the right time.

Premature ignition of the spark plugs causes a loss of power and overheating, which can cause detonation, pre-ignition, burnt pistons, scored cylinders and broken rings.

## **10. Electrical System**

The electrical system of the aircraft includes everything which works with electricity, except magnetos which are engine-driven and serve only to produce the current used by the spark plugs. The ignition system is not connected to the electrical system of the aircraft.

The electrical system provides energy not only for starting the aircraft but also to power the multitude of controls, such as instruments, landing gear, flaps, radios, lights, heating fans, de-icers, windshield wipers, etc.

## **11. Components of the Electrical System**

**Storage battery:** provides electrical energy to start the engine.

**Master Switch:** on/off switch for the electrical system.

**Starter motor:** turns the engine to start it; powered by the storage battery.

**Generator or Alternator:**

- Provides current to the electrical system and recharges the battery.
- Works when the engine is running.



- Once the battery has provided the energy for starting the engine, and the engine is running the alternator takes over the transfer of energy to the electrical system.

**Voltage regulator:** prevents the generator or alternator from over-loading the system and prevents the battery from becoming over charged.

**Bus Bar:** receives the current from the generator (or alternator) and battery and distributes it to the various electrical circuits.

**Circuit breakers:** protect the components against damage due to excess voltage, short circuits, etc.

**Ammeter / Voltmeter:** indicates the voltage of the current in the system.

**Generator Warning Light:**

- Indicates if the generator is working;
- Generally aircraft which are not equipped with an ammeter or voltmeter have a generator warning light.

## **410.07 – Propellers and Engine Instruments**

### **1. The Propeller**

The role of the propeller is to convert the rotating movement of the crankshaft into thrust or forward motion.

To do this, the propeller is so designed that, as it rotates, it pushes air backward and thereby causes a reaction which pushes the aircraft forward. The force it generates is called thrust. As the aircraft moves forward, the propeller cuts a corkscrew or helical path through the air.

Unlike a jet engine which moves a small amount of air backward at high speed, the propeller moves a large amount of air backward at relatively low speed.

A propeller blade is an airfoil section, like the section of a wing. When it turns, the blade meets the air at a certain angle of attack. Like a wing, it generates lift and induced drag. However, in the case of a propeller, the lift generated acts forward and is called thrust, and the drag acts against the rotation of the propeller and is called resistive torque.

Propellers installed in front of the engine which pull the aircraft forward are called tractors. Those installed behind the engine and which push the aircraft are called pushers.

### **2. Pitch**

The distance the propeller would theoretically travel forward for each revolution is called pitch.

The angle of the propeller blade to the airflow (like the angle of incidence of the wing) determines the pitch. Therefore, there is coarse pitch (i.e. the blade is adjusted to a large angle) and fine pitch (i.e. the blade is adjusted to a small angle).

### **3. Coarse Pitch**

A propeller with a coarse pitch setting will cover more distance with each revolution. Thus the aircraft will move forward at a greater speed for a given power setting. An analogy can be found in the fourth and fifth gears of an automobile.

Coarse pitch is used for high speed cruise flight and for high-altitude flight.

### **4. Fine Pitch**

A propeller with a fine pitch setting will produce less torque (i.e. less drag) and therefore will turn faster around the axis, allowing the engine to produce more thrust for a given engine RPM. It is analogous to first gear in an automobile.

Fine pitch gives better performance for take-off and climb.

### **5. Types of Propellers**

**Fixed Pitch:** The angle cannot be adjusted. The pitch angle was chosen by the constructor of the propeller to give the best possible performance in all flight conditions.

**Adjustable Pitch:** The pitch angle can be adjusted on the ground.

**Controllable Pitch:** The pitch setting can be adjusted by the pilot while in flight.

**Constant speed:** The pitch adjusts automatically to keep a constant RPM as set by the pilot.

### **6. Pitch Control Systems**

The system used by the pilot to adjust the pitch can be mechanical, hydraulic or electrical.

### **7. Feathering**

When a multi-engine aircraft loses an engine, it is preferable to feather the propeller of the stopped engine by turning the blades into the extreme coarse pitch setting. This prevents the

propeller from wind-milling, which may cause more damage to the engine and which generates un-necessary drag.

## **8. Thrust Reversing**

Thrust reversing is accomplished by turning the blades to a negative pitch angle, thereby generating negative thrust. This is used to slow the aircraft after landing or for manoeuvring on the ground.

## **9. The Importance of Basic Engine Instruments**

While an aircraft has many complex instruments, those which give indications on the engine are probably the most important. Gauges register the condition of the essential components of the engine. They can give warning of potential problems which may if uncorrected lead to engine failure.

The colour code consists of green, yellow and red. This indicates respectively the normal operation zone, the caution zone and the maximum permitted value.

## **10. Engine Instruments**

**Oil Pressure Gauge:** Indicates the oil pressure supplied by the oil pump to lubricate the engine. Excessive pressure will force oil into the combustion chamber where it will burn, causing damage to the engine.

Insufficient pressure may cause even more critical problems. There will be no film of oil between the working surfaces of the engine. Friction between the metal pieces will cause serious damage and eventually failure.

**Oil Temperature Gauge:** Indicates the temperature of the oil, which is an indication of the performance of the engine.

**Carburetor Air Temperature Gauge:** Indicates the temperature of the fuel-air mixture entering the manifold or enters the temperature of the air entering the carburetor. If icing conditions exist, the pilot will apply carburetor heat.

**Tachometer:** Instrument which indicates the speed at which the crankshaft is turning in hundreds of revolutions per minute. On aircraft with fixed-pitch propellers, the throttle controls the number of revolutions per minute.

**Cylinder Head Temperature Gauge:** Displays the temperature of one or many cylinder heads. An extremely high cylinder head temperature is an immediate sign of engine overload.

**Manifold Pressure Gauge:** Aircraft with constant speed propellers are equipped with a manifold pressure gauge, which indicates the power generated by the engine. The throttle controls the manifold pressure rather than the RPM. Usually located on the instrument panel near the tachometer because they both give information on the power generated by the engine. A drop in pressure usually indicates icing in the carburetor.

# REVIEW QUESTIONS:

1- What are the disadvantages of a radial engine? \_\_\_\_\_

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2- What is the function of the two cylinder valves? \_\_\_\_\_

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3- What is "timing"? \_\_\_\_\_

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4- What is the positioning of the valves and piston at the beginning of the intake stroke? \_\_\_\_\_

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5- Why does a lean mixture result in higher engine temperatures? \_\_\_\_\_

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6- What are seven reasons to lean the mixture? \_\_\_\_\_

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7- What does grade 100/130 tell a pilot about the composition of the fuel? \_\_\_\_\_

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8- What is the quickest way to prevent or eliminate detonation? \_\_\_\_\_

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9- Why is it important to properly synchronise ignition? \_\_\_\_\_

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10- Fine pitch gives better performance in which phases of the flight? \_\_\_\_\_

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## Example of Preparatory Examination

What is a “controlled airspace”?

- a) airspace where traffic is controlled by an Air Traffic Control unit;
- b) airspace where safety regulations are always in effect;
- c) Class F airspace;
- d) Class D airspace.

What equipment is needed to fly a glider into Class B airspace?

- a) radio equipment;
- b) radio-navigation equipment;
- c) a Mode C transponder;
- d) All of the above.

What are the entry requirements for Class C airspace?

- a) aircraft must receive a clearance from ATC when flying VFR;
- b) no clearance is required;
- c) aircraft must be equipped with a 2-way radio but do not need a transponder;
- d) None of the above.

Except for the purposes of taking off, landing, attempting to take off or land and unless so instructed by ATC, no aircraft may over-fly an aerodrome at less than:

- a) 2000 feet AGL;
- b) 1000 feet AGL;
- c) 500 feet AGL;
- d) 3000 feet AGL.

When two aircraft are converging, the glider must cede the right-of-way to :

- a) a commercial aircraft;
- b) a balloon;
- c) a helicopter;
- d) a dirigible.

6. What are the lifting agents?

- a) mountain effect and valley effect;
- b) stable and unstable air;
- c) convection, radiation, advection and conduction;
- d) Convection, orographic, frontal, mechanical turbulence, convergence.

7. After the passage of a cold front, the wind :

- a) veers and becomes turbulent;
- b) veers and becomes stable;
- c) backs and becomes turbulent;
- d) backs and becomes stable.

8. If the thermal gradient is strong, the air will be:

- a) stable;
- b) unstable;
- c) the winds will be weak;
- d) none of the above.

9. An “air mass” is defined as a large portion of the \_\_\_\_\_ possessing uniform characteristics of \_\_\_\_\_ and \_\_\_\_\_ in the horizontal. Find the missing words.

- a) stratosphere, temperature, pressure;
- b) tropopause, stability, pressure;
- c) atmosphere, stability, humidity;
- d) troposphere, temperature, humidity.

10. What is the effect of wind on the rate of climb of an aircraft?

- a) no influence;
- b) a headwind will increase the rate of climb;
- c) a headwind will reduce the rate of climb;
- d) a crosswind will affect the rate of climb.

11. After a hot and sunny morning, where are the best soaring conditions found?

- a) over a forest;
- b) over a large body of water;
- c) over a hillside facing south;
- d) on the lee side of a mountain.



12. Which side of a mountain range is dangerous?

- a) windward side;
- b) lee side;
- c) over top;
- d) all of the above.

13. At a constant airspeed in a level turn, the greater the inclination :

- a) the greater the rate of turn;
- b) the smaller the radius of turn;
- c) the greater the load factor;
- d) all of the above.

14. While on a transit flight in high tow position, the tow aircraft experiences a sudden loss of altitude. To correct the slack rope thus created, it is necessary:

- a) to enter level flight;
- b) to yaw away from the loop to reduce the glider's relative speed;
- c) to dive behind the tow plane;
- d) cable to release.

15. On some straight-winged aircraft, fin-like vertical surfaces are affixed to the upper surface of the wings to extend the laminar layer of airflow. These surfaces are called:

- a) slats;
- b) wing fences;
- c) safety plates;
- d) spoilers.

16. Swept-back wings ensure:

- a) directional stability;
- b) longitudinal stability;
- c) lateral stability;
- d) both A and C.

17. A low-wing glider is on final with a crosswind. The pilot must:

- a) crab through the flare and landing;
- b) a side-slip through the flare and landing;
- c) crab on final, a sideslip through the flare and level wings on landing;
- d) crab through the flare but land with the longitudinal axis parallel with the runway.

18. For a given aircraft, indicated stall speed:

- a) is greater when flying downwind than when flying upwind;
- b) increases with altitude;
- c) decreases with altitude;
- d) does not vary with altitude.

19. In which of these situations are the best thermalling conditions found?

- a) in light winds;
- b) in unstable air;
- c) in humid air;
- d) none of the above.

20. In a steep left turn onto final, there is a risk of :

- a) a violent stall of both wings;
- b) a stall of the right wing;
- c) excessive bank;
- d) a stall of the left wing.

21. The magnetic compass is not reliable :

- a) in a turn;
- b) on a north-south heading;
- c) on an east-west heading;
- d) in a climb or descent.

22. What happens to a magnetic compass when the aircraft accelerates on a West heading?

- a) it indicates a turn to the South;
- b) it leads the turn;
- c) it indicates a turn to the North;
- d) it lags the turn.

23. What is the purpose of a clearing S turn ?

- a) thermalling flight;
- b) it is a signal for the tow plane;
- c) to check for traffic;
- d) it gives the passengers a better view.

24. What effect would a flight from a low pressure area to a high pressure area have on the altimeter?

- a) it will read high;
- b) it will read low;
- c) it will not be affected;
- d) it will indicate a greater altitude than the real one.

25. When must the pilot of a glider file a flight plan?

- a) when flying further than 50 NM from the point of departure;
- b) depart When flying further than 25 NM from the point of departure;
- c) gliders are not required to file flight plans;
- d) no flight plan is necessary if the glider is equipped with an ELT.

26. What does “Controlled Airspace” mean?

- a) the airspace surrounding an airport;
- b) airspace of defined dimensions inside which all air traffic is controlled;
- c) airspace immediately overhead an airport;
- d) airspace inside which Air Traffic Control services are guaranteed..

27. An aircraft is at 500 feet AGL over an un-controlled airport. In what class of airspace is this aircraft?

- a) class B airspace;
- b) class D airspace;
- c) class E airspace;
- d) class G airspace.

28. degrees If you are flying North-West, what is your heading in degrees?

- a) 120.
- b) 045.
- c) 330.
- d) 270.

29. If you are flying  $135^{\circ}$ , in what cardinal direction are you flying?

- a) North.
- b) South.
- c) South-East.
- d) North-West.

30. If you fly directly North, what will your compass read?

- a) 180 degrees.
- b) 090 degrees.
- c) 270 degrees.
- d) 000 degrees.

31. Twenty minutes after take-off, you estimate that you have covered 50 NM. What is your groundspeed?

- a) 70 KTS.
- b) 150 KTS.
- c) 30 KTS.
- d) 1000 KTS.

32. You are planning a flight from Gimli, MAN to Brandon MAN. The distance is 150 NM and you are planning a speed of 75 KTS. How long will it take you to get to Brandon?

- a) 1 : 55.
- b) 1 : 30.
- c) 2 : 00.
- d) 2 : 15.

33. You are on a navigation flight and decide to calculate the distance you have covered. You know that your speed has been 105 kts for about 30 minutes. How far are you from your point of departure?

- a) 75 NM.
- b) 52.5 NM.
- c) 55 NM.
- d) 48.5 NM.

34. What is the shape of the planet Earth?

- a) oblong rectangle
- b) circle
- c) oblate Spheroid
- d) octagon

35. This type of imaginary line divides the earth in two equal halves; a section of this line will be the shortest distance between two points on the planet's surface.

- a) isogonic line
- b) isotherm
- c) rhumb line
- d) great Circle

36. This type of line cuts all meridians at an equal angle.

- a) great Circle
- b) isobar.
- c) parallel of Latitude
- d) rhumb line.

37. What term refers to the angle between a magnetic meridian and a geographic meridian?

- a) magnetic deviation.
- b) magnetic inclination.
- c) magnetic variation.
- d) deceleration.

38. What is the term which refers to a line which joins areas of equal magnetic variation?

- a) agonic line
- b) isogonic line
- c) isotherm
- d) isobar

39. What term refers to the line which joins areas of zero magnetic variation ?

- a) agonic line
- b) isogonic line
- c) isotherm
- d) isobar

40. Using the Standard Phonetic Alphabet, spell "BRAINS".

- a) Boston Roger Almond Italy Nicole Sugar
- b) Bravo Romeo Alpha India November Sierra
- c) Baker Robert Able Italy New York Suzanne
- d) Bravo Romeo Alpha India November Susan

41. What effect does a coating of frost on the wing profile of an aircraft in flight have on that aircraft's stall speed?

- a) the stall speed is unchanged.
- b) the stall speed is will be reduced in all situations.
- c) the stall speed increases in level flight only.
- d) the stall speed will increase in all situations.

42. In a spin, the ailerons are \_\_\_\_\_ and indicated airspeed is \_\_\_\_\_.

- a) firm; constant
- b) loose; increased
- c) firm ; increased
- d) loose; constant

43- In what direction to the vortices turn behind the wingtip of an aircraft?

- a) counter-clockwise behind both wingtips.
- b) clockwise behind both wingtips.
- c) clockwise behind the left wingtip and counter-clockwise behind the right wingtip.
- d) counter-clockwise behind the left wingtip and clockwise behind the right wingtip.

44. The mass of an aircraft affects which of the following points?

- a) centre of Pressure
- b) centre of Reaction
- c) centre of Gravity
- d) centre of Aircraft

45. What term refers to the imaginary line running from a point on the leading edge to a corresponding point on the trailing edge of a wing?

- a) longeron
- b) wingspan
- c) chord
- d) camber

46. What is the relationship between induced drag and the aspect ratio of a glider?

- a) aspect ratio diminishes when angle of attack is low.
- b) if aspect ratio is high, induced drag is low.
- c) if aspect ratio is low, induced drag is reduced.
- d) the relationship between induced drag and aspect ratio varies in function of the indicated airspeed.

47. What is the angle of incidence?

- a) the angle between the airfoil and the relative airflow.
- b) the angle between the chord line and a longitudinal reference line on the fuselage.
- c) the angle between a transversal reference line on the fuselage and the relative airflow.
- d) the angle between a longitudinal reference line on the fuselage and the chord of the horizontal stabiliser.

48. What happens to the Centre of Pressure of the airfoil when the angle of attack increases and approaches the stall angle?

- a) it moves forward
- b) it moves backward
- c) it stays momentarily
- d) nothing

49. What is inherent stability?

- a) stability due to the aircraft's general tendency to return to its original flight trajectory.
- b) stability due to the design of the aircraft.
- c) stability due to the aircraft's tendency to return to its initial flight trajectory.
- d) stability due to dihedral.

50. What is the dihedral angle?

- a) the angle between the wing and a vertical line.
- b) the angle between the wing and a horizontal line.
- c) the angle between the wing and horizontal stabiliser.
- d) the angle between the wing and the fuselage.

51. Coarse pitch is used when:

- a) the aircraft is in cruise flight;
- b) the aircraft is climbing;
- c) the aircraft is descending;
- d) the wings are stalled;

52. If I can change the pitch of my propeller blades only on the ground I have a \_\_\_\_\_ propeller:

- a) fixed-pitch
- b) controllable
- c) adjustable
- d) constant Speed

53. On high-performance, low-wing aircraft, the fuel system is fed:

- a) by gravity
- b) by engine vibrations
- c) by the turbocharger
- d) by pump

54. What is the purpose of a tachometer?

- a) indicates the power generated by the engine in Revolutions Per Minute.
- b) indicates the temperature of the engine
- c) indicates the speed of the aircraft
- d) indicates the fuel remaining

55. What are the consequences of applying carb heat?

- a) an increase in power
- b) a reduction in power
- c) engine shutdown
- d) no effect